ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/261164891

Designing a system of interactive robots for training collaborative skills to autistic children

Conference Paper · September 2012

DOI: 10.1109/ICL.2012.6402179

CITATIONS
30

READS
393

3 authors:



Maya Dimitrova
Bulgarian Academy of Sciences, Institute of Robotics
81 PUBLICATIONS **353** CITATIONS
SEE PROFILE



Niko Vegt
Erasmus University Rotterdam
15 PUBLICATIONS **172** CITATIONS
SEE PROFILE



Emilia Ivanova Barakova
Eindhoven University of Technology
247 PUBLICATIONS **3,408** CITATIONS
SEE PROFILE

All content following this page was uploaded by Emilia Ivanova Barakova on 22 July 2014.

The user has requested enhancement of the downloaded file.

Designing a System of Interactive Robots for Training Collaborative Skills to Autistic Children

Maya Dimitrova
Institute of Systems Engineering and Robotics
Bulgarian Academy of Sciences
Sofia, Bulgaria
e-mail: dimitrova@iser.bas.bg

Niko Vegt and Emilia Barakova
Faculty of Industrial Design
Eindhoven University of Technology
Eindhoven, The Netherlands
e-mail: e.i.barakova@tue.nl

Abstract—**Using robots to reward and stimulate children doing tasks together can be helpful in improving their social skills. Robots implemented 3 types of behavior scenarios – imitate, enhance and counteract – in a collaborative game of teaching robots perform movements shown by hand gestures. The paper presents a novel account of ASD symptoms based on the interplay of empathic concern and empathic accuracy in different personalities with and without cognitive deficits. Performance of autistic children was compared with two age groups of typically developing children – under and above the age of 7. The study confirmed the limited resource hypothesis – cognitive and motivational – bringing about the observed phenomena in situations of limited attention resources and performance under distraction. The robotic framework for educating children has shown potential for developing of various complex cognitive and social skills and has substantial developmental impact.**

Keywords-robots, autism, empathy, behavioral training with multiagent system of robots, collaboration through immitation games, design of interactive robot scenarios, learning robots

I. INTRODUCTION

Autistic children respond positively to interaction with robots and technology in general [1]. Deploying robots in educating children with an autism spectrum disorder (ASD) seems to be an obvious solution. Teaching social competences through robots is promising, and has already produced positive results, however still being far from conclusive results.

In terms of participation in society autistic children benefit from intensive training in social interaction [2]. Scenarios for imitation and turn-taking games with a multi-agent system of interactive colored light blocks have been tested [3]. It has been shown that autistic children can be encouraged through games with robots and tangibles to make social contact [4], [5]. This is also shown in the research by Legoff on using Lego in therapy sessions [6]. Autistic children increase their social skills significantly after playing in couples with Lego.

Numerous studies have led to a relation between the development of motor skills and social skills [7], [8], [9]. The implementation of interaction through movement is therefore an interesting topic to investigate. In [3] it is argued that "interaction with objects is a developmental stage of social behavior, and that shortcomings in the motor level of interaction can result in impaired social behavior." Making robots encourage movement helps develop motor skills and might therefore stimulate social activity.

Based on the recent advancement of the theory of mirror neuron system [10], and imitation learning [11], a platform of moving mini-robots is developed. These robots can perform movements and lightings – sequences of actions, with the goal to perform consistent behaviors from the observer viewpoint/opinion. The measurable outcome of the training with robots is set to be the amount of social interaction, enhanced by the game in terms of self initiated social contact (SISC) indicators, proposed by Legoff [6]. The robots were taught to perform three types of interaction – *imitate*, *counteract* or *enhance* the movement of the child towards a goal. Having pairs of children play with the mini-robots it is expected that the social contact will improve and the children will *collaborate* to get the reward from the robots which will, for instance, repeat their hand movements.

The main deficit in children with ASD can be characterized by the inability to employ social triggers/mechanisms/benefits for the achievement of a behavioral goal – focusing predominantly on improving cognitive skills. Two dominant (and contradictory) theoretical views are proposing a Theory of Mind (ToM) deficit [12], or a Mirror Neuron (MN) system deficit [13], [14]. A ToM deficit account will state that children with ASD will find it difficult to imagine the mental state of the other person whereas, on the contrary, this may be lack of interest for not seeing the purpose of doing this. A MN system theory will state that not observing activation in certain areas of the brain, responsible for mental enacting of other people's actions signifies deficit in the ability to imitate, yet this may be for a similar reason as above – not seeing meaningful reason to focus attention on such activity.

Rameson and Lieberman have proposed a social cognitive neuroscience approach, based on direct observation of neuronal activity of induced mental states as a theory capable of resolving the above ambiguities [15]. The authors have applied this method to observe neural activation during empathic response and map it onto mirror-neuron system-related brain areas. According to Rameson and Lieberman, empathy is a complex psychological state, consisting of cognitive and emotional components, being either self-focused or other-focused. These can be of more experiential nature (empathic concern) or of more propositional nature (empathic accuracy) [15].

In a subsequent study was discovered that "stronger neural responses were observed when participants were instructed to empathize, which suggests top-down effortful cognition may

978-1-4673-2427-4/12/$31.00 ©2012 IEEE

amplify empathic responses [16, p. 8]. Another important result in this study is the effect of attentional constraints on "everyday empathy" – "although empathy may not be universally automatic, it appears to be more automatic for individuals, high in trait empathy" [i.e. 16, p. 8]. The latter result is in strong support of the claims of Rachel Cohen-Rottenberg [17] that the nature of the autistic deficit is a matter of resource, which, being limited, constrains cognitive performance of multiple, irrelevant or parallel tasks that is often accompanied by strong feelings of fear to miss-perform in a social situation, rather than on deficits of trait nature (as in [18]). This is consistent with the proposal for "social motivation" deficit account in [19], stating that impairments are matter of deficit of "resource", which in the social sphere is called motivation (i.e. whenever there is motivation for acting it signifies the presence of resource for it). We agree strongly with this position and propose a personality account that assumes a variety of effects of the limited *cognitive* resource on the manifestation of the otherwise typical personality traits.

The personality account of the present study is inspired by the works of D. C. Funder on the triple relation of persons, situations and behaviors [20]. According to his theory personality is consistent across situations. As proposed in the theory, situations tend to *elicit* behaviors, whereas personalities tend to *emit* behaviors. It is added to this framework the self awareness of emitting behavior or letting the situation elicit it in [21]. This framework is applied in the current study to explain the particular behaviors, emitted by autistic and normal children of different age, while performing collaboration tasks in a game with mini-robots.

II. Personality Account of Imitation Learning

The proposed personality account of imitation learning is based on the investigations of Rameson and Lieberman on empathy as a trait, or a state, i.e. as a personality feature [15], [16]. The personality account states that people can be described by features, represented as degrees of manifestation of these features along orthogonal dimensions. These have long been represented by the extroversion and neuroticism orthogonal dimensions of H. Eysenck [22], however nothing restricts the number of dimensions, characterizing a person, like empathy, friendliness, generosity, quietness, eccentricity, sociability and so on. Our main claim is that there is no such a thing as autistic personality – rather there is a cognitive-resource deficit of specific autistic nature that can manifest itself within any type of personality, and this is in agreement with the position of Rachel Cohen-Rottenberg [17]. It employs the conceptualization of empathy of Rameson and Lieberman as consisting of two processes – empathic concern and empathic accuracy [15]. Our modification of this theory is in placing these processes one into the other – the empathic concern contains the empathic accuracy as a focal process. In addition, these can be of positive/negative sign along a single dimension. The end points of this dimension are – complete lack of empathy to the left and extreme degree of empathy to the right. Note that altruism is not included in this scheme. It is considered a separate, independent dimension, unlike the common assumption that it is the highest manifestation of empathy. In this framework altruism is an independent from the empathy dimension and can vary from complete lack of altruism to extreme manifestation of altruism. The main idea is illustrated in figures 1, 2 and 3.

In the present study 3 types of robot behaviors were modeled – *imitate*, *enhance* and *counteract*. Children taught movements to robots, which could repeat correctly the hand movement (imitate), quickly pick up the movement (enhance), or perform different from the demonstrated movements in the counteract mode. In figure 1 the general case of imitation learning in a personality context is illustrated.

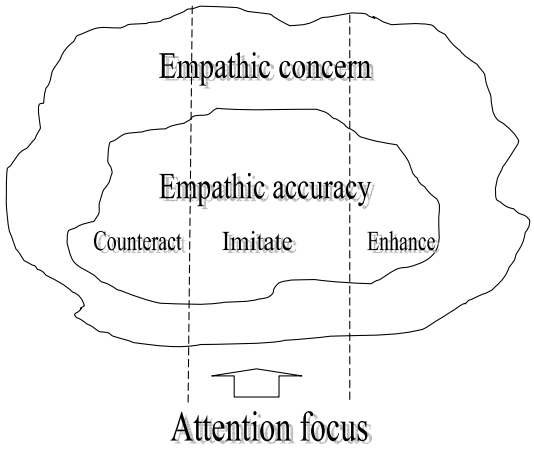


Figure 1. Teaching of behaviors influencing personality features (see text).

In the general – common case – the teaching of behaviors can be represented as performing actions that influence the empathic dimension of one's personality and is controlled by a sufficient amount of cognitive resources, defining the attention focus. It is generally necessary to focus one's attention in order to imitate, or teach imitation. Enhancement and counteracting are assumed more automatic processes from the opposite ends of the empathic behavior spectrum. Our account states that ASD is mainly limited-resource deficiency. Attention focus is characterized by high concentration, but limited span.

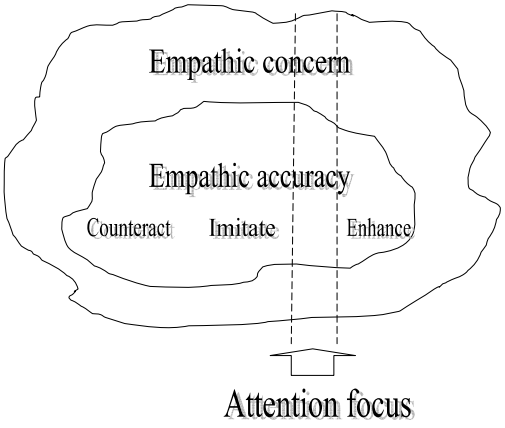


Figure 2. Teaching of behaviors under limited attentional resources.

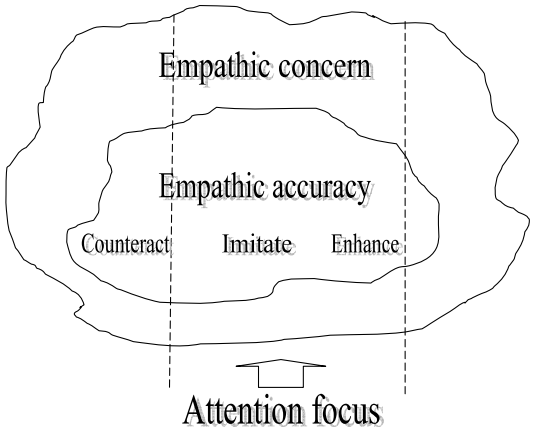


Figure 3. Teaching of behaviors under distraction.

Figure 2 provides one hypothesis about teaching of behaviors to autistic children. It is hypothesized that the attention focus is shifted by the instructions towards conscious or automatic enhancement behaviors, imitation being a variety of it. Therefore we may observe inability to distinguish between counteract and imitate behaviors due to the resource restriction.

Figure 3 provides illustration for the opposite case, characterizing the process of learning behaviors by little children. The attention focus is broad, yet shallow. It lets children get distracted easily, and therefore do not distinguish imitate from enhance behavior (being with one and the same sign).

The second hypothesis to be tested in the current study is that with age normally performing children move from the case in figure 3 towards the case in figure 1. In a way, it can be said that education is a process of *personality* modification via some process of *behavior* modification.

A research through design approach is performed in the current study to investigate human-robot interaction through movement imitation. The design of an interaction scenario served as the starting point for this study. To support the scenario, a technological platform was developed.

III. Materials And Methods

A. Encourage Imitation

We developed scenarios that supported the implementation of different robot interaction behaviors with imitation as the key incentive for interaction. The goal was to encourage couples of children to cooperate by agreeing to perform one and the same movement pattern. The robots will recognize the movement pattern (through communication with camera that is positioned above the play table) and respond by repeating, counteracting or enhancing the movement. A common task was implemented and by providing a clear goal to teach robots imitate hand movements, cooperation between the children and more social interaction were expected. This hypothesis was co-developed with the psychologists specialized in autism from Royal Dutch Kentalis. Kentalis is a national organization in the Netherlands providing diagnostic, care and educational services to, among others, autistic children. They proposed testing of the robot interactions on a group that has previously taken the so-called TOM (theory of mind) training.

Robot imitation behavior was implemented as a reward system for the interaction between the children. When the children were agreeing to perform the same movement pattern with their hands, they would be rewarded by robot imitating the pattern. In order to test how different kinds of robot response would affect the children's collaboration, three different behavioral strategies were performed by the robot: *counteracting*, *imitating* and *enhancing* of the perceived movement pattern inspired by [2].

The study was performed in the context of play supporting social interaction. Two children had to participate in the play interacting with robots through movement. Giving them a collaboration task supported social interaction and the implementation of a multi-agent system of robot was expected to invoke a more open (explorative) attitude and encourage social interaction as well [4]. These three contextual elements had to provide enough reason for social interaction and enable a test on the different robot interaction behaviors.

B. Interaction Scenario

Three robots were standing on a table, waiting to start a game. The goal of the first game was to make these robots perform a movement pattern chosen by the children. Different patterns were first demonstrated by the robots so that the children could rehearse and memorize the pattern. Then the robots stopped the demonstration and performed neutral behavior and the children were supposed to perform one and the same movement pattern together with one hand above the table. If the children performed such a movement together, the robots would respond. The responding behavior differed per task. The robots could *imitate*, *enhance* or *counteract*.

Imitation behavior involved copying the children's hand movement accurately. The enhancing behavior implied very quick recognition of the children's movements. As soon as the children were somewhat performing the same movement, the robots would perform the right pattern.

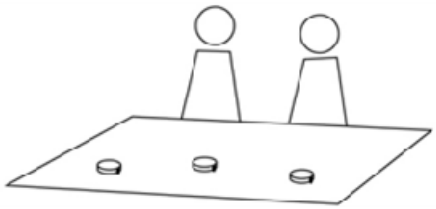


Figure 4. Start position.

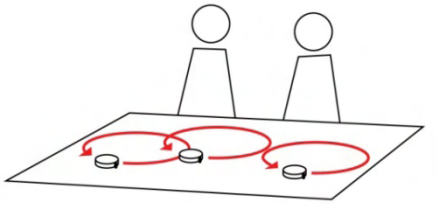


Figure 5. Robots demonstrate a movement pattern.

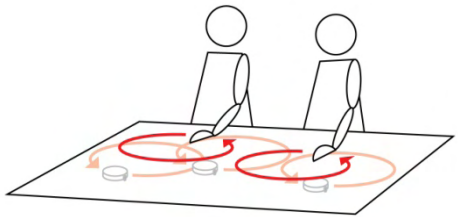


Figure 6. Children describe and rehearse the pattern.

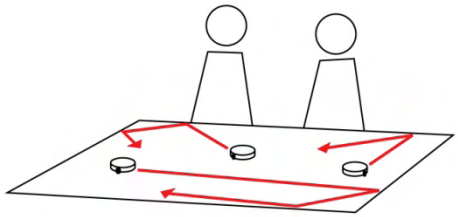


Figure 7. Robots stop demonstration and perform neutral behavior.

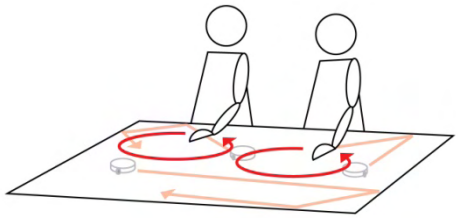


Figure 8. Children teach the pattern together through hand movement.

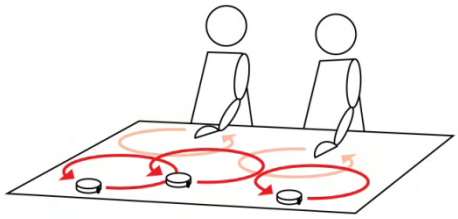


Figure 9. Robots enhance, imitate or counteract (differs per task).

In counteraction mode the robots were not able to pick up the right movement pattern but started performing different patterns. With this behavior the children could not finish the game. A round was finished if the robots performed the right pattern or if three minutes had passed (see figures 4-9).

C. *Tests*

The testing of the interaction scenario was performed in three iterations. The first test round was performed at a primary school with couples of children of different age (between 6 and 10). These tests led to a tighter specification of the target group in terms of age (level of development). The second test round was done at a primary school with children aged 6 till 7. The robots learned to recognize the desired behaviors, however the robots were steered by the researcher in order to correctly implement the robot interaction behavior (imitating, counteraction, and enhancing) and exclude errors due to the technological implementation, which is especially possible by the *enhance* behavior. The effect on social interaction was measured and qualitative insights were gathered on the implementation of the scenario and the platform. The final tests were done with children with a diagnosed autistic spectrum disorder (age 7 till 9). This group of children had previously taken ToM training. These tests were performed in the same way as the second test round. This enabled the comparison between the effects on autistic children and typically developing children.

During all tests couples of children of the same gender were brought to an empty room where a table with the robots was standing. There the researcher introduced himself and an explanation of the robots, their behavior and the purpose of the game was given. Especially in the test with autistic children much care was given to this introduction; being clear about every step in the game and what was expected from them. After assuring that everything was clear, the researcher withdrew from the game area to the laptop in a corner of the room and the interaction scenario started.

In round one and two the children were placed on opposite ends of the table for technical reasons, making image recognition easier. But because the platform wasn't autonomous in the second and third test rounds the children were standing side by side to better facilitate cooperation and imitation.

D. *Technological Platform*

To support the scenario an autonomous technological platform was developed. The robots used for the platform are AdMoVeo robots (figure 10). They hold many sensors and actuators accommodating a versatility of applications. For this project the driving and lighting functionalities were involved, and also sensors for autonomous collision avoidance (infrared distance sensors) [23]. The behavior related to the different interaction behaviors was communicated from a laptop to the robot. This behavior could be overruled by avoidance of other robots or avoiding the edge of the table. Neutral behavior involved driving straight and forward. Three possible figures could be taught – circle, square and triangle. Robots learned to repeat or foresee hand movements demonstrating one of the predefined shapes.

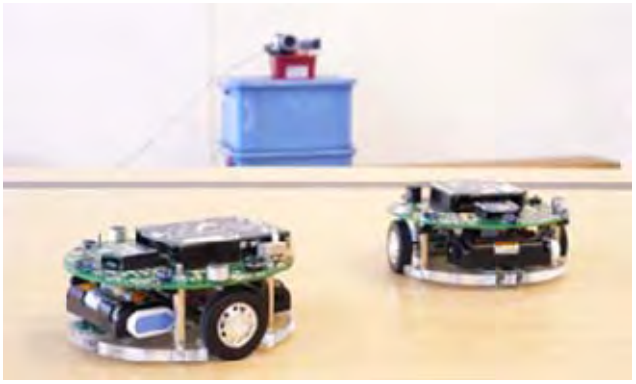


Figure 10. AdMoVeo robots.

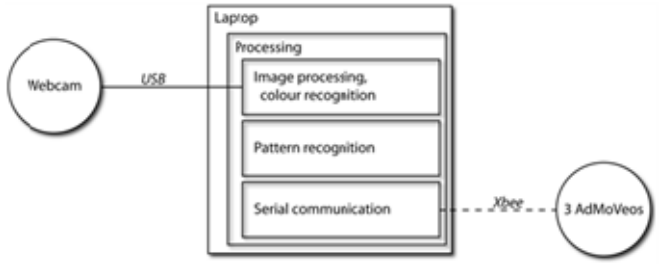


Figure 11. Schematic representation of the technological platform controlling the AdMoVeo robots.

The platform involved image recognition, serial communication and robot behavior handling (figure 11). The movements of the children had to be recognized from a webcam image and processed to understand their movement patterns. The result had to be communicated to the robots and they had to respond correspondingly.

The movements that the children would make were recognized from an overview perspective (figure 12). A webcam was implemented above a table to provide a top view image of the children and interaction area. This video image was processed. The experimental setup and the robot behaviors were inspired by our previous work [24]. The recognition of the children's hands above the table was registered through hand color detection and the patterns were recognized with a pattern recognition algorithm [24],]25]. For the simplicity of the implementation, for these particular test we re-implemented the behaviors on the Unistroke recognizer [24], while for further development we intend to use more generic solutions provided by the method described in [25], [26].

E. Measurement

The interaction scenario contained three different robot interaction behaviors and a collaboration task (through imitation) for the children. The experimental layout is illustrated in figure 12. The social interaction between two children with ASD was observed and recorded on video while they performed three collaboration tasks and interacted with a multi-agent system of moving robots on a table.

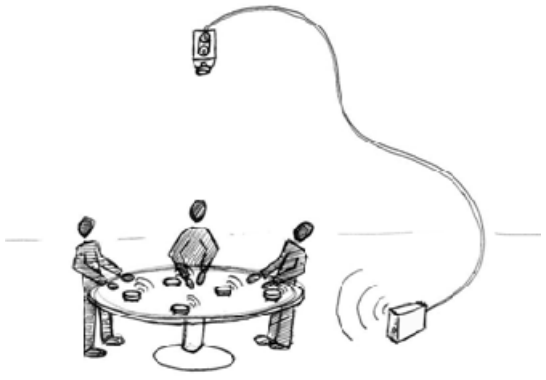


Figure 12. Experimental setting.

In order to get to know to what extend interaction through movement and teaching robots is an engaging task, the children were questioned afterwards through a short open interview. The full study was recorded on video and assessed on self-initiated social contacts (SISC) by the researcher and an unbiased expert.

During each teaching task the amount of SISC was measured. This measurement tool is developed by Legoff to assess social interaction during therapy [6]. In his research on using Lego© as a therapeutic medium social interaction is distinguished in three elements: "(1) initiation of social contact with peers, reflective of social interest and motivation for social contact; (2) duration of social interaction, which reflects the development of communication and play skills; and (3) decreases in autistic aloofness and rigidity, with development of age-appropriate social and play behaviors" [6]. For this study mainly the first element (SISC) is useful because elements 2 and 3 are interesting for longitudinal studies with more than one contact moment. The duration of social interaction was also considered to be interesting because it reflected a difference in the quality of the interaction between the children. A SISC is counted if it meets the following criteria:

(1) it is unprompted and spontaneous;

(2) it is not part of a daily routine or required activity;

(3) it involves either verbal or nonverbal communication or a clear attempt to communicate with a peer;

(4) the peer has to be of approximately the same age or developmental level as the subject (i.e., not a much older or younger child); and

(5) it is not a reciprocal response to another child's approach" [6].

The study variables are presented in figure 13.

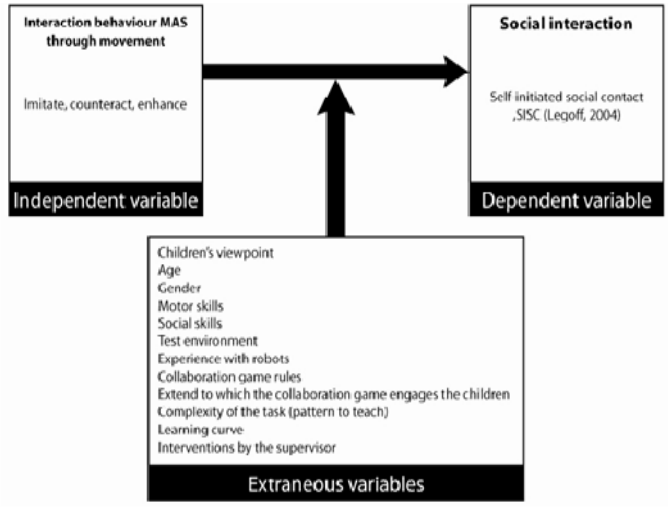


Figure 13. The study variables.

Each recorded task was cut into chunks of 15 seconds, which is the longest social interaction between the children measured from the pilot study. Each chunk was rated for the length of SISC. This rating was divided into four categories of social contact based on the SISC criteria:

- No social contact
- Short social contact (1 word or sentence)
- Medium social contact (more than 1 sentence, less than 10 sec.)
- Long social contact (10 sec. or more)

A test was performed to address the effect of the different interaction behaviors on the imitation between the children. According to previous studies autistic children had more social contact with each other when the system would counteract [4]. In this case it was assumed that if the social contact would rise, the robot behavior would have a negative effect on the collaboration task because the goal was to encourage non-verbal communication (*imitation*).

IV. RESULTS

A pilot study was performed with children from primary school in 3 different groups – group 3 (age 6-7), group 4 (age 7-8) and group 5 (age 8-9). Children of group 3 had difficulties in focusing on the game. Typically developing children from group 4 appear to be most suitable for the game. They can concentrate on the collaborative task without trying to see through the system. For the actual test two groups, one from a primary school with typically developing children consisting of 6 couples of children and a group from Kentalis organization in Eindhoven, The Netherlands, consisting of 5 couples (1 couple of girls and 4 couples of boys) took part in the experiment.

The three tasks per couple with different robot interaction behaviors (*imitation*, *counteraction* and *enhancement*) were compared in amount of SISC per 15 seconds. The statistical analysis showed that there is no significant difference of social contact between the tasks (Kruskal -Wallis one-way analysis of variance by ranks, p=0.291). So the relation between the robots' interaction behaviors and the amount of social interaction occurring during a collaboration task could not be quantified further.

The graphs in figures 14 and 15 suggest a different effect on social interaction with enhancing behavior that is interesting, as well as the suggested similarity between imitate and counteract. A decrease in measured social contact can be related to increased involvement with the imitation task. Enhancing robot behavior seems to encourage children most to collaborate.

The explanation for the similarity between imitate and counteract can be found in the implementation of these behaviors. When looking at the reactions of the children while playing, they found the robots 'bad listeners' mainly with the counteracting behavior, but also during imitating and neutral behavior. It seemed that imitation and counteracting behavior was not perceived different from the neutral behavior. This suggests that these behavior types were not perceived at all and strengthens the assumption that enhancing behavior encourages imitation tasks.

The fact that most of the children were talking about the robots 'listening' and the surprised reactions if one robot did perform a movement correctly showed that the task was engaging. Some children left their place at the table and started running around, trying to get the attention of particular robots. The amount of social interaction seemed to increase with more movement and with distraction from the task.

Therefore, the explorative character of multi-agent games enhances social interaction. Exploration made the children less focused on the task and seemed to increase the interaction with the other child. In this respect there was a clear difference between the autistic and normally developed children. The autistic children were more focused on the interaction with the robots. They understood the system more quickly and were less explorative. This can also partly be explained by the age difference. Younger children (6 – 7 year old) were much more distracted by the explorative character of the multi-agent system than older children.

Another interesting effect was the fact that counteracting behavior made the children imitate the robots in several cases. In two of the five tests with autistic children counteracting behavior made them shift from teaching the movement pattern to imitating the wrong movement pattern from the robots. Autistic children may tend to neglect imitation (as part of non-verbal communication) in social interaction, but with robots this appears not to be the case.

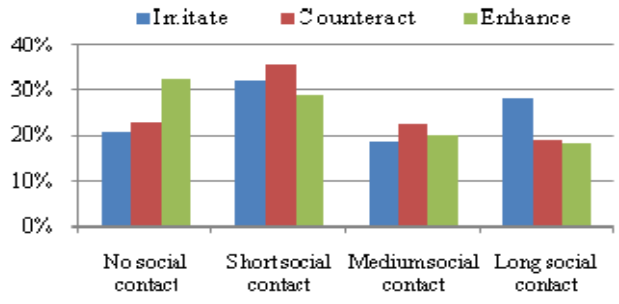


Figure 14. Categories of SISC per robot interaction behavior.

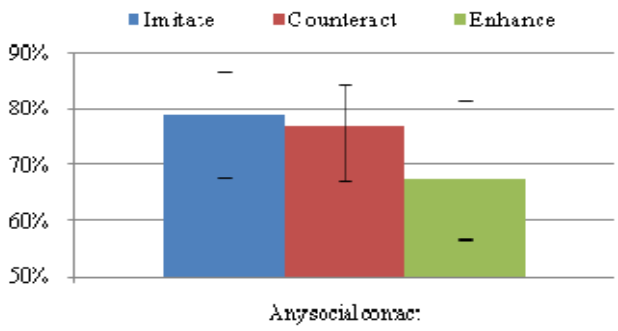


Figure 15. Percentage of any SISC per robot interaction behavior.

V. DISCUSSION

In this study the collaboration between children was mainly encouraged through playful interaction with robots that performed abstract behaviors resembling human-to-human interaction. The concept was co-developed with trainers of autistic children from Kentalis institute in Eindhoven, The Netherlands, who saw the treatment as a possible supplement to train social skills for the groups of children that previously took ToM training, i.e. children actively involved in educational activities. After analysis it has become clear that the system of robots can encourage children to train collaboration through games in which simple elements of social behavior are embedded – the children imitate (to teach the robots) each other, also synchronize each other's movement.

Implementing enhancing behavior seems to be best for collaboration training, because it results in the best execution of tasks. The problem with this conclusion is the fact that it is difficult to measure the amount of imitation as non-verbal communication. In this study social contact based on speech was measured, but the assumption that less social contact relates to more imitation behavior is debatable, although the fact that the children were assigned to collaborate through imitation makes the relation more likely. A suggestion for a continuation study would be to test enhancing and counteracting behavior on the amount of imitation between the children.

The test provides interesting starting-points for further investigation on interaction through movement with multi-agent systems. It seems that in this case counteracting and enhancing interaction behavior were recognizable. For useful implementation of convincing imitation behavior the platform needs further technological development.

The pilot study with typically developing children with different age groups showed the influence of the overall learning skills and the ability to have a "theory of robot operation" or in other words "to see through the system". In younger children the continuous motion of the robots requires full attention, resulting in difficulties with focusing on their collaborative task. In addition a distracting factor for this age group (6 years old) seemed to be the emergent behavior of the moving robots. A difference can be seen with older children (7 or 8 year old): they have less difficulty with focusing on the task. So for children younger than the age of 7 it seems not advisable to implement a moving multi-agent system for educative tasks. The older children, on the contrary, interacted to share opinions on how the system of robots works. This observation confirms the theoretical framework outlined in the beginning of this paper. For the group of autistic children we cannot say whether the social interactions increase with the age, because during the actual test the children were at age range between 7 and 9. Older children were not available at this school. However, it is interesting to test this hypothesis.

Other tests with autistic children show that playing with a multi-agent system of colored light blocks [4] encourages explorative play, rather than repetitive play. Multi-agent systems become more and more used to control or analyze complex systems. For controlled educative purposes we have seen that the complexity of the system increases. In previous studies, the interactions between the elements of the multi-agent system were meant to increase the interaction [3], [4], [25]. In the current study learning the skill of imitating each other and synchronizing the movements between the children which will result in entertaining behavioral response by the multi-agent system of robots was not explicitly tested. Instead the overall level of interaction, based on initiation of social contact was counted. Although this is a clearer indicator of social interaction, the way the children learn to imitate each other and synchronize their action can show positive effects on their development and be used for training younger children. In the course of the game the children who can successfully imitate can learn to agree on a common task to make the robots perform as they like. If the concept of playful interactions with the robots are developed as a game (i.e. with a goal and competitive elements) wider range of skills can be trained.

So far a system of camera-observer can record the human movements and control the response of the multi-agent system of robots. These functions can be implemented in the robots themselves, so the training, and the recording the outcome of the skill development of the children is embodied in the robots so they can be used everywhere and can learn to adapt the complexity of the games.

During this study the focus was on the interaction scenarios, so there was less time spent on the implementation of an autonomous system. When making the platform autonomous many new interaction possibilities arise. Intelligent systems can be implemented in order to cover more complicated interaction scenarios. It would also reduce the effect of the researcher on the study and enable formal modeling of robot interaction behaviors. For children with ASD the reduction of people involved gives an extra benefit, because it provides a more secure and predictable environment.

VI. CONCLUSIONS

The paper compared performance of children with ASD with two different age ranges of normally performing children – below and above the age of 7 - on collaborative play. Robots implemented 3 types of behavior scenarios – imitate, enhance and counteract. The experimental design allowed testing two hypotheses following a novel account of ASD symptoms based on the interplay of empathic concern and empathic accuracy in different personalities. Autistic children tended to mismatch *imitate* and *counteract* behaviors due to excessive focus on the play. The study confirmed the limited resource hypothesis – cognitive and motivational – bringing about the observed phenomena in situations of limited attention resources and performance under distraction. Further tests are needed to confirm these hypotheses in human-robot interaction settings that are being suitable to reveal the complexity of the ASD and to design educational systems for amending child's behavior.

ACKNOWLEDGMENT

The authors want to thank the teachers and children that were involved in the tests from the two primary schools: 'De Tweesprong' in Breda and 'De Hasselbraam' in Eindhoven as well as the people from Royal Kentalis in Eindhoven, The Netherlands, the centre for remedial education in Eindhoven,

who supported us with the study with autistic children: Juliane Cuperus and Caroline Mesmanhe.

REFERENCES

[1] J.C. Murray, L. Ca, K. A. Bard, M. D. Ross and K. Thorsteinsson, "The influence of social interaction on the perception of emotional expression: A case study with a robot head", Lecture Notes in Computer Science, Berlin/Heidelberg : Springer, vol. 5744/2009, 2009, pp. 63–72.

[2] E.I. Barakova and T. Lourens, "Expressing and interpreting emotional movements in social games with robots", Personal and Ubiquitous Computing, 14(5), 2010, pp. 457-467.

[3] J. C. J. Brok and E. I. Barakova, "Engaging autistic children in imitation and turn-taking games with multiagent system of interactive lighting blocks", in ICEC 2010, H.S. Yang et al. Eds. LNCS vol. 6243, 2010, pp. 115-126.

[4] E. Barakova, J. Gilessen, and L. Feijs, "Social training of autistic children with interactive intelligent agents", Imperial College Press, Journal of Integrative Neuroscience, vol. 8, 1, 2009, pp. 23-34.

[5] H. Kozima, C. Nakagawa, and Y. Yasuda, "Children–robot interaction: a pilot study in autism therapy," in Progress in Brain Research, vol. 164, C. v. Hofsten and K. Rosander, Eds., Elsevier, 2007, pp. 385-400.

[6] D. B. LeGoff, "Use of LEGO(c) as a therapeutic medium for improving social competence" No. 5, s.l.: Springer Science+Business Media, Inc., Journal of Autism and Developmental Disorders, vol. 34, 5, pp. 557-571, October 2004.

[7] W.L. Stone, O.Y. Ousley, and C.D. Littleford, "Motor imitation in young children with autism: What's the object?" Nashville: Plenum Publishing Corporation, Journal of Abnormal Child Psychology, vol. 25, 1997, pp. 475-485.

[8] M. R. Leary and D. A. Hill, "Moving on: Autism and movement disturbance,'' Ment. Retard., vol. 34, 1, pp. 39–53, Feb. 1996.

[9] E. I. Barakova and W. Chonnaparamutt, "Timing sensory integration for robot simulation of autistic behavior", IEEE Robotics and Automation Magazine, vol. 16, 3, 2009, pp. 51-58.

[10] M. Iacoboni, "Imitation, empathy and mirror neurons", Annual Review of Psychology, vol. 60, 2009, pp. 653-670.

[11] H.G. Justin, G. D. Williams, A. G. Waiter, D. I. Perrett, A. D. Murray and A. Whiten, "Neural mechanisms of imitation and 'mirror neuron' functioning in autistic spectrum disorder", NeuroImage, 24(2), 2005, pp. 610-621.

[12] J. Scholz, C. Triantafyllou, S. Whitfield-Gabrieli, E.N. Brown and R. Saxe, "Distinct regions of right temporo-parietal junction are selective for theory of mind and exogenous attention", 2009, PLoS ONE 4(3): e4869, [doi:10.1371/journal.pone.0004869]

[13] G. Rizzolatti and M. Fabbri-Destro, "Mirror neurons: from discovery to autism", Experimental Brain Research, vol. 200, no. 3-4, 2010, pp. 223-237.

[14] E.I. Barakova and L.G.M. Feijs, "Brain-inspired robots for autistic training and care", in Neuromorphic and Brain-Based Robots: Trends and Perspectives, J. Krichmar and H. Wagatsuma, Eds., Cambridge University Press, Edinburgh, pp. 178-214, Augist 2011.

[15] Rameson, L.T. and M.D. Lieberman, "Empathy: A social cognitive neuroscience approach", Social and Personality Psychology Compass vol. 3,1, 2009, pp. 94–110.

[16] L.T. Rameson, S.A. Morelli, and M.D. Lieberman, "The neural correlates of empathy: experience, automaticity, and prosocial behavior", Journal of Cognitive Neuroscience, vol.8, 2011, pp.1-11.

[17] Rachel Cohen-Rottenberg "Unwarranted conclusions and the potential for harm: My reply to Simon Baron-Cohen", 2011, www.autismandempathy.com.

[18] S. Baron-Cohen and S. Wheelwright, The Empathy Quotient: An investigation of adults with Asperger Syndrome or high functioning autism and normal sex differences, Journal of Autism and Developmental Disorders, vol. 34, no. 2, April 2004.

[19] C. Chevallier, G., Kohls, V. Troiani, E.S. Brodkin, and R.T. Schultz, "The social motivation theory of autism", Trends in Cognitive Sciences, 16(4), 2012, pp. 231-239.

[20] D. C. Funder, "Towards a resolution of the personality triad: Persons, situations, and behaviors", Journal of Research in Personality, vol. 40, 2006, 2, pp. 1-34.

[21] M. Dimitrova, A Lekova, and M. Adda, "Personality filter in mobile networks with communication constraints", in Proc. 12th International Symposium on Symbolic and Numeric Algorithms for Scientific Computing SYNASC 2010, IEEE Computer Society, 2011, pp. 565-568.

[22] H. J. Eysenck and S. B. G. Eysenck, Manual of the Eysenck Personality Scales (EPS Adult), London: Hodder & Stoughton, 1991.

[23] S. Alers, AdMoVeo: an Educational Arduino Robot, [Online] Department of Industrial Design, Eindhoven University, 2009. http://www.admoveo.nl/.

[24] S. H. M. Alers and E. I. Barakova, "Multi-agent platform for development of educational games for children with autism", IEEE ICE CIG 2009, pp . 47-53, 2009J. Wobbrock, A. Wilson, and L. Yang, Unistroke Recognizer in JavaScript, University of Washington and Microsoft Research, 2007.

[25] E. I. Barakova and D. Vanderelst, "From spreading of behavior to dyadic interaction-a robot learns what to imitate", International Journal of Intelligent Systems, vol. 26, 2011, 228-245. DOI 10.1002/int.20464

[26] T. Lourens, R. van Berkel, and E. Barakova, "Communicating emotions and mental states to robots in a real time parallel framework using Laban movement analysis", Robotics and Autonomous Systems, vol. 58, 2010, pp. 1256-1265.

View publication stats