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SERVICE AND INTERACTIVE ROBOTICS (A TAPUS, SECTION EDITOR)

Social Robots in Therapy and Care

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Abstract

Purpose of Review This work presents a comprehensive overview of social robots in therapy and the healthcare of children, adults, and elderly populations. According to recent evidence in this field, the primary outcomes and limitations are highlighted. This review points out the implications and requirements for the proper deployment of social robots in therapy and healthcare scenarios.

Recent Findings Social robots are a current trend that is being studied in different healthcare services. Evidence highlights the potential and favorable results due to the support and assistance provided by social robots. However, some side effects and limitations are still under research.

Summary Social robots can play various roles in the area of health and well-being. However, further studies regarding the acceptability and perception are still required. There are challenges to be addressed, such as improvements in the functionality and robustness of these robotic systems.

Keywords Social robots · Service robots · Companion robots · Human-robot interaction · Healthcare robotics

Introduction

Social robots provide cognitive support in healthcare scenarios through social interaction. In this field, researchers are focused on developing social robots to perform tasks with a high degree of autonomy, while holding natural interaction with the patients and the clinical staff [1, 2]. Social robots have been developed in multiple clinical settings and home-based areas, providing physical, cognitive, and social support, as well as coaching activities, such as exercise training, education, and monitoring [3, 4]. Social robots are being used to support the specific needs of the clients, especially in managing chronic illness using education and encouragement [5]. In this context, the stakeholders should be involved in the creation of social robots (i.e., patients, healthcare professionals, software developers, and caregivers) [6]. Several techniques are being used at different stages to create and evaluate this technology. For instance, during the design process, collaborative and inclusive methodologies are being followed [7]. This inclusive design is mainly aimed at involving the target users, in such a way that they can contribute to the decision-making, and thus increasing the acceptance and effectiveness of the impacts caused by the robots.

Figures 1 and 2 introduce healthcare scenarios where the authors are implementing social robots. Figure 1 a represents interventions with children with cerebral palsy, where the robot demonstrates and encourages how to perform motor activities. Figure 1 b and c show a setup where social robots developed by participative design are implemented in the treatment of autism. Figure 2 a illustrates a social robot motivating and assisting a patient under cardiac rehabilitation, and Fig. 2 b shows a social robot supporting clinicians during gait rehabilitation of patients with neurological impairments. These scenarios are examples of social robots supporting conventional procedures within different communities.

In this sense, this review was conducted to investigate the evidence and implications of social robots in healthcare scenarios. This work addresses recent studies focused on the perception and acceptance models and applications of social robots. Additionally, the literature review is divided into two

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Fig. 1 Social robots in healthcare scenarios of children. **a** A Nao robot introducing himself to a child with cerebral palsy. **b** Ono robot in an autism therapy. **c** CASTOR robot within an autism therapy

populations: (1) children population and (2) adults and the elderly population. Finally, the discussion and conclusion sections embrace the analysis of the opportunities and limitations of this technology, along with some insights to overcome the current limitations and to clarify its potential in healthcare scenarios.

Social Robotics Acceptance and Perception

According to literature evidence, social robots are being tested and accepted in healthcare areas, such as rehabilitation and clinical assistance [6]. The most relevant works focus on the integration of all stakeholders related to the clinical service. To this end, several metrics are used to measure the perception of the users, caregivers, therapists, and healthcare professionals towards social robots [8–10]. Some of this metrics include semi-structured interviews, focus groups [11], pictures sorting tasks [12], and different kinds of questionnaires (e.g., UTAUT (unified theory of acceptance and use of technology), Robot Attitudes Scale, NARS (Negative Attitudes towards Robots Scale), RoSAS (Robotic Social Attributes Scale)) [10]. These qualitative measurements enable the understanding of the implications in the social factors during the human-robot interaction. For instance, ethical issues [13], usability, social presence [8], discomfort/comfort, and even the fictional view are assessed.

In [11], a group of elderly people was evaluated to observe their acceptance of different kinds of social robots. In this study, the participants perceived social robots as safety tools since they can detect emergency events. Similarly, positive opinions were obtained in [14], where patients recognize the potential of social robots to improve the social capabilities of the users, as well as to alleviate their loneliness and isolation. Regarding the opinions made by the healthcare staff, social robots are tools that complement and enhance care tasks [14, 15]. However, in the elderly population, there are three main concerns: (1) fears for losing human contact; (2)

Fig. 2 Social robots in healthcare scenarios of adults and elderly people. **a** A Nao robot assisting cardiac rehabilitation. **b** Nao robot assisting gait rehabilitation

infantilization, which refers to see the robots as toys, causing adverse effects regarding its use; and (3) deception (i.e., belief that robots are something that they are not) [14, 16].

Regarding studies with children, mainly positive outcomes can be seen concerning the perception. Carrillo et al. [17] presented an in situ design and development of a robotic social tool for pediatric rehabilitation. During phase two of this study, the patient, therapist, and parent perception were evaluated regarding the trust, usefulness, and benefits of the robot. Results were positive regarding these constructs, showing social robotics as a potential tool in pediatric rehabilitation. In the same way, Rabbit et al. [18] observed the acceptance of social robot-based therapy in procedures for children with disruptive behaviors through an evaluation of the parents. The results indicated that social robots were highly acceptable.

Additionally, Looije et al. [19] implemented three scenarios where a robot interacted with 17 children through different activities (e.g., quizzes, games, small talk, and walking). The activities were focused on supporting the child's self-management of diabetes. Firstly, parents and caregivers were very skeptical about the robot's role. However, when the scenarios were performed, they perceived the robot as a positive tool in many ways, such as improving communication skills.

Bearing in mind the aforementioned, some of the challenges regarding social robots in the child population can be summarized in two ways. On the one hand, some studies are focused on assessing the perception of the children considering their physical appearance [20]. On the other hand, how to maintain the relationship in long-term periods and how positive perception can be improved. For example, developing social robot approaches more personalized according to the age of the child to keep intelligence perception [19].

Social Robots for Children

The review was divided into four topics where social robots have been studied in healthcare scenarios with children, such as (i) social robots supporting the emotional part of dealing with a disease (cancer, diabetes), (ii) social robots supporting therapy or interventions in children with autism spectrum disorder, (iii) social robots enhancing well-being during inpatient stays, and (iv) social robots providing distraction during a medical procedure (anxiety and stress reduction). More details of the works referred to in this section are explained in Table 1.

Support for Dealing with a Disease

In three studies, a Nao (SoftBank Robotics, France) robot was used to support children in dealing emotionally with their diseases, such as DM1 (diabetes mellitus type 1) [19, 21] and cancer [22]. The studies presented a sample ranging from 11 to 27 children. These trials had 3 to 8 sessions, each session with a duration between 23 to 60 min.

The study by Looije et al. evaluated the Nao robot helping children with DM1 to learn more about the disease and to deal better with it, thereby supporting their self-management [21]. Similarly, the study by Henkemans et al. provided diabetes self-management education in a clinical setting in terms of children's acquisition of knowledge about their illness [19]. In both studies, findings showed that the children enjoyed the activities with Nao and learned more about diabetes than they already knew. Moreover, Looije et al. showed that according to parents and hospital staff, Nao had positive effects on the child's mood and openness.

Regarding the study by Alemi et al., Nao was used to create a friendship bond with young oncology patients to alleviate their pain and distress [22]. The robot was programmed to have different roles in each session, such as assistant to the session leader, psychotherapist, and doctor chemo-hero. Nao was able to show emotions with speech tone and body motions while acting on a structured scenario. The children reported a drop-in level of anger, fear, anxiety, and depression over the session.

In these studies, findings suggested that the use of such a robot assistant can provide added value for the healthcare program. Notwithstanding, these findings need to be corroborated with a larger sample of children and with long-term studies to observe whether these results are maintained, improved, or worsened over time.

Children Interventions for Autism Spectrum Disorder

Twelve trials of robot interventions for autism spectrum disorder in children between the ages of 4 and 12 years were identified. These studies used humanoid-like robots, such as Nao, Robonova (Hitec Robotics, South Korea), Caro (Center for Robotics Research at KIST, South Korea), Zeno (Hanson Robotics, Hong Kong), Ono (Ghent University, Belgium), and Kaspar (University of Hertfordshire, UK). The nature of the roles of the robot was diverse. Some studies used the robot as an assistive tool for therapist interventions [23–25], whereas in others, it was a primary method of therapy [26, 27]. All studies programmed the robot before the study according to their objectives. Some researchers used a set program where they could pause the program if needed [28].

Seven trials presented a small sample ranging from 2 to 21 children [26–32]. In contrast, four studies used a medium-small sample between 36 and 45 children with ASD [23–25, 33], and only one study used a considerable

Table 1 Publications that report the effects on well-being of a child, categorized according to the purpose of the robot

Author	Target population	Objective	Design—robot	Measures	Outcomes—key findings
1. Emotional support for dealing with disease					
Henkemans et al. [20] (2017)	27 children (girls and boys) aged 7–14 with a diagnosis of T1DM	To assess the effects of a personal robot, which provides education for diabetes self-management in a clinical setting	The Nao robot was implemented in four sessions. The children and Nao were competing against each other, a quiz about diabetes.	Diabetes knowledge; behavior during interaction; basic need satisfaction in relationship scale.	Playing an educative quiz with a social and personal robot over a prolonged period of time can help children to learn more about their illness and how to self-manage.
Alemi et al. [22] (2015)	Eleven children, ages 7–12, diagnosed with cancer.	To create a friendship bond between a humanoid robot and young oncology patients to alleviate their pain and distress.	The Nao robot called Nina was used in eight sessions. Nina was programmed to play a different role in each session, such as a doctor, chemo-hero, nurse, a cook, and an ill kid.	The Multidimensional Anxiety Children Scale (MASC); Children's Depression Inventory (CDI); Children's Inventory of Anger (CIA, Nelson and Finch, 2000).	The control group did not improve in any of the anxiety, depression, or anger levels while the experimental group clearly showed us that the use of a social robot as a psychologist assistant helped to lower the children's psychological problems.
Looije et al. [19] (2016)	17 diabetic children in the age of 6–10 years old. All children got the diabetes diagnosis more than a year and a half ago.	To evaluate the scenario to support self-management for children with DM1 visiting the hospital.	Nao robot named Charlie was used in a series of 3 sessions of 1 h, at least 2 weeks apart. The interaction with Charlie starts with an introduction and with small talk and walking followed by one of the games. The games are related to diabetes knowledge.	Scores by child on DM1 knowledge, fun aspects of the robot, aspects of self-determination; pre/post-test comparison; observations (notes, videotaping), focus on activities, interaction with robot, empathy for robot.	The children gain knowledge from questions presented during the sessions. No improvement in competence, relatedness, autonomy (scores 1st session already quite high). Opinion parents and hospital staff: the robot had a positive effect on the child's mood and openness.
2. Children interventions for autism spectrum disorder					
Srinivasan et al. [24] (2015)	36 children between 5 and 12 years of age children (32 males and 4 females; 20 Caucasian, 6 African American, 4 Asian, 3 Hispanic, and 3 of mixed ethnicity) with ASD.	To assess the effects of three interventions, rhythm, robotic, and standard-of-care, on the imitation/praxis, interpersonal synchrony, and overall motor performance.	Nao robot was used over 10 weeks during 36 sessions. The children were divided into three groups: rhythm group, robot group, and comparison group.	Joint Attention Test (JTAT); Bruininks-Oseretsky test of motor proficiency (BOT); affective states; repetitive and maladaptive behaviors.	The rhythm and robot groups demonstrated improvements in gross motor performance. The robot group demonstrated greater social attention than the comparison group but lower than the rhythm group.
Peca et al. [25] (2015)	27 Romanian children, 18 with ASD, and 9 with pervasive development disorder (PDD).	To investigate if a synchronous interaction game, in which the child has the lead, facilitates the manifestation of testing behaviors in children with ASD.	The humanoid robot called Robonova was used in each session. Each child was exposed to 2 game sessions, a contingent interaction (imitating child) and noncontingent interaction session, each 80 s in duration, separated by a 5-min pause.	Social intention (eye gaze, positive affect, initiations, intention testing); Test per initiation frequency; Contingent (mirrored behavior).	The results suggest that the participants manifested a high motivation for the interaction game in both human and robot interaction condition. There are no significant differences in terms of testing behaviors, motivation while interacting with Robonova robot compared with the human.

Table 1 (continued)

Author	Target population	Objective	Design—robot	Measures	Outcomes—key findings
Chevalier et al. [32] (2016)	6 autistic children (10.9 ± 1.8 years) and 7 autistic adults (26.1 ± 7.9 years).	To analyze the impact of proprioceptive and visual integration profiles on an individual's emotion recognition performance.	The study has two phases. Phase 1: developed a database of 96 videos expressing four basic emotions on four test platforms (Nao, Zeno, a virtual agent, and a female human). Phase 2: Evaluated the database with the participants.	Videotaping; AASP questionnaires.	There are no significant differences between platforms. The results informed that the integration of visual and proprioceptive cues of an individual with ASD influences his/her abilities in recognizing emotions. Participants with ASD relying on proprioceptive information had lower recognition scores than the other participants with ASD.
So et al. [29] (2018)	13 Chinese children aged 6 to 12 years with ASD.	To evaluate the use of social robots to improve non-verbal communication skills, especially gesture, of children with ASD.	The Nao robot was used in this study programmed to produce eight gestures. The study had two phases. Phase 1: recognize 8 gestures; phase 2: produce 8 gestures.	Recognize gestures and produce gestures were tested on 2 trained gestures, and untrained.	The results showed that the social robot Nao effectively can teach gestural recognition and gestural production to children with ASD.
Yun et al. [28] (2017)	15 Korean males' children with ASD between 4 and 7 years old.	To evaluate and verify the effects of behavioral interventions that used a robot as a facilitator for behavior in children with ASD.	Caro robot was used during 8 sessions. Each session with three sets of interaction: therapist observer-robot, child-robot, and therapist observer-child.	Autism Diagnostic Observation Schedule (ADOS); Vineland Adaptive Behavior Scale (Korean version); Social communication Questionnaire; Social Responsiveness Scale; Child Behavior Checklist (CBCL, Korean version).	The results showed significantly higher percentages of eye contact, especially in the first sessions. There are no significant differences between the robot group and the control group in terms of facial recognition.
So et al. [33] (2018)	45 Hong Kong participants with ASD aged 4 to 6 years old.	To examine whether children with ASD could catch up to the level of gestural production found in age-matched children with typical development and whether they showed an increase in verbal imitation after the completion of robot-based training.	The robot Nao was used to produce 14 gestures. A total of 18 sessions were implemented. For each training or assessment session, the participants were accompanied by a teacher and the sessions were administered by a researcher.	Gestural production in training, novel stories, gestural recognition; Bruininks-Oseretsky test of motor proficiency (BOT, second edition); Attention Network Task (ANT)	The results suggested that the robot-based intervention can prevent the delay in the production of intransitive gesture in young children with ASD. Participants with ASD who received robot-based gestural training produced intransitive gestures more accurately in training stories than those who did not receive training.
David et al. [30] (2018)	5 Romanian children with ASD were enrolled in this study. All children were recruited from the Autism Transylvania Association (Cluj-Napoca, Romania)	To investigate if the JA performance of ASD children depends on the social cues that the robot used in the therapy session.	The robot Nao was used during 20 sessions. Each child went through the following three scenarios: baseline measurements, robot-enhanced	Joint attention score. They used a behavioral grid developed by integrating indicators such as head orientation, pointing, relevant verbalization (vocal instructions that	The results indicated that pointing is an important cue for engaging ASD children in JA activities, beyond gaze orientation. The authors suggest that robot interaction

Table 1 (continued)

Author	Target population	Objective	Design—robot	Measures	Outcomes—key findings
			treatment, and standard human treatment.	are in the context of the experiments/tasks being implemented) and delays in performing such behaviors.	follows a similar pattern as human interaction and pointing is a key ingredient to engage ASD children.
Kumazaki et al. [34] (2018)	68 Japanese children with ASD, including 30 (10 females and 20 males) children with ASD and 38 (13 females and 25 males) children with TD.	To assess if children with ASD would demonstrate better JA under the social robot condition than under the human agent condition, and children with ASD would show improvement in JA tasks with a human after interacting with the social robot.	During each session, the participants interacted with the Comm U robot or human agent for approximately 5 min.	Behavior during session (videotaping).	The intervention group had better outcomes in terms of JA than the control group who interacted with a human agent during all sessions. The simple exposure to the social robot CommU increased JA.
Zheng et al. [31] (2018)	14 children (12 males and 2 females; 12 Caucasians, 1 African American, and 1 Asian) with ASD.	To design a novel joint attention intervention system for children with ASD.	A Nao robot called Norris was used in four sessions. Each session involved eight repeated LTM-RI model. This model had three steps.	Preferential attention; joint attention score.	Results showed that the participants looked at the robot longer than other objects and this interest did not change significantly over the sessions.
Zorcec et al. [27] (2018)	Two young children with 2 years old diagnosed with ASD.	To explore the possible added value of the humanoid robot Kaspar as an intervention tool, in therapeutic and educational purposes in children with autism or robot-assisted play in the context of autism therapy in a hospital setting.	The humanoid robot Kaspar is used over 10 sessions in different activities such as imitation games, learning skills of greetings, and learning emotions.	Behavior during session. This behavior involves the child performance in imitation games, in recognition and production of gestures; smile and proper eye contact were assessed in the greeting activities.	During the intervention, parents stated that after 8–10 sessions of practicing, greetings as well as recognition and appropriate reactions to happy and sad emotions, are used in daily life too. The children started using greetings in their everyday life without anxiety, resistance, or discomfort.
Wood et al. [26] (2018)	12 children (7 male and 5 female) aged between 11 and 14. 11 of the 12 children had been diagnosed with ASD while one child was diagnosed with global developmental delay which gave the child ASD traits.	To analyze differences in children's activity performance after a period of intervention with a social robot	9 visual perspective-taking skills (VPT) activities were developed and implemented as interactive games. The games were devised to become incrementally more difficult.	The Smarties test; The Sally-Anne test; the Charlie test.	The children engage in most activities with the robot. The preliminary results suggest that a robot can assist children with ASD develop their VPT and helps to improve the performance at the beginning and at the end of the session.
Ramírez-Duque et al. [23] (2020)	38 children diagnosed were enrolled in this study. 23 children were diagnosed with ASD, and 15 children without ASD, but with one of the following conditions: down syndrome, congenital hydrocephalus, or	To provide a comprehensive robot-assisted intervention for CwASD, showing the conditions in which, a robot-based approach can be useful to assess autism risk factors for an autism diagnosis purpose.	The robot Ono was used as the mediator in JA elicitation activities. The first mediator therapist/robot began the JA task conducting the children's attention towards the objectives from 5 min approximately. Then, the mediator first	Joint attention score; adult seeking; eye contact.	The results showed poor performance in JA tasks; higher visual robot compared with visual contact towards the therapist; low exhibition of adult seeking.

Table 1 (continued)

Author	Target population	Objective	Design—robot	Measures	Outcomes—key findings
	general learning disability.		greeted the participant and provided the first level of antecedent stimulus.		
3. Support for well-being during the stay					
Nakodi et al. [35] (2015)	No objective stated. The study focused on explorative field study and free interaction.	Children and adolescents in hall psychiatric ward. No numbers of children were presented.	The robot Paro was used. The contact with Paro only started after permission from the staff.	Observation interaction child-Paro.	Children showed less anxiety and more relaxation with the interaction of the robot. Children improved their communication skills.
Jeon et al. [36] (2015)	4 children between 5 and 10 years old hospitalized for at least 48 h. Intervention took place in a surgical or oncology unit of a hospital in the USA.	Explorative filed study.	Huggable robot bear and virtual bear both programmed with three types of interactions: conversing with child about likes/dislikes, singing nursery and playing "I spy" game. The child had free interaction with a virtual bear (2 children) and a robot bear (2 children) during a 4-h period.	Qualitative analysis of child's responses to programmed interactions (videotaping).	A huggable robot appeared to be more physically and mentally motivating to engage than virtual bear. Huggable robot was perceived as a peer that they could connect with emotionally and socially.
Jeon et al. [37] (2017)	54 children (33 boys, 21 girls) hospitalized for at least 48 h. Intervention took place in bed-spaces in various units in hospital.	To study the impact of different embodiments on socio-emotional engagement of child and co-present family members.	Huggable robot bear and virtual bear, each programmed with 3 types of interactions and external control by teleoperator outside the bed-space to respond to the children's responses. Plush toy likewise "puppeteer-ed" by CLS present at the bedside.	Video observation child: interactions, physical movements and verbal utterances; Video observation family members, CLS; questionnaires CLS.	The children enrolled with Huggable robot increased their physical movement from start to end session. No differences in effect on engagement between robot and virtual bear. Although, children interacted longer and talked more with robot compared to virtual or plush bear.
Logan et al. [38] (2019)	54 children ages 3 to 10 years old were randomly exposed to 1 to 3 interventions.	To assess the feasibility and acceptability for families and hospital staff to integrate social robotic technology into pediatric care.	Interactive robot teddy bear called Huggable, table-based avatar version of the bear, and plush teddy bear with human presence.	Indicator of feasibility included tracking of enrollment and completion rates; and analysis of procedural difficulties that emerged during intervention implementation; Facial Affective Scale; Face Pain Rating Scale Revised.	Children exposed to the Huggable robot reported more positive affect relative to those who received a plush animal. The robot interactions were characterized by greater levels of joyfulness and agreeableness than comparison interventions.
4. Distraction during a medical procedure					
Beran et al. [41] (2015)	57 Canadian children (30 males, and 27 females) receiving flu vaccination, between 4 to 9 years.	To evaluate distraction effect during flu vaccination by (1) robot, (2) standard procedure (with minimal or no distraction).	The robot Nao gives commands to blow for distraction (cognitive-behavioral strategies).	Relative crying and smiling time (relative to duration procedure), based on videotaping; Feedback from parents on the robot.	Children were more likely to smile when encountering medical procedures with a robot. However, the robot had no effect on the crying time of the child. Preliminary

Table 1 (continued)

Author	Target population	Objective	Design—robot	Measures	Outcomes—key findings
					insights suggest that when robots are designed and programmed with humanistic characteristics, they are highly engaging to children, eliciting a positive response in the form of smiling.
Jibb et al. [39] (2018)	40 Canadian cancer patients (24 males, 16 females) aged 4 to 9 years	To assess the feasibility of a trial examining the impact of the Nao robot, programmed to use cognitive-behavioral pain and distress management strategies with children during an SCP access.	The Nao robot made an introductory statement and executed only a standard set of dancing movements while singing. The actions began while the clinic nurse prepared for the procedure and continued until a sterile dressing was placed over the inserted needle.	BAADS; Face Pain—Revised (FPS-R); Children's Fear Scale; Acceptability questionnaire (Likert and free text)	Children presented in their distraction arm more positive and adaptative behaviors than those in the cognitive-behavioral arm.
Rossi et al. [40] (2020)	139 Children, of which 69 interacted with the robot (27 males and 41 females).	To evaluate the distraction strategy personalized starting from forms filled in by the parents, nurse evaluation of pain, and self-assessments	The robot Nao was pre-programmed to execute a different interaction strategy with respect to the children's age and with two different modulations in terms of non-verbal social cues according to the initial anxiety level of the child as evaluated by the nurses.	A questionnaire to report the children distress by a parent; Faces Rating Scale to measure children self-reported pain; FLACC scale to reported children pain as rated by a nurse	The robot distraction strategy had an effective distracting power which allowed the children not to focus on the injection, no matter what age. The child's anxiety level had an impact on the effects of the interaction with the robot.

size of 61 children [34]. The studies had 1 to 36 sessions (median = 13.85), each session with a duration between 10 and 45 min (median = 32 min). All studies presented the results against a comparison condition, either with each participant with a pre-test or post-test or with another group. Similar outcomes were found between robot and human interventions (peers or therapeutics). However, the study by Srinivasan et al. reported that the robot never was superior to the human, and the human condition did better on several social indices [24]. The results also showed that the child devoted maximum attention to the robot without increasing social attention throughout the treatment sessions. It was also reported by Ramirez et al. that children exhibited lower visual contact towards the therapists and higher preference to look towards the robot and manifested few or no events related to adult seeking behavior [23].

On the other side, social behaviors were presented to increase eye contact [28, 31], and improve and develop visual perspective-taking skills [26]. Some studies reported improvements in the production and recognition of facial emotions [29, 33]. It is important to note that Chevalier et al. [32] informed that the combination of the body and facial emotion expressions plays an important role to improve emotion recognition performance. Notwithstanding, they also reported that the integration of visual and proprioceptive cues of a child with ASD influences their ability to recognize emotions. It suggests the importance of identifying the skills and functionality of each child when therapy is designed in order to ensure the appropriate development and activity performance.

On the other hand, however, some studies reported that there is no evidence that participants with ASD applied the acquired skills interacting with others in their daily life. The study by Zorcec et al. reported that after ten practice sessions, the parents stated that the recognition and appropriate reaction to happy and sad emotions were used in daily life [27]. Also, this study reported that after ten sessions, the children started using greetings in their everyday life without anxiety, resistance, or discomfort.

Some studies suggest that the robot increases attention (JA) [30, 31, 34] However, David et al. reported that to increment JA performance, the use of pointing is crucial to engage ASD children [30]. Ramirez et al. informed that children with ASD demonstrated worse JA during their interaction with the robot despite using signaling in their study [23]. It should be noted that the other studies used the Nao or Kaspar robot, while Ramirez et al. used the Ono robot. This may suggest that the use of different social robots may affect the child's performance, considering that it was also reflected in [32] who reported that the child's performance decreased with the Zeno robot compared with that with the Nao robot.

Eventually, the results of the current studies support the idea that robots might be utilized as active agents of reinforcement in semi-structured behavior for children with ASD. Nevertheless, the visual fixation on the robot may restrict the child's opportunities to engage with social partners. Social robots for children with ASD appear to have positive outcomes. However, studies with larger samples and more prolonged follow-up are needed to establish strength, confidence, and continued maintenance of these outcomes.

Support for Well-being During Hospital Stay

Fourth studies were focused on well-being during medically or surgically hospitalization. The studies used a pet-like robot: Paro (AIST, Japan) and Huggable Bear (MIT, USA) [35–38] and were carried out in the hall of the psychiatric ward [35] and in the child's bed-space [36, 37]. Paro was used in a psychiatric ward of children and adolescents [35]. Patients could play freely with Paro to bring relaxation and an improvement in communication for some patients. However, with some patients who had an attachment problem or ASD when they had contact with the robot, their experience was unpleasant or even dangerous. According to these findings, the authors concluded that clarification is needed about what kind of psychiatric patients can gain benefit and have a good relationship with the robot and how the robot can assist in their treatment.

The Huggable bear was used in an experiment which studies and compare the effects of three types of bears (robot bear, virtual bear on a screen (avatar), plush teddy bear) in terms of acceptability, stress, and anxiety levels in medically or surgically hospitalized children suffering from chronic and severe pain [36, 37]. To quantify and compare the effect of bear interaction on promoting verbal and physical engagement of hospitalized children, the children were asked to interact freely and play with the assigned bear if they wanted. Although the children showed more interaction with the robot compared with that with the virtual bear and plush teddy bear, the authors indicated that there are no significant differences between the huggable and the virtual bear in their effect on children's engagement. On the other hand, they considered the offer of a robot (or virtual bear) less appropriate when a child is exhausted and lacks energy for social interaction. Likewise, the preliminary results by Logan et al. [38] suggested that hospitalized children benefit from social robots, as evidenced by increases in reported positive effect after exposure to the robot relative to the other interventions.

These studies indicate that a pet-like social robot may have a positive effect on a child's well-being through distraction, engagement, or a positive impulse on communication. However, children with specific psychiatric diagnoses are necessary to evaluate the scenario and the social robot to avoid any harmful or unsafe experience to the child.

Distraction During a Medical Procedure

Three studies were used as a social robot to evaluate their distracting potential in a medium and large sample of children [39–41]. Each research evaluated the same experiment in which children were distracted during flu vaccination by a Nao robot. Notwithstanding, each covered different strategies of distraction and type of outcome. The distraction strategies deployed by Nao during flu vaccination were able to reduce the level of fear, pain, and anxiety or stress. The children and parents also smiled for a relatively more extended period during the vaccination session [41], However, the study by Rossi et al. [40] showed that it is not possible to report that the robot's emotional distraction was useful for children who present high initial anxiety due to the small number of subjects in this situation.

These studies show that the use of a social robot has a promising potential as a distraction during a medical procedure, especially in vaccination, if the child does not have high levels of anxiety before the procedure.

Social Robots for Adults and Elderly People

Regarding the elderly population, this review was divided into two topics, namely (1) social robots as companions for elderly people with diseases and (2) social robots as service robots in elderly care and well-being. More details of the works referred to in this section are explained in Table 2.

Table 2 Publications that report the effects on healthcare in adults and elderly people, categorized according to the purpose of the robot's role

Author	Target population	Objective	Design—robot	Measures	Outcomes—key findings
1. Social robots as companions for elderly people with diseases					
Niemela et al. [43] (2016)	Elderly dementia patients and care staff	To evaluate the impact of Paro regarding the complexity of the interaction and physical assistance.	Paro robot was used during 1–2 months by the caregivers.	Focus groups; interviews.	Paro was effective for decreasing anxiety of patients. Caregiver's positive comments about the stress, communication were given after the use of Paro.
Moyle et al. [44] (2018)	20 facility Elderly Care Staff	To explore care staff perception of Paro and look-alike non-robotic animal in dementia care.	A descriptive qualitative design to measure the perception of a Paro robot in nine long-term care facilities.	Perception interviews.	Healthcare staff preferred Paro over a toy as a tool for dementia treatments. Potential to improve the quality of life of patients was a remarkable commentary inside the care staff.
Bemelmans et al. [45] (2015)	91 elderly patients with dementia	To evaluate the outcomes of an intervention using Paro in psychogeriatric care.	A multicenter quasi-experimental time series ABAB study within subject comparison to measure the short-term effects of Paro robot on dementia treatments.	Goal attainment scale (IPPA); mood scale (Coop/Wonka).	Paro was clearly effective for interventions aiming at a therapeutic effect. Its use could increase the quality of care and quality of life. Perception of care professionals positively changed before using the robot.
Shen and Wu., [46] (2016)	41 elderly participants	Benchmark the use of a humanoid robot against a human exercise instructor. The comparison was made under similar controlled settings.	Comparison between control, robot instructor, and human instructor scenarios. Nao robot was used to deploy the experiments.	Surveys applied after the end of the study; Joint bending; Movement quantity.	The robot could motivate the elderly people better than the human instructor. The participants' perception improves across time. The perception of the intelligence associated with the robot was reduced after a number of sessions.
Céspedes et al. [47] (2020)	4 adult participants	To evaluate the effects of a social robot over gait patterns in a therapy with Lokomat.	A repetitive measurement study during two conditions (control and robot) using a Nao robot	Poor posture time; heart rate	The preliminary findings showed that the use of a Nao robot improves poor posture time during Lokomat sessions.
Coşar et al. [48] (2020)	11 elderly participants	To enrich the day-to-day of elderly people at home by developing an assistive robot with several modules that provides monitoring, complementary care and social support.	Use case experiences with ENRICHME in time periods of approximately 10 weeks.	Interviews and Environmental data.	Positive outcomes show that the elderly like to use the platform, they were engaged with various functions of the system and they perceive ENRICHME safe and secure. A few users express they would no longer use the robot
Abdollahi et al. [49] (2017)	4 elderly participants	To evaluate long-term companionship. To measure the likability and acceptance. To analyze the features of the robot.	One-on-one (robot vs human) pilot study in a Senior Community Center. This longitudinal study used a Ryan Companionbot platform.	The Saint Louis Mental Status (SLUMS); Examination and Patient Health Questionnaire (PHQ-9).	The robot was successfully integrated in a dementia treatment scenario. The subjects liked to interact with Ryan and accepted the robot as a companion. The participants believed that the robot helps them to

Table 2 (continued)

Author	Target population	Objective	Design—robot	Measures	Outcomes—key findings
					maintain their schedule and stimulated them mentally. Regarding the features, researchers found the robot needs personalization.
Bechade et al. [50] (2019)	42 elderly participants.	To evaluate and build a strategy based on emphatic behaviors that allow social interaction with a robot.	Three experimental sessions (i.e., humor/negotiation and emotion game/humor/quiz) were developed using an autonomous and Wizard of OZ system. Pepper robot	Annotations of the interaction videos; Questionnaire regarding the engagement and interaction appraisals.	The patients engaged to the therapy due the attractiveness caused by using a robot and the understandability of the tasks requested by Pepper. The researchers found that users have concerns about data safety and the robot must be personalized.
Damnholdt et al. [51] (2015)	Elderly participants residing at Vikaergard Rehabilitatio-n Centre in Denmark.	To investigate the attitudes towards robots in a rehabilitation center regarding robots' personality and appearance.	A longitudinal study with one scenario was performed. The robot used was Telenoid.	NEO-Five Factor Inventory (NEO-FFI); Attitudes towards Social Robots Scale (ASOR-5); Anthropomorphism Questionnaire (AMPH-10)	The main results suggested that the attitudes towards the robots were not significantly affected by the baseline information of the robot. Also, the explicit attitudes towards Telenoid were maintained across time. Finally, the researchers report limitations regarding the functionality of the robot.
Soler et al. [52] (2015)	101 elderly participants recruited for phase I. 110 elderly participants performed phase II.	To compare the effects of different dementia therapeutic methods using humanoid robots, animal-like robots, and real animals.	Patients were assigned by living units, based on dementia severity, to one of the three parallel therapeutic arms to compare: control, Paro and Nao (Phase 1) and Control, Paro, and Dog (phase 2). In the daycare center, all patients received therapy with Nao (phase 1) and Paro (Phase 2). Therapy sessions were held 2 days per week for 3 months.	Global Deterioration Scale (GDS); Severe Mini-Mental State Examination (sMMSE); Mini-Mental State Examination (MMSE); Neuropsychiatric Inventory (NPI); Apathy Scale for Institutionalized Patients; Apathy Inventory (AI); Quality of Life Scale (QUALID).	Positive results demonstrated that (1) after the use of Nao, in the nursing home, the sMMSE remained the same (in dementia, this indicator, it is supposed to decrease); (2) the frustration of the users decreased; (3) the apathy, irritability and lability improved after the use of Nao; (4) night behaviors improve after the use of Paro. Negative results showed a decreased quality of life in patients who use the Paro robot.
2. Social robots as service robots in elderly care and well-being					
Fischinger et al. [53] (2016)	Elderly people	To evaluate the interaction and the design of the HOBBIT robot.	A longitudinal study was conducted with users who will have HOBBIT at their houses.	Usability measures; acceptance measurements; affordability measurements	The results showed that the interaction with Hobbit was perceived as easy and intuitive. However, limitations as the robustness of the system need to be addressed in the future. Regarding the acceptance, patients

Table 2 (continued)

Author	Target population	Objective	Design—robot	Measures	Outcomes—key findings
					consider that the most helpful feature was picking objects from the floor
Manh Do et al. [55] (2017)	Elderly care patients	To evaluate the functionality of the robot (i.e., falls detection, human position tracking, etc.)	Robot-integrated smart home (RiSH) tested under laboratory conditions.	Usability measurements	Through sensor fusion integrated in the RiSH platform the system was capable of recognizing the human body activity (86%) and tracking human location. Regarding the limitations of the study, fall recognition module will be enhanced.
Hendrich et al. [57] (2015)	Elderly patients	To describe the software and development of a service robot implemented in the European project Robot-Era	A longitudinal study in with elderly users in Peccioli and Orebro with Robot-Era.	Usability questionnaire; Acceptability questionnaire; Perceived performance questionnaire; Videos	Users preferred the scenario where the robot interacts trough the speech rather than the tablet. The results of the usability and acceptability were very encouraging. Additionally, the researchers remark that technical issues need to be resolved in the future.
Portugal et al. [58] (2019)	Elderly Care Center	To develop an assessment of a service robot focused on physical enhancement in elderly.	A longitudinal pilot study in an elderly care center placed in the Netherlands was carried out with the robot (named Tom by the caregivers)	Video Analysis	The reactions from the residents and the healthcare staff were overall positive. They smiled when the robot comes to them and the mood of the residents improves. Novelty effect decreased but the people became more acquainted with the presence of the robot
Peleka et al. [59] (2019)	Elderly with MCI	To develop and evaluate the effects of a service robot in home scenarios.	Pilot trials of the RAMCIP robot in Barcelona, Spain.	-	Results showed that the service robot was capable of performing the proposed tasks and support the users.
Korchut et al. [60] (2017)	Adults with cognitive impairments and medical staff	To identify the requirements and needs of elderly and adults diagnosed with Alzheimer	A study in Poland and Spain using surveys was conducted in order to determine the challenges for service robots.	Surveys	The results showed that service robots need to have main functionalities as follows: (i) reacting in emergency situations, (ii) reminding about medication, and (iii) turning off the gas and lights. Overall, it is expected that the robot has a positive impact on adults/elderly users and help them in daily life activities.

Social Robots as Companions for Elderly People with Diseases

Companion robots have the main aim of enhancing health and psychological factors of the elderly people by providing companionship [42]. Robots such as Paro, Nao, Pepper (Softbank Robotics, France), and Buddy (Blue Frog Robotics, France) are currently used with this purpose. This section presents ten studies where companion robots were used in elderly care for dementia and physical rehabilitation. The number of participants registered is 43 on average. Some of the studies discussed hereunder are made in long-term periods (i.e., 1–3 months).

Companion robots are widely used in mental health to aid and support loneliness, depression, and anxiety. In [43], the researchers performed a long-term study using Paro as an assistant for caregiving. The study showed that Paro decreased the anxiety in specific situations like self-dressing. In dementia patients, care staff reported benefits of using this animal-like robot as companions [44]. Moreover, the effects of Paro in nursing home residents have been demonstrated to have significant positive effects on mood and IPPA (Inventory of Parent and Peer attachment) score [45].

Humanoid-like robots (e.g., Nao, Pepper, Buddy) are also used to accompany elderly people. Shen et al. [46] showed the results of 41 patients who used a Nao robot as a teacher and instructor of physical exercise. The results showed that the robot has a potential to guide exercise, deliver information to the users, and provide motivation as it is done by a human instructor. In [47], a Nao robot was also used to support neurological rehabilitation. The main role of the robot was monitoring the cervical and thoracic posture in order to achieve complete gait rehabilitation. The results showed that patients under interaction with Nao improved the evaluated parameters.

In [48], the researchers present the development of ENRICHME (Project H2020/EU.3.1.4). ENRICHME is an assistive robot for home-based scenarios aimed to improve the quality of life of elderly and vulnerable people. The system consists of three main elements (i.e., a mobile robot platform, an ambient intelligence system, and the network care platform) that allow ENRICHME to provide companionship and physical aid to the users. Use case experiences were performed in Greece, UK, and Poland during an approximately 10-week period. Positive outcomes show that the elderly like to use the platform as they have "someone" to talk to, and they were engaged with various functions of the system, and they perceived ENRICHME safe and secure. A few users express they would no longer use the robot.

A pilot study using a Ryan Companionbot (Dream Face Technologies, USA) was developed in order to investigate the subject's engagement and enjoyable attitudes towards a robot [49]. In this study were found results, such as elderly users kept the interest of having conversations with the robot and the robot helped users to maintain their schedule and improve their mood. In [50], a Pepper robot is also a humanoid platform used as a companionship robot for elderly people. This research was aiming at finding an evaluation of the dialog between the robot and the user. The pros of this study are that the robot could adapt its social behavior regarding the elderly needs and a globally positive response to the robot behaviors.

Summarizing, most of the studies reported positive effects of social robots within the elderly population. Nevertheless, some studies highlighted some issues and limitations of this technology. On the one hand, Damholdt et al. saw the perception of the robots especially in elderly people [51]. The researchers concluded that robots do not yet have agentive relevance (i.e., they are not perceived as items influenced by the actions of users which decisions need to be taken); hence, cognitive-affective discrepancies are not relevant. On the other hand, advanced dementia studies have been compared with different tools to support conventional therapies. For instance, Soler et al. [52] followed up the use of a Nao robot, a Paro robot, and a dog in 211 patients for 3 months. Several measurements were analyzed; QoL (quality of life), cognitive state (sMMSE), and Global Deterioration Scale (MMSE) do not have significant changes between groups (even the QoL slightly decreased during the therapy with Paro).

Notably, the participants showed an increased apathy and improvement of irritability while performing the sessions with the Nao. There are also some remarkable limitations in many studies, such as inadequate methodology (i.e., lack of participants, poorly designed experimental protocols, and short testing periods) during the study [52], high costs of the robots [44], studies performed during short time periods, and novelty effects that affect results of the studies [46].

Social Robots as Service Robots in Elderly Care and Well-being

Service robots are defined as assistive devices designed to support daily activities providing more independence to the users [42]. In this section, five studies are presented. These studies are focused on the development and assessments of service robots, such as HOBBIT (Vienna University of Technology, Austria), RiSH (Oklahoma State University, USA), Robot-Era (Project FP7/2007-2013), and RAMCIP (Project EU Horizon 2020/643433). The robots are mainly used to support elderly people in home environments and healthcare centers.

Fischinger et al. [53] presented the HOBBIT project, which is focused on the development of a care robot. In this work, a controlled laboratory study with 49 participants was performed. Six representative scenarios were developed to analyze the mutual care interaction paradigm. The results showed that users highly appreciate entertainment and household functionalities of the robot. However, researchers reported constraints on the robustness of the robot that does not allow a positive perception of usability and fluid interaction. Two years later, the HOBBIT project was tested on a real scenario [54]. In this study, the robot features were improved. Results showed that the robot's adaptive functionality increases the interaction with the users.

Moreover, a robot-integrated smart home (RiSH) was developed to aid elderly people [55]. Essential functions as recognizing human body activity and detecting falls were designed. The robot was able to recognize 37 human activities and detect falls with an accuracy of 80%. The preliminary results showed that RiSH has capabilities in monitoring and assisting residents. On the other hand, a project called Robot-Era [56] was designed to create a domestic robot for elderly care scenarios. This platform was evaluated with 70 elderly subjects [57]. The outcomes of this research suggested positive perception of the elderly people towards the acceptability and the usability of the system. In elderly care centers, service robots are also being under research. Portugal et al. [58] propose a robotic social system based on information and communication technology. The main aims of the robot in this scenario are (i) supporting the elderly by motivating them, (ii) remaining them active by giving independence, and (iii) improving their well-being.

Regarding the interaction, patients and caregivers remarkably like the robot. Days later, the people became more acquainted with the presence of the robot. Finally, RAMCIP [59], a service robot for mild cognitive impairment (MCI) patients, was developed aimed to provide proactive and discreet assistance. In order to fulfill the requirements of the robot, the researchers analyze the needs of the population. The skills of the robot include communication, grasping, and self-navigation. Pilot trials with multiple users take place in Barcelona, Spain; results showed that the service robot was capable of performing the proposed tasks and supporting the users.

Despite the positive effects demonstrated by service robots in elderly populations, currently, some challenges must be addressed. The novelty effect is decreased in some studies as the robots can become repetitive and predictable [58]. This issue can affect social interaction, which is reduced by time. Service robots also should be able to recognize threatening situations by monitoring online health parameters, detecting falls, and dangerous situations [60]. Moreover, improvements on the functionality and the robustness of the systems must be performed.

Conclusions

Acceptability and perception metrics are essential to evaluate the performance of the human-robot interaction. Several studies report that the values of these metrics are improved when it is implemented in a familiarization phase with the robot before performing the studies [26, 27]. The study should ensure that the subject feels competent, safe, and confident when interacting with the social robot [61]. In [35, 62] are also pointed out several issues that considerably affect results in human-robot interaction studies. In this way, it is also remarkable the collaboration of a multidisciplinary team in the design and perming of the studies, such as researches (engineers, scientists), healthcare staff (physicians, psychologists, physiotherapists), and caretakers [63].

The studies identified in this literature review indicate that social robots can develop several roles in the area of healthcare and well-being (i.e., companion, partner or coach/instructor, and assistive tool). The children's population outcomes suggest that social robots might have the potential for engaging children, distracting, openness, improving eye contact, joint attention, and recognition of facial emotions. Also, children develop their visual perspective-taking skills and decrease the level of anger, fear, anxiety, and depression. Such effects have also been noted for adults and the elderly population under intervention with social robots, and users showed signs of improvements in social connections, communication, and mood, and diminished loneliness, isolation, depression, and anxiety.

Social robots could be a valuable tool in the repertoire of healthcare personnel to support children, adults, and the elderly in a medical environment that has to deal with the stresses and loneliness involved. Likewise, social robots could help and improve therapy in children with autism. The potential of social robots looks promising, but currently, some challenges must be addressed. (i) The novelty effect is reduced as a cause of repetitive and predictable robot behaviors, which produces less interest in creating a social interaction by the time. (ii) Improvements in the functionality and the robustness of the systems must be performed. (iii) Existing evidence is scarce, and more research is needed, for example, on how (supervised, unsupervised), for which patients, and when (which procedures, during the waiting time) the offer of a robot is useful. Moreover, as reported in the review by Dawe et al. [5], it is not clear whether the benefits proposed by these studies will continue with the long-term use of robots and the increased exposure and integration of robots into society.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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