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CONTI, Daniela <http://orcid.org/0000-0001-5308-7961>, TRUBIA, Grazia, BUONO, Serafino, DI NUOVO, Santo and DI NUOVO, Alessandro

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Social robots to support practitioners in the education and clinical care of children: The CARER-AID project

Daniela Conti[1], *Grazia Trubia*[2], *Serafino Buono*[2], *Santo Di Nuovo*[3] *& Alessandro Di Nuovo*[1]

Abstract

The Controlled Autonomous Robot for Early detection and Rehabilitation of Autism and Intellectual Disability (CARER-AID) project aimed at verifying the effects of the introduction of a humanoid robot in the clinical routine as a supervised autonomous assistant to support clinical staff in the care of individuals with Autism Spectrum Disorder (ASD) associated with Intellectual Disability (ID). The CARER-AID project was undertaken by a multidisciplinary team composed of experts in artificial intelligence and robotics and clinical psychologists experienced in the treatment of ID. The literature shows that children with ASD seem to prefer robotic devices over non-robotic instruments and indeed humans. Starting from this, CARER-AID clinical studies provided experimental evidence that demonstrated several potential benefits of robot-assisted therapy when treating children with neurodevelopmental disorders, such

[1] Sheffield Robotics, Sheffield Hallam University, College of Business, Technology and Engineering, Sheffield, United Kingdom.
[2] Unit of Psychology, Oasi Research Institute – IRCCS, Troina, Italy.
[3] Department of Educational Sciences, University of Catania, Catania, Italy.

Correspondence to: Daniela Conti, Sheffield Robotics, Sheffield Hallam University, College of Business, Technology and Engineering, City Campus, Howard Street, S1 1WB Sheffield, United Kingdom. E-mail: d.conti@shu.ac.uk.

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as ASD with or without ID. Alongside the study in a clinical setting, the project also investigated the acceptability and the attitudes towards social robotics in an educational context. The study evaluated the teachers' perception of introducing a humanoid robot in a kindergarten and the attitudes of children with Typical Development (TD) towards.
The results of the clinical and educational studies showed the usefulness of social robotics in supporting practitioners in their interventions with both TD and neurodevelopmental disorders. The CARER-AID project offers a unitary vision of a robot that can serve in different aspects and levels of the care, from the education to the therapeutic rehabilitation, from assessment to monitoring of results, providing assistance to caregivers and professionals at school and in clinical settings.

Keywords: Acceptance; Autism Spectrum Disorder; Intellectual Disability; Kindergarten; Robot-Assisted Therapy.

1. Introduction

In recent years, robotics research has indicated numerous benefits of using robot assistants in the treatment of children with Neurodevelopmental disorders such as Autism Spectrum Disorders (ASD) (Robins, Dickerson, Stribling, & Dautenhahn, 2004; Rabbitt, Kazdin, & Scassellati, 2015; Conti, Trubia, Buono, Di Nuovo, & Di Nuovo, 2018).

Considering the complexity of ASD as “spectrum disorder”, which encompasses diverse disabilities and severity levels, it is appropriate to use a multi-modal therapeutic intervention that can be adapted to the individual’s needs to obtain the best benefits from the treatment (Dawson, Rogers, Munson, Smith, Winter, Greenson *et al.*, 2010). Indeed, several studies have shown that some individuals with ASD prefer robots to humans and that robots generate a high degree of motivation and engagement in individuals who are unlikely or unwilling to interact socially with human therapists (see Rabbitt *et al.*, 2015 for a review). Specifically, scientific evidence has indicated that children with ASD during a play task seem to have a preference for robotic devices over non-robotic instruments and indeed humans (Simut, Vanderfaeillie, Peca, Van de Perre, & Vanderborght, 2016). For this reason, various researchers began to investigate this new field of application for robotic, showing initial promising results.

Humanoid social robots have been used to improve ASD diagnosis in children (Rabbitt *et al.*, 2015). The success of this approach can be favored by the preference of interacting with a humanoid social robot rather than a non-embodied computer screen, as found in young children and older adults (Feingold Polak, Elishay, Shahar, Stein, Edan, & Levy-Tzedek, 2018). Users are more likely to consider human-robot interaction more satisfying when the robot can exhibit human-like behaviors (Maggi, Dell’Aquila, Cucciniello, & Rossi, 2020). Specifically, because robots can display different characteristics of people’s social behavior, this may contribute to creating “a simplified, safe, predictable and reliable environment where the complexity of interaction can be controlled and gradually increased” (Robins, Dautenhahn, Boekhorst, & Billard, 2005; p. 108). Furthermore, evidence shows that people who experience physical interactions with robots during a rehabilitation treatment, consider them as more engaging and motivating than interactions with other screen-based information technologies (Matarić, 2017). This is probably because robots evoke emotional reactions potentially leading to specific emotional bonds between human and machine (Eyssel, 2017). Therefore, when the robot held the child's attention and interest in both itself and the tasks, it was possible to extend the educational (Baxter, Ashurst, Read, Kennedy, & Belpaeme, 2017) or rehabilitative sessions for a longer time period (Conti, Di Nuovo, Cangelosi, & Di Nuovo, 2016; Rudovic, Lee, Mascarell-Maricic, Schuller, & Picard, 2017).

2. The CARER-AID project

The Controlled Autonomous Robot for Early detection and Rehabilitation of Autism and Intellectual Disability (CARER-AID) project experimented a humanoid robot as a supervised autonomous assistant to support caregivers in early diagnosis and to improve the treatment of individuals with ASD associated with Intellectual Disability (ID). The robot introduced as part of the diagnostic team during the administration of the psycho-diagnostic tests to enrich the data that the psychologist can use to refine the diagnosis, helping them to perform early diagnosis and to distinguish among the ASD types and ID levels. This research program was undertaken by the Marie Skłodowska-Curie experienced researcher (DC) under the supervision of a multidisciplinary support team composed by the academic staff of the Sheffield Robotics (UK) in partnership with Oasi Research Institute-IRCCS in Troina (Italy). The final output of the research project was a set of use cases that will be implemented and empirically validated via pilot studies and proof-of-concept trials in kindergarten and clinical environments. Furthermore, the project accomplished a series of actions for the widespread scientific dissemination of the experimental results and outreach activities to give evidence also to the general public, especially targeting families with individuals affected by ASD and ID, of the actual opportunities offered by robot and, thus, increase their acceptance and willingness to use robots in the care of children and disabled people.

Specifically, the work has mainly focused on two sectors highly connected: teachers' and students' acceptance and attitude towards humanoid robots, and children with Typical Developmental (TD) or with ASD and ID.

2.1. Research Impact

The CARER-AID project contributes to alleviating the increasing concern worldwide about the diagnosis and treatment of children with ASD by proposing the use of robot assistants.

Toward its vision, this project introduced five main innovations:
1. to identify the acceptability and attitude of social robotics by teachers and practitioners;
2. to design a set of use cases in which a socially assistive robot gives support to the education of children with TD in a kindergarten setting;
3. to design a set of use cases in which a socially assistive robot gives support to the diagnosis and rehabilitation of ASD and ID;
4. to implement novel control strategies for autonomous and safe robot-child interaction that can support the intelligent personalization of activities;
5. to validate the use cases with the integration of the robot in everyday educational activities and standard therapeutic protocols in a healthcare center.

3. The CARER-AID methodology

3.1. Participants

The two-year overall project involved the following participants:
- 114 Italian teachers (N = 114, Males = 18, Females = 96, M_{age} = 51.07 years, range = 26-68, SD = 8.22);
- 158 MPsych students consisting of Italian students (N = 80, Males = 6, Females = 74, M_{age} = 25.1 years, range = 22-30, SD = 2.17), recruited at the University of Catania, and British-English students (N = 78, Males = 16, Females = 62, M_{age} = 20.6 years, range = 19-30, SD = 2.21), recruited at the University of Plymouth;
- 52 children (N = 52, Males = 28, Females = 24, M_{age} = 5 years, range = 5-6, SD = .33) enrolled from four classes of the same kindergarten school in Catania, Italy;
- 81 children (N = 81, Males = 45, Females = 36, M_{age} = 5 years, range = 5-6, SD = .33) recruited in a kindergarten school in Catania, Italy;
- 7 children (all males, age range = 66-121 months, mean chronological age = 104.3 months, SD = 18.6) were selected from patients diagnosed with ASD and ID. Specifically, one participant was diagnosed with mild ID level, one moderate ID level, two with severe ID level, and two with profound ID level. The 7 participants at the time of the study were hospitalized and receiving treatment at the Oasi Research Institute – IRCCS (Italy), a specialized institution for the rehabilitation and care of patients with intellectual disabilities.

All procedures performed in studies involving human participants were under the ethical standards of the institutional research committee (Oasi Research Institute of Troina 2017/01/17/CE-IRCCS-OASI/4 and Sheffield Hallam University No. Z6559086), and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all participants or parents included in the project. In accordance with University and Oasi Institute ethics procedures for research with children, parents provided written consent prior to their children's participation. Children also provided verbal assent prior to taking part in the tasks, and tasks could be discontinued at any time at no disadvantage to the children. All the data was securely stored and was not presented in any way that might disclose individual identities or performances. Furthermore, the kindergarten teachers, and psychological team in the IRCSS, actively participated in the design of the procedure and approved the final implementation.

3.2. The NAO Robot

The robot used for the project was the Softbank Robotics NAO (Model H25, Version 4), which is a small, toy-like humanoid robot, very popular for child-robot interaction studies. NAO is 57.4 cm high, weighs 4.3 kg and can produce very expressive gestures with 25 Degrees of Freedom (DoF) (4 joints for each arm; 2 for each hand; 5 for each leg; 2 for the head and one to control the hips) (Softbank Aldebaran Robotics, 2018). NAO can detect faces and mimic eye contact moving the head appropriately, and also can change the color of the LEDs in its eyes' contour to simulate emotions and capture a lot of information about the environment using sensors and microphones. The NAO robot is programmed with a graphical programming tool, named *Choregraphe* (Pot, Monceaux, Gelin, & Maisonnier, 2009).

4. CARER-AID outcomes

4.1. Teachers and Students acceptance and attitude towards humanoid robots

First, we evaluated the predictive factors and attitudes of curricular and specialized teachers towards socially assistive robotics, and the intention to use robots in teaching activities. In this research, we investigated the impact of the personality factors measured with the Big Five Questionnaire, on acceptability questionnaires derived by Eurobarometer and by the Unified Theory of the Acceptance and Use of Technology (UTAUT), administered respectively before and after showing the possible uses of the NAO robot in education and teaching. The study was conducted in four schools; participants were 114 teachers of the primary and middle school level. The results highlighted the primary role of the personality factors Openness to Experience and Extraversion for promoting the acceptability and reduce the prejudicial reject regarding the use of educational and assistive robotic technologies (Conti, Commodari, & Buono, 2017).

In the context of potential users, the project has investigated the cultural influences of English and Italian psychology students in the perception of usefulness and intention to use a robot as an instrument for future clinical practice and, secondly, the modality of presentation of the robot by comparing oral versus video presentation. To this end, we surveyed 158 Italian and British-English psychology students after an interactive demonstration using a humanoid robot to evaluate the social robot's acceptance and use. The Italians were positive, while the English were negative towards the perceived usefulness and intention to use the robot in psychological practice in the near future. However, most English and Italian respondents felt they did not have the necessary abilities to make good use of the robot (Conti, Cattani, Di Nuovo, & Di Nuovo, 2015, 2019).

4.2. Social Assistive Robotics in children with Typical Development and Neurodevelopmental Disorders

Subsequently, we have moved our interest in children, before with typical development and after in children with ASD and ID.

We present an experiment that investigates the attitude of 52 pre-schooler children before and after the interaction with a humanoid robot in a kindergarten setting, as shown in Figure 1. We found that children exposed to the robot decrease their distress and positively change their attitude toward the technological device. This suggests that early, controlled exposure may facilitate future acceptance (Conti, Di Nuovo, & Di Nuovo, 2019).

Figure 1 – *An experimental session in a school*

In another study, we presented an experimental study with 81 kindergarten children on memorizations of two tales narrated by a humanoid robot. Variables of the study are the content of the tales (knowledge or emotional) and the different social behavior of the narrators: static human, static robot, expressive human and expressive robot. Results suggest a positive effect of the expressive behavior in robot storytelling, whose effectiveness is comparable to a human with the same behavior and better when compared with a static inexpressive human. Higher efficacy is achieved by the robot in the tale with knowledge content, while the limited capability to express emotions made the robot less effective in the tale with emotional content (Conti, Cirasa, Di Nuovo, & Di Nuovo, 2020).

In a recent study conducted in a clinical setting, the aim was to integrate the robot within the standard treatment, i.e. the TEACCH (Treatment and Education of Autistic and related Communication Handicapped Children) approach (Mesibov, Shea, & Schopler, 2004), and to evaluate the follow-up phase. To support the therapists, we integrated a humanoid robot within the standard clinical treatment of children with ASD. In this research, using the A-B-A1 single case design, we propose a robot-assisted affect recognition training and present the results on the child progress during the 5 months of the clinical experimentation. In the investigation, we included a test of the generalization of learning and the long-term maintenance of the new skills via the NEPSY-II affection recognition sub-test, as shown in Figure 2. The results of the single case study suggest the feasibility and effectiveness of using a humanoid robot for emotion recognition training in children with ASD (Conti, Trubia, Buono, Di Nuovo, & Di Nuovo, 2019).

Figure 2 – *An experimental session with child*

Subsequently, we focused on a preliminary evaluation on integrating robot-assisted therapy in the treatment of children with ASD and ID, which is the most common case. The experiment integrated a robot-assisted imitation training in the standard treatment of six hospitalized children with various level of ID, who were engaged by a robot on imitative tasks and their progress was then assessed via a quantitative psycho-diagnostic tool. Results show success in the training and encourage the use of a robotic assistant in the care of children with ASD and ID except for profound ID, who may need a different approach (Conti, Di Nuovo, Trubia, Buono, & Di Nuovo, 2018; Conti, Trubia *et al.*, 2018).

Focusing in this area we investigated on the use of novel deep learning neural network architectures for automatically estimating if the child is focusing their visual attention on the robot during a therapy session, which is an indicator of their engagement. To study the application, the authors gathered data from a clinical experiment in an unconstrained setting, which provided low-resolution videos recorded by the robot camera during the child–robot interaction. Two deep learning approaches are implemented in several variants and compared with a standard algorithm for face detection to verify the feasibility of estimating the status of the child directly from the robot sensors without relying on bulky external settings, which can distress the child with autism. One of the proposed approaches demonstrated very high accuracy and it can be used for off-line continuous assessment during the therapy or for autonomously adapting the intervention in future robots with better computational capabilities (Di Nuovo, Conti, Trubia, Buono, & Di Nuovo, 2018).

In a preliminary study, the authors present a pilot clinical trial, focused on imitation skills, with three children affected by ASD and ID under treatment in a research center specialized in the care of children with disabilities. The success of the experiment suggests that the robot can be effectively integrated into the ASD therapies currently used in the center. Analysis of these initial results encourages the development of effective protocols in which the robot becomes a mediator between the child with ASD and humans and suggests some research directions for focus in the future (Conti, Di Nuovo, Buono, Trubia, & Di Nuovo, 2015).

5. Conclusions and Future Research

The CARER-AID project offered a unitary vision in which the robot can serve in different aspects and levels of the care, from the education to the therapeutic rehabilitation, from assessment to monitoring of results, providing assistance to caregivers and professionals at school and in clinic settings. This possibility of generalization, including the acceptance of the robot in different contexts, constitutes an advancement over most of the other research programs that usually focus only on the intervention.

The technological advancement proposed by the research program is the introduction of autonomous behaviors that will improve usability and overcome the limitations of the Wizard-of-Oz (WoZ) technique. Specifically, the WoZ approach pretends that the robot is autonomous but actually relies on a hidden human to control the robot remotely.

Moreover, the proposed research in clinical settings explicitly addresses also patients with ID, which lead to significant differences in cognitive and adaptive skills respect to individuals with ASD only.

In conclusion, the results of the CARER-AID project indicate the underlying potential of the application of social robots in the care field.

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