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# Robotics in Clinical and Developmental Psychology

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## Introduction

Robots are among us in several contexts. This chapter deals with the state of the art of the use of Socially Assistive Robots (SARs) for development and clinical purposes, considering all the main phases of the life cycle. The reflection on this type of “artificial assistants” is accompanied by some considerations on the use of the “Relational Agent” (RA), that is, an unembodied digital system used in assistance. Although there are still many substantial technological issues, in the medium-long term, it is plausible that robots will prove essential in carrying out many activities, including those linked to clinical psychology. A crucial step toward this goal is the evaluation of the current effectiveness of their application in developmental/clinical situations. It will also be essential to highlight critical aspects and potentialities while paying attention to the perception that those involved in the developmental/clinical setting have of these robotic agents. A growing number of empirical evidences on the usefulness of robots does not necessarily correspond to an equal perception of their usefulness for everyone. Conti et al. (2019) showed that culture and how the robot’s potentials is presented influence the discrepancy between efficacy and perception of robots themselves. Skills training, enjoyment, self-confidence, and coping with life difficulties are among the primary objectives of robot-mediated activities. These objectives are mostly aimed at the “improvement of professional or daily activities due to physical rehabilitation, sensory–motor, or cognitive training; increase in emotional well-being through positive stimulation and enjoyment; enhancement of personal competence and autonomy by achieving a sense of control and self-confidence; and enhancement in the quality of individual life through mastering of activities of coping with life difficulties” (Libin and Libin, 2004, p. 1791). In a framework that can be called robototherapy, robotic assistance is aimed at the reenactment of one’s own negative life experiences by working on the improvement of coping strategies, with the ultimate goal to create new positive life skills (Libin and Libin, 2004). These intervention programs, based on stimulation assistance and rehabilitation for people with physical and cognitive impairments, special needs, or psychological problems, may sensibly reduce the use of pharmacological interventions. To this purpose, robot partners need to be explicitly configured according to the individuals’ psychological and clinical profile. Ideally, then, the robot partner should be able to learn from past experiences and flexibly tailor its behavior to produce sensitive and adequate feedback to the assisted person (Wiener, 1950).

This chapter is divided into three main sections that address the potential and limitations of the use of SARs in clinical situations in three different phases of the life cycle: childhood, adulthood, and elderly.

## Robots and Children

The first phase of the life cycle we consider is childhood. We will here describe different clinical situations: autism spectrum disorder (ASD), cancer, chronic diseases (cerebral palsy and diabetes).

Autism Spectrum Disorder (ASD), as described by DSM 5, is defined as a persistent deficit in communication and social interaction that manifests itself in various contexts (e.g., [Marchetti et al., 2020b](#); [Manzi et al., 2020c](#)). Additionally, ASD is characterized by restricted and/or repetitive behavior patterns, interests, or activities. Children with ASD may vary in terms of both specific manifestations of symptomatology and severity. This high variability corresponds to a considerable heterogeneity of interventions. In recent years, interest in using SARs for the treatment of children with ASD has increased significantly. In a pioneering study by [Robins et al. \(2004\)](#), for example, children with ASD showed improved social behaviors with robots as reflected in increased imitation and shared attention. One of the fundamental aspects of the use of robots in therapy with children with ASD is to engage children in prolonged therapeutic sessions and thus maintain the focus of their attention on specific social tasks ([Scassellati et al., 2012](#)). One of the motivations for which children with ASD find engagement with robots stimulating is that these agents are simple (both in appearance and in terms of behavior), predictable and not intimidating, as humans can be in their social complexity ([Robins et al., 2005](#); [Scassellati, 2007](#)). The literature on therapy using SARs for children with ASD is very extensive, and it allows to categorize studies according to the type of robot used (anthropomorphous and non-anthropomorphous), and the area of treatment. Besides, two other up-and-coming areas of research concern, on the one hand, the use of robots for diagnosis and, on the other, the effectiveness of interventions in different cultures.

In the following, we will analyze the main areas in which interventions with children with ASD have been carried out so far using SARs.

[Kozima et al. \(2005\)](#) developed the Keepon robot, which resembles a snowman, to interact with both typical and atypical developing children, specifically with ASD. This robot can communicate some basic emotions through the body (pleasure, excitement, and fear) and engage the subject by directing attention to itself. In a longitudinal study involving two 3-year-old children with ASD, the authors observed the effectiveness of the Keepon robot in building dyadic and triadic interactions ([Kozima et al., 2005](#)). Specifically, the analysis of the interactions showed that one of the two children presented both spontaneous dyadic interactions - touching Keepon with a stick - and interpersonal dyadic interactions - putting a paper cylinder on Keepon. For the second child, the authors found the emergence of triadic interactions, where Keepon functioned as child-mother or child-nurse interaction mediator (or shared theme). Moreover, for both children, there was a change in an imitation game from unidirectional (the child imitates the robot) to mutual imitation between the child and the robot. This process is very important as imitation is a fundamental element of social communication.

Additionally, a longitudinal study by [Robins et al. \(2005\)](#) with four children with ASD between 5 and 10 years of age investigated how repeated exposure to a humanoid robot, Robota, could play a decisive role in basic social interaction skills. The protocol consisted of (1) a familiarization phase, in which the child was free to interact with the robot without the caregiver or the experimenter intervening; (2) a phase in which the child was actively encouraged to interact with the robot by imitating its movements; (3) a phase in which the child could freely interact and play imitation games with the robot. The data showed that, toward the last sessions of the intervention, the children touched, imitated, and were closer to the robot than in the first sessions. An interesting result, though not significant, was the increase over time of the children's gaze toward the robot. While offering encouraging results in the use of robots as interactive partners for ASD children, the study also stresses the importance of a longitudinal approach with more interaction sessions to gain some significant benefits from the child-robot interaction. Moreover, as shown by the qualitative analysis of the data, children used the robot as a mediator of shared attention with the teacher, caregiver, and experimenter. For example, it was found that children, once adapted to the robot, began to include the experimenter in their world, interacting with the researcher and actively trying to share their experience with the robot. This data highlights the primary purpose for which a robot is used in interventions with children with ASD: to mediate and ultimately foster relationships between these children and the human.

In a study by [Pioggia et al. \(2007\)](#), the android FACE was used to analyze the effect of the interaction between FACE and four ASD individuals aged 7 to 20 years. FACE is made of a body and a human-like face; it can express the six fundamental emotions (happiness, sadness, fear, anger, surprise, disgust) in a repeatable and flexible way. The following were considered: the spontaneous behavior of the participants and their reactions to the therapist's pressures; the subjects' attention to FACE gaze movements; the subjects' spontaneous imitation of FACE facial gestures and expressions. The three children involved in the study showed a considerable improvement in the imitation of emotions, while only the 20-year-old boy - who had more severe symptoms - showed an increase in verbal communication.

Similarly, a pilot study by [Conti et al. \(2015\)](#) with three children with ASD and intellectual disability (ID) analyzed the effectiveness of an intervention with the NAO robot in improving children's body imitation. The main activity of the protocol consisted of an imitation game, in which the child first had to imitate the movements of the robot and then start a sequence of actions that the robot would imitate. To the initial action categories defined by [Robins et al. \(2005\)](#), a new category was added - human interaction - reflecting the child's voluntarily looks at or utterances said to the researcher. The data from these three cases showed that the way in which the child interacts with the robot depends primarily on the child's abilities and the severity of the disorder. One of the three children used to avoid new situations and people, and tended to get distracted the most; this same child showed considerable interest in the robot, as indexed by reducing the distance between himself and the robot and touching it for a longer time than the other children. The second child - characterized by a severe intellectual disability - although more easily demotivated when

the imitation failed - was also the one who realigned himself to the activities when the robot called him by name. Finally, the third child - characterized by greater restlessness - was the one who spent most time with the robot and imitated its actions the most. Another important result is the increase in the third child's interactions with the researcher as the intervention session progressed; once again, this phenomenon shows the effective mediation function of the robot between child and therapist over repeated sessions.

As introduced above, another area where the effectiveness of interventions with robots has been tested is joint attention. A study by Carlson et al. (2018) used a non-humanoid robot in the form of a teddy bear called "CuDDler" to improve joint attention abilities of children with ASD. The study specifically assessed whether children after eight therapy sessions improved their initial joint attention (IJA) and response joint attention (RJA). Twenty children between 4 and 6 years of age were recruited; half were assigned to the experimental condition and half to a control condition in which children interacted with toys. The results showed that, after the intervention, the group that interacted with the robot improved both IJA and RJA. However, the post-test performance of the training group on the two variables considered did not differ significantly from that of the control group. The authors attributed the latter result to individual differences and the small sample size. Only two children showed significant improvement: those with a diagnosis between mild-to-moderate and moderate-to-severe. Therefore, one of the questions the researchers asked was whether this type of robot and this specific experimental protocol are more effective in the case of specific ADS diagnoses than others.

The use of humanoid robots in enhancing children's joint attention with ASD has attracted a lot of interest. In a study with six pre-school children with ASD, Warren et al. (2015) investigated the use of a system implemented in the NAO humanoid robot capable of improving joint attention skills through the use of prompts. The intervention consisted of four meetings over two weeks. The system was developed to act in real-time and consisted of: (1) the robot; (2) two monitors that were activated when the child followed the robot's prompt; (3) an eye-tracker and cameras to observe if the children followed the robot's prompt and for how long; (4) a Wizard-of-Oz system to mark the correct answers. If the child followed the robot's prompts, an experimenter would trigger a reward (a clip from a children's cartoon) via a button and start the next test; if not, the next step would still be taken. In this study, a hierarchy of prompts to the child was used, from simple prompts using the child's name and look, to prompts that combined pointing, to prompts that included all the previous ones with the addition of audio and/or visual activation. The results of the study showed that the children turned to the target in all sessions and on most trials. Additionally, the children's performance, measured by the number of prompts required before reaching the target, improved during the sessions. Also, the time the children spent observing the robot increased significantly during the interaction sequence in which the robot provided the prompt compared to other sequences that did not have prompts.

Several theoretical works addressed the use of robots for ASD diagnosis. They postulate that robots can elicit measurable behavioral responses to social stimuli as well as produce the same stimuli for different subjects (Scassellati, 2007; Tapus et al., 2007). However, one of the great intrinsic limitations of using the robot for diagnosis is the absence of the fundamental clinical sensitivity in usual clinical practice. It is essential to emphasize in this regard that the robot could help in collecting quantitative measurements of children's behavior with ASD, as also shown in the study by Warren et al. (2015) that evaluated how long children looked at the robot during a prompt. In the future, as suggested by Scassellati (2007) and Tapus et al. (2007), the behaviors recorded by the robot during interactions could be transformed into quantitative measurements useful for diagnosis. Although the field is fascinating and may have important implications for diagnosis, we are still far from being able to validate the effectiveness of robots' use for clinical purposes. Certainly, diagnoses made by robots will have to take into account a wider range of diagnostic indicators (cognitive, linguistic, etc.) in order to obtain a more sensitive diagnostic screening and to validate the diagnostic classifications thus gained. Also, appropriate comparison groups without ASD will be needed to ensure that diagnostic approaches are both sensitive and ASD-specific. Finally, it will be necessary to examine the incremental advantage of using a robot over human interaction for diagnostic purposes.

Since Autistic Spectrum Disorders also involve social challenges, treatments and interventions need to be adapted to the target cultures (Dyches et al., 2004; Wakabayashi et al., 2006). Several intercultural studies show that culture-based treatments are crucial for individuals with ASD (Tincani et al., 2009; Conti et al., 2015). For example, a study by Rudovic and colleagues (2017) explored the cultural differences between Asia (Japan) and Eastern Europe (Serbia) in ASD children's engagement with the NAO robot during an experimental session. The study used Howlin et al. (1999) protocol for teaching expression and recognition of emotions, adapted to use NAO. The protocol consisted of four phases: (1) pairing, i.e., familiarization with the way NAO expresses emotions through the body; (2) recognition, i.e., recognition of emotions expressed by NAO; (3) imitation, i.e., imitation of emotions expressed by NAO; (4) story, i.e., stories were told and the child had to associate or show how NAO would feel in this story. Seventeen children from Asia (Japan) and 19 children from Eastern Europe (Serbia) were recruited for the study. In this study, the levels of engagement (the occurrence and relative timing of the children's behavior) and the emotional dimensions (valence, arousal, and the children's face-expressivity) of the intervention were analyzed. The two cultures did not differ on the emotional dimensions in the different phases. On the other hand, the two cultures showed difference in the engagement level: the average Japanese engagement did not vary as much as in Serbs, for whom the highest engagement levels occurred in the Pairing and Story phases. Moreover, examining the intercultural differences in engagement time in the different phases, the data showed that Serbian children engaged more than the Japanese children in all phases except for the Story. However, this could be explained by the fact that most of the children who reached the last stage showed generally higher levels of engagement. Another interesting finding is related to the quickness with which the children engaged in the task for each phase of the experiment: the results showed that in the pairing phase, Serbs engaged much faster than their Japanese peers. Finally, the results on the average duration of the engagement in each phase showed

how time increased for Serbian children in the last phases. However, only the pairing and recognition phase were significantly different between the two cultures. A possible explanation for these differences could be due to higher levels of impairment of Japanese children. The authors highlight the great variability in the severity of the children's symptomatology as an important limitation of the study, which might have undermined the possibility to interpret the intercultural differences in-depth. Nevertheless, this study outlines the importance of taking the cultural context into account for future experimental protocols.

The use of interactive robots in interventions for individuals with ASD is a unique approach that has received considerable scientific and media attention. Much of this work is pioneering and aims to understand how a robot can be integrated into clinical settings. However, at this early stage, there are very few empirical tests available on the clinical efficacy of robots for individuals with ASD. As shown by a review by Diehl et al. (2012), most studies on the use of robots for children with ASD have several methodological limits such as the following: small sample size; few studies have compared the effectiveness of robots in groups of children with ASD that differed in severity; left children interact alone with the robot; no studies have tested the independent contribution of the robot to the clinical application. Despite the obvious limitations, various studies have shown that robots can be very useful technological aids for specific interventions for children with ASD. Besides, some very interesting and yet to be fully explored perspectives have opened up, such as the use of robots to support diagnosis and the importance of cross-cultural studies. On a more general level, as we will see also in the following paragraphs about other clinical situations, robots can represent a mediator of relationships for children with ASD who, by their nature, present difficulties in social interactions.

Moving away from ASD, robot interventions have proved some efficacy also in other clinical scenarios, including those involving children with cancer. Very often, hospitalized children with cancer can present symptoms of distress and anxiety. These symptoms are due to a variety of factors, including intrusive medical procedures, the need to interact with many unknown professionals, and the difficulty for parents to be always present during their child's stay in the hospital. These situations, which do not exhaust the complexity of the secondary consequences of the disease, are added to these children's increased sense of loneliness. Therefore, not only do children with cancer undergo physical but also very stressful emotional situations; this can lead to a reduction in cooperation and less adherence to protocols. However, several studies involving Child Life Specialist - pediatric health care professionals who help children and families to cope with the challenges of hospitalization, illness, and disability (Brewer et al., 2006) – have shown that the intervention of specialists has a positive impact on children's health, by distracting them from pain and anxiety and promoting more positive emotions. Based on these considerations, it has been proposed the development of robots that could support specialists and, at the same time, play with children. Alongside these functions, the robot can play a useful mediation role between the child, parent, and professional, supporting the construction of a triadic relationship between these actors. The studies that have analyzed the impact of social robots on children with cancer can be divided into two areas: those who have used robots with animal-like features and those who have used humanoid robots.

With respect to the use of robots with animal-like features, related studies follow from findings showing how the use of animals can have a positive psychological effect on hospitalized children.

A first study conducted by Okita (2013) with 18 children with cancer (6–16 years) and their parents used the animal robot Paro. Paro is a seal-like robot with the ability to interact in a multimodal way: it talks, moves, and reacts to touch. The main objective of the study was to understand whether Paro is more effective when used alone with patients or together with parents. In the "alone" condition, the robot's functioning was explained to children only, and they were left alone with the robot. In the "together with parents" condition, the robot was presented both to parents and children, who were left to interact with each other in a dyadic situation mediated by the robot. The study analyzed the perception of the child's pain, the parents' perception of the child's pain, and the reduction of the emotional anxiety of both the child and the parent. As for the perception of pain in children, it decreased only in the "together with parents" condition. Instead, parents perceived a reduction in their child's pain in both conditions, showing how in the "alone" condition, parents underestimated their child's pain level. Concerning the reduction of anxiety in the "alone" condition, the children did not show any change. At the same time, in the "together with parents" condition, there was a significant decrease in negative emotional traits, but not an increase in positive traits. Again, according to parents, their children's negative emotional traits decreased also in the "alone" condition. However, there was no increase in positive emotional traits. At the same time, in the "together with parents" condition, there was both an increase in positive emotional traits and a significant decrease in negative emotional traits. The results on children's pain perception and parents' perception of their child's pain show that the use of Paro can be very positive for both parents and children, although the condition in which the robot was used as a mediator of the child-parent relationship is preferable. Overall, the results suggest that Paro helped to reduce pain and emotional anxiety when children and parents were together.

This positive effect of animal robots on the distress and pain condition of children with cancer has been confirmed by another study by Jeong et al. (2017). This study compared the effect that a plush toy (a teddy bear), a teddy bear-shaped social robot, and the social robot avatar used by child life specialists can have on the reduction of anxiety and stress in hospitalized children. Fifty-four children between 3 and 6 years from different hospital departments (surgery, oncology, and others) were recruited, with a prevalence of children from the cancer ward. Since the children were mostly fanned, the experiment was conducted in bed space. The avatar and the robot interacted with the children according to the same protocol (talking, singing, playing an interactive game), while the plush toy was used in its classical mode (simple manipulation). The effect on Child Life Specialists was also evaluated. One of the characteristics of the robot is to act both on the patient and on the environment by supporting dyadic (child-parent, child-therapist) and triadic (child-parent-therapist) interactions. The study showed that the robot had positive effects on children compared to other companions in terms of longer duration of triadic interactions, becoming a useful mediator of the relationship. Also, children

used more verbal utterances and more physical movement in the condition in which the robot was present, showing how the robot can be a useful motivational tool for children.

As we have seen, different studies show that the psychological intervention of a specialist with children with cancer has a positive effect on children's perception of pain and anxiety. The studies described below further show the positive effects on children with cancer of two different types of humanoid robots: the NAO robot and a new humanoid platform, Arash.

A study by [Alemi et al. \(2016\)](#) examined whether interaction with the NAO robot could decrease distress levels (anxiety, depression, and anger) in children with cancer. For this research, 11 children with cancer were recruited alongside a control group that did not undergo interaction sessions with the NAO, but a classic psychological intervention. The children experienced eight interaction sessions with the NAO in groups: an introduction session; one in which the NAO became a doctor, a chemo-hero (a fantastic character from a children's book), a nurse, a cook, a child with cancer; two concluding sessions in which the NAO asked the children their dreams for the future; and the goodbye session. The results revealed that the experimental group that had interacted with the NAO robot showed improved levels of anxiety, and lower depression, and anger. In contrast, the children in the control group showed no improvement.

In another study by [Jibb et al. \(2018\)](#), the NAO robot was used to reduce the pain and stress experienced by children with cancer during Subcutaneous Port (SCP) needle insertions, a specific medical procedure. For the study, 40 children with cancer between 4 and 9 years were recruited; these children had already experienced the SCP needle insertions. The children were assigned to three experimental conditions: one in which the robot was implemented to use cognitive-behavioral strategies for pain and stress management, called MEDIPORT; a second one, in which the robot simply actively distracted the children by singing and dancing; and a third one, in which the procedure took place without any particular instruction to children, parents, and nurses. In the MEDI-PORT protocol, the robot was programmed to perform vocalizations and movements typical of psychological interventions to relieve painful medical procedures according to the different phases of the medical procedure (making its presence felt, encouraging the child, asking to breathe). In the conditions in which the robot was used, a parent and a nurse were also present in the setting together with the child. No substantial differences were found in the children's perception of pain in the two conditions in which the robot was used, as in both conditions, the children reported only a moderate reduction in pain. An important data that emerged from the parents' considerations is that they perceived the medical procedure as faster. Finally, the nurses perceived the presence of the robot as not disturbing, showing that the robot was well accepted during the procedure. Even if the quantitative data on pain and distress were not significantly different in the two conditions, the qualitative data showed a very positive result in the use of the robot by both children, parents, and nurses in the MEDI-PORT condition. Finally, the nurses rated the children less anxious during the procedure. In general, these preliminary results suggest that the robot can – to some extent – relieve distress in children in pain and, more generally, that the use of robots in clinical assistance is very promising. This was supported by a further investigation where [Meghdari et al. \(2018\)](#) used a newly implemented humanoid robot, Arash, in a pediatric hospital environment to entertain, assist and educate children with cancer suffering from physical pain caused by both the disease and its treatment process. Arash is designed to interact with children between 5 and 12 years of age. The study primarily compared the Arash robot and an audiobook to assess children's acceptance and enjoyment while listening to the two tools while telling stories. It was shown that children perceived the robot Arash as more emotionally engaging than the audiobook. Additionally, the emotions experienced by the children during the reading of the stories were more positive with the robot Arash than the audiobook, thus suggesting that a humanoid robot may help to reduce distress in children with cancer as they perceived it as more emotionally engaging.

In general, empirical evidence suggests positive effects from the use of robots with children with cancer. An interesting finding, regardless of the type of robot used, is that these tools can be effectively used as mediation artifacts during painful practices or simply during children's hospital life. Additionally, these studies show that not only do robots have positive effects on children, but also on their parents and operators by both mitigating parental anxiety and supporting specialists in specific procedures. Nevertheless, as already outlined, these studies are not without limitations, the most important of which include the small number of subjects, cultural specificities, different robot's features, and age inhomogeneity, which will need to be considered in future related research.

The positive effect of using psychological strategies to manage painful medical procedures for children is widely recognized in the literature. Vaccinations and dental procedures represent a key event in medical care during the various stages of life, but even more so during childhood, when they represent a source of considerable distress and pain for children. Different strategies are used to reduce pain and distress in children during vaccination. One of the most used and effective strategies is to encourage parents to reassure children and show empathy for their pain. Another widely used strategy is breathing, although the results of its effectiveness are not clear. This technique is also often associated with the use of visual stimuli that can distract children from pain and anxiety during vaccinations. From these premises, a study by [Beran et al. \(2013\)](#) evaluated the use of a humanoid robot as a highly engaging and innovative method to facilitate distraction and breathing, in order to reduce distress during childhood vaccinations. The study involved 57 children aged between 4 and 9 years, an age range in which the pain due to vaccinations seems particularly evident. In order to analyze the effect of the introduction of the robot, two groups were compared: a group of children in which the NAO robot was used, and a control group in which classic strategies for managing pain and distress were used. A researcher was always present in the room, so the setting was composed of: child, parent, pediatrician, and researcher; depending on the experimental condition, the NAO robot was either present or not. The robot was programmed to distract the children before, during, and after the injection and to encourage the children to breathe. The results showed that the presence of NAO sensibly reduced the pain perceived by the child, as also assessed by the parents, nurse, and researcher. Also, distress behavior was significantly lower in the condition in which the robot was present. Finally, children who felt more pain from vaccinations greatly reduced the perception of pain in the NAO condition than children with a higher pain threshold.

Continuing on this front of research, [Beran et al. \(2015\)](#) studied the emotional reactions of children and parents to the vaccination procedure through video analysis where the duration of children's smile and crying were analyzed. The results revealed that children in the condition where the robot was present smiled for a greater proportion of time than in the condition where NAO was not present. Similarly, in the condition in which the robot was present, parents smiled for a greater proportion of time than in the condition in which it was not present. However, the proportion of time in which the children cried did not differ significantly between the two conditions. Therefore, although the robot does not seem to extinguish the pain perceived by children, it can help children and parents to live this experience better by creating a more friendly environment.

As for dental treatment, a pioneering study by [Yasemin et al. \(2016\)](#) analyzed the use of a humanoid robot, IRobi, to reduce dental treatment anxiety, a common case that mainly affects children's experience of the treatment. It is common in dental practice with children to try to distract them in order to reduce unpleasant perceptions, avoid negative behaviors, as well as to escape treatment. For this study, 33 children between 4 and 10 years of age were recruited. The children were divided into two groups: in the first group, the children were treated only by the dentist; in the second group, there was also the robot. In the condition in which the robot was present, it conversed with children, instructed them before and during the treatment, distracted them, encouraged them, and played with them. Average heart rate levels and video analysis showed that children in the control condition where the robot was not present were more stressed and anxious, while for children in the condition where the robot was present, heart rate was similar before and during treatment, thus showing a beneficial effect of the robot in managing children's anxiety. Another important result was reported by dentists, who perceived a more positive attitude in the children after the treatment and greater availability in the condition where the robot was present. Finally, the majority of children who underwent the dental procedure in the presence of the robot stated that they appreciated its presence.

Studies on the use of humanoid robots in outpatient settings with children undergoing medical practices that can cause physical pain and distress, show in general that these technological tools are highly accepted by children and generate a positive response during and after treatment. Also, the future prospects are very promising, such as the use of robots in the waiting room of outpatient clinics to relieve the anxiety of children and parents, or as support in administrative tasks such as demographic data collection in these situations. At a practical level, these studies suggest that robots may be managed and adapted quite easily within these contexts: first, the robot's language content and actions can be programmed according to the child's age to ensure adequate content and language level, thus improving the effectiveness of the robot during intervention; second, since the robot is programmed in advance, healthcare professionals only need to activate the robot when the child arrives.

However, once again, these studies are not without limits. First of all, the studies are limited to analyzing data collected at individual specialized centers and, furthermore, they do not consider cross-cultural variability. Therefore, a replication of such studies in other centers and in other cultural contexts would be desirable in the future. Finally, although the cost of introducing humanoid robots in outpatient medicine is not prohibitive, to justify the financial investment it should be evaluated whether the use of robots is more effective than other methods of diversion.

Assistive robotics (AR), which involves exoskeletons and other robotic supports for the therapy of children with cerebral palsy, is a widely used practice. Cerebral palsy is the most common cause of motor disability in children. This pathology affects the posture and movements of the subjects, creating significant limitations in their daily life activities. Generally, cerebral palsy damages the areas of the brain responsible for muscle control, and the main symptoms are related to motor skills, muscle tone, reflexes, and coordination. However, the complexity of this pathology is not limited to motor problems alone, but can also have consequences at the level of general cognitive functioning, nutrition, hearing and sleep, to name but a few. The following section will mostly present works using SARs that primarily provide social as well as physical assistance to children suffering this condition. SARs have proved an enormous potential for the rehabilitation of children with cerebral palsy as there is no specific treatment available for the disease, and the intervention of these robots can help children to maximize their potential and improve their quality of life. Care robots can be of two forms: non-humanoid or humanoid. Here, we will only consider humanoid robots because they are useful not only for motor rehabilitation but also for their positive relational aspects. Furthermore, humanoid robots - equipped with arms, hands, legs, and head - allow both a more precise motor rehabilitation and, given their intrinsically social nature, promote an increase in children's motivation ([Fukudome and Wagatsuma, 2011](#)).

A recent project by [Fridin et al. \(2011\)](#) called "Robotics Agent Coacher for CP motor Function" (RAC CP Fun) has innovatively combined the rehabilitation of cerebral palsy by creating a platform that can be used with humanoid (embodied) robots. For this platform, new algorithms have been developed for social interactions between children and robots (interactive physical exercises) and the implementation of a software that could recognize and measure children's movements (eye contact and face/body/voice expressions of emotions of the child). This project highlighted the positive effects of the use of humanoid robots by testing the platform on the NAO robot with typically developing children. The results of this experiment showed how children created positive interactions with the robot and were particularly engaged in motor training sessions, laying the foundations for the possible use of a humanoid robot in rehabilitation therapies with children with cerebral palsy.

The use of humanoid robots in the rehabilitation of children with cerebral palsy has recently attracted increasing interest. In fact, [Rahman et al. \(2015\)](#) used the NAO robot once a week for a total of eight meetings with two children with cerebral palsy aged 9 and 13. Each session consisted of four interactive scenarios between the child and the robot: (1) introductory rapport, in which the child was encouraged to communicate with the robot; (2) sit to stand, in which the child was encouraged to imitate the robot; (3) balance, that is an exercise done by the robot to improve the balance of children's lower limbs; (4) ball kicking, that is an activity to support the lower limbs. The purpose of these scenarios was to increase truncal balance, coordination, and coarse motor skills. In the introduction scenario the child interacted freely with NAO: this first phase facilitated engagement in the subsequent tasks where

the children imitated the movements of NAO. The children's generally showed a great motivation to continue the exercises, as the use of NAO made the context more playful. Additionally, the use of NAO proved to be very promising in the role of relational mediator, by strengthening the relationship between therapist and child. In this experiment, for example, it was observed that a child's motivation to interact with NAO in a free play session increased shared attention with the therapist. Nevertheless, some criticalities were found in association with the robot ability to move. For example, in the second scenario, the child was asked to sit down and then stand up: because NAO has some limitations with respect to its degrees of freedom of movement, it does not perform the sequence of actions in a typically human-like manner; therefore, the therapist had to intervene to ensure that the child did not learn incorrect movement routines. Another critical aspect to be taken into account for cerebral palsy is that this pathology involves different levels of severity and different symptom localizations: in the study by [Rahman et al. \(2015\)](#), in fact, it was found that a child with minor motor problems tended to get distracted more easily because the tasks were too simple compared to his real abilities. This impels us to reflect on the essential need for care robots to be used in a personalized way with respect to the severity of the symptomatology manifested by the child.

Partially overcoming this limitation, motivation to adopt a robotic agent during therapy in cerebral palsy was further provided by a study by [Tasevski et al. \(2018\)](#) that the humanoid robot MARKO. MARKO, in addition to being equipped with humanoid physical characteristics, has the ability to perform large motor exercises, generate emotional facial expressions and enter into a natural dialog with the therapist. In the study, 12 children with typical development and 17 children with cerebral palsy (CP) or similar motor disorders were recruited. Each child underwent an experimental session in which the therapist and a parent were also present in order to encourage the child in case the interaction with the robot did not continue. As in the study by [Rahman et al. \(2015\)](#), there was a first phase of interaction between the child and MARKO to involve and engage the child in the interaction. In the second part of the interaction, the robot asked the child, combining verbal communication and expression of emotions, to find and - depending on the child's possibility of movement - to indicate or take a puppet that is on the ground. Finally, the robot asked the child to perform certain actions with the body that constitute the focal point of the therapy. The study involved a total of 36 children with CP between 2 and 12 years of age, divided into two groups: a control group of 15 children that experienced therapy without the robot and an experimental group that experimented the therapy with the robot. Verbal production in the situation of interaction with robots was compared with sessions of exercises without robots. The results showed that the presence of the robot increased verbal production, i.e., children seemed to be more interested in communicating with the robot and, therefore more engaged in interactions. One of the most important aspects from this study is that the robot represented a positive motivational factor for children during the therapy session in continuing the exercises. Moreover, children appeared to be greatly engaged in triadic interactions where the other partners were the therapist and the robot. The latter aspect has been further explored by two other studies that employed robots in the interaction between children with cerebral palsy and another social partner. Specifically, a study by [Rincón et al. \(2013\)](#) used the robot as a mediator during a free play session with the child's mother, and showed how in the condition in which the robot was present the child appeared more motivated and engaged in communication with the mother. In a second study with three pre-school children aged 4, 5, and 6 from [Ljunglöf et al. \(2011\)](#), the robot was used as a mediator of interaction between children with cerebral palsy and healthy peers. Also, in this case, an analysis of the interaction showed that the presence of the robot promotes play and interaction skills.

As for the other studies, also these ones have limitations: on the one hand, the clinical effectiveness of the use of humanoid robots has not been tested compared to other types of interventions that do not involve them; on the other hand, since cerebral palsy is extremely variable in terms of location and severity, there is a need to take into consideration homogeneous samples. Notwithstanding these limitations, it is undeniable that the use of humanoid robots with children with cerebral palsy represents a very promising field in terms of rehabilitation and psychological support to children. In particular, although the humanoid robots used were not created for rehabilitation, they are nevertheless technological tools able to motivate children to do exercises and, not negligible fact, they can be useful mediation tools in the interaction between child, parent, and therapist. These positive aspects kind of overweight limitations, especially in terms of motivational propensity to continue therapy. It is hoped that, in the future, it will become possible not only to use humanoid robots that promote the relationship between child and therapist but also that enable therapy without the constraints related to the current possibilities of movement of the robot.

In recent years a number of studies have addressed the role that robots can play in supporting children with diabetes in the management of their disease. Children with type 1 diabetes need to self-manage their daily habits in order to minimize the impact of the disease on their health in the short and long term. Self-management allows a better quality of life for the child as the ability to monitor the disease decreases its negative effects in the short and long term. However, between the age of 4 and 12 years, self-management skills are still developing and are closely interdependent on cognitive and emotional development. In such a scenario, robots, although not able to act in the direct management of the disease (think of insulin injections), can nevertheless be used as support its management by increasing, for example, these children's motivation to write a diary in which to record their habits. Early studies have thus examined what features a humanoid robot should be equipped with to support children with diabetes.

A study by [Baroni et al. \(2014\)](#) interviewed children and parents to study in which areas the use of robots could be helpful in the management of the disease. In general, both children and parents stated that robots would be useful as a support in different contexts such as home, school, and hospital. Children mainly saw the robot as a possible companion to play with, while parents saw the robot as a useful tool in daily commitments for diabetes management. These interviews also showed that both children and parents see the inclusion of robots in the hospital context as an advantage to make the environment more friendly. Both children and parents would be happy to use the robot to manage diabetes-related tasks, such as remembering insulin injections or detecting blood glucose during the night. This is most important particularly for parents, who would be also constantly updated about the



child's self-management, by receiving reports from the robot. Another aspect where both children and parents see the usefulness of using robots is with respect to acquiring knowledge about the disease in general (help with tasks) and specifically, such as learning how to calculate carbohydrates or how to use the insulin pump. In addition, it appears that robots can also be useful to motivate children by, for example, congratulating them on writing their diary, or as a real tool to support the inclusion of the child in the school context, for example by speeding up insulin injection at mealtimes.

In particular the diary is a useful tool in the management insulin intake in that helps to trace the link between glucose levels and daily activities. A study by van de [Van Der Drift et al. \(2014\)](#) explored the effect that the NAO humanoid robot can have on diary writing. For this investigation, three fundamental interactive aspects were implemented in the robot, evaluated according to the literature as incentives for diary writing: being physically present, the ability to self-disclose, simulate an empathic response. For the first point - which is part of the reflections on the role of embodiment in HRI - it was decided to use the NAO robot especially because it has physical characteristics very similar to those of a child. As far as self-disclosure is concerned, studies have shown that for self-disclosure to take place, a reciprocal self-disclosure is necessary: the NAO robot has, in fact, been equipped with some self-disclosure routines in order to encourage children to provide the important information to be included in the diary. Finally, the NAO robot was equipped with some behaviors that simulated an empathic response to what children said or did (for example, expressing negative feelings in response to the child's distress). Not only did the diary have to be filled in by the child with regard to the contents related to the illness, but also with regard to how the child felt emotionally so that the robot could respond empathically. The results of the study demonstrate the positive effect of the robot on the compilation of the diary as the children provided comprehensive information in response to the robot's use of self-disclosure. Reciprocal self-disclosure in particular is a characteristic that can positively influence and motivate children to write down their eating habits and glucose values in a diary this practice. A study by [Kruijff-Korbayova et al. \(2014\)](#) analyzed whether the implementation of out-activity talk (OAT) dialogs in the NAO robot has a positive effect on the management of the disease by children. The topics covered in the OAT sub-dialogs were: hobbies, what diabetes involves, nutritional habits, discussing diabetes with friends, relationships with adults about the disease, and diary writing. Congruently with previous works, it was hypothesized that a mutual self-disclosure between child and robot has a positive effect on the self-management of the disease. Fifty-nine children with diabetes took part in the study, about half of whom were included in the control group, in which interactions with the robot were group-based, and the other half assigned to two experimental conditions, Out-Activity Talk (OAT) and No-Out-Activity Talk (NOAT), in which interactions with the robot were individual. In both experimental conditions, the diary-writing was mentioned, but with differences: in OAT, a part of the dialog was centered on the diary, and at the same time sub-dialogs on the topics listed above were activated; in NOAT, a part of the dialog was centered on the diary, but sub-dialogs were not activated. The data on the perception of the robot under the two experimental conditions did not show any differences, as did the adjectives assigned by children to the two robots, showing that children enjoy interacting with the robot regardless of the type of dialog. However, the children in the OAT condition reported more frequently than the NOAT condition the desire to interact with the robot again. This data shows that the OAT sub-dialogs increases children's engagement levels because they perceive a greater pleasure during interactions with dialogs much more similar to those with a human being (the topics are varied and close to the child's interests). Finally, mentioning the diary in the two experimental conditions prompted its more accurate compilation than the diary filled in by the control children.

Besides the importance of keeping a diary, children with type 1 diabetes need to be autonomous in the management of insulin intake. This process is highly dependent on the idiosyncratic characteristics of each child. Accounting for these requirements, the results of a study by [Blanson-Henkemans et al. \(2012\)](#) led to the development of a series of useful functions for these social robots in order to make children with type 1 diabetes more autonomous, also taking into account the individual specificities of the subject. From this study at least four areas in which robots can provide support to these children emerge: (1) making them aware of their health condition, teaching them to become "diabetes experts"; (2) making informed decisions, for example helping them to deal with unexpected or new situations; (3) developing their self-management skills and habits; (4) managing the social environment, for example in difficult situations by reassuring and directing the child toward people available in the social environment (parents, teachers, siblings), or acting as a friend. However, as outlined both in [Baroni et al. \(2014\)](#) and [Blanson-Henkemans et al. \(2012\)](#), the dream-robot is quite far from being realized due to some technological constraints. For example, to fulfill the parents' wish for the use of the robot as an inclusive tool for their children, the robot would need to understand complex social situations such as those that develop in school among their peers. In the current state of development, the robot is not yet able to meet this expectation.

One of the purposes of this section was to illustrate how different child-pathologies can benefit from the use of SARs: from neurodevelopment disorders, like autism, to chronic medical conditions, like cerebral palsy, diabetes and cancer, to distress due to the outpatient's practices, like vaccination and dentistry. The review of the literature on the use of SARs with children has shown an extremely heterogeneous scenario in terms of the types of robots used and the experimental protocols adopted. The wide variety of interventions that can be carried out with SAR with children have also different purposes: from rehabilitative, to supportive, to a combination of these two. Starting from these premises, it is important to identify some aspects that appear transversal for all the interventions indicated for the different pathologies and medical situations.

### **Types of Intervention**

SARs can be used for different purposes of intervention with children: rehabilitative or supportive, or a combination of these two. This differentiation is more blurred in interventions conducted by humans, whereas with SARs, the boundaries are defined because the robot is specifically programmed. The decision to use the SARs in rehabilitative, supportive or combined interventions depends

also on the type of child-pathology. SARs are used with a rehabilitative purpose for children with autism and cerebral palsy, and with a supportive aim for children with cancer, diabetes and outpatients' practices. A combined approach has been used with children with CP and diabetes. The distinction between the different types of intervention with SARs is not well defined in the design of the experimental protocols but represents an implicit approach. The difference, although not always expressed, between interventions lies within the technological constraints of SARs. Therefore, it is fundamental to rethink interventions trying, on the one hand, to combine them in different pathologies, when possible, and on the other hand to integrate also expressive interventions (another pole of the supportive-expressive psychological therapies). This last issue would represent a turning point in the use of SARs not only as devices in clinical settings but as agents for the improvement of a more general psychological well-being.

### **The Role of Embodiment**

Research in robotics shows that humans generally prefer interacting with a physical robot compared to its virtual counterpart. Also children with physical diseases or neurodevelopmental disorders have shown to tendentially prefer physical robots. Although current research has proved greater effectiveness of embodied SARs in intervention sessions involving children, it is important to encourage studies comparing other types of technologies. Robots are often expensive technological tools, and the evaluation of their effectiveness compared to less costly devices, such as virtual characters, represents a first experimental step to examine the cost-benefit of using robotic technologies.

### **Robot as a Mediator**

SARs are valuable tools to improve social skills in children with autism, reduce distress levels in children with cancer, increase motivation in interventions for children with cerebral palsy and diabetes, and reduce anxiety and pain in outpatient practices with children. Despite these different positive outcomes in several contexts and with diverse clinical populations, a positive transversal effect is that SARs can become mediators of the dyadic (child-robot) and triadic (child-robot-caregivers/therapists/healthcare workers) relationship. The effectiveness of robots both as intervention tools for children and as mediators can be due to at least two factors: on the one hand, robots are widely accepted by children because they are perceived as toys; on the other hand, robots are introduced to children by an adult, mostly the caregivers, and therefore become more acceptable by kids. Children's acceptance of SARs should also be considered in the light of the presence of the adult who, through a scaffolding process, introduces the robotic tool to the child, and shows him/her its playful aspects.

### **Wizard-of-Oz vs. Semi-autonomous Robot**

The general opinion about robots is of autonomous agents who are able to help humans. This idea is also extended to SARs: autonomous robot supporting healthcare specialists during interventions. However, this scenario is not the current reality yet. We are faced with technological tools that usually are tele-operated by humans. The same occurs for child-interventions through SARs. The interactions between children and robots through the Wizard-of-Oz technique produce a simulation of the autonomy of the robot, which can be used efficiently in short intervention sessions and for certain pathologies and age groups. Therefore, it will be crucial in the future to implement semi-autonomous systems that sustain long-term interactions, thus enabling the effectiveness of the SARs interventions with not severe cognitive pathologies and different age groups.

### **The Generalization of the Interventions**

The studies presented in this section had at least two main objectives: to analyze the rehabilitative and supportive efficacy of a robot interacting with a child, through a precise experimental protocol; and to compare the effectiveness of the intervention through SARs with other technological tools or other types of intervention. Research has demonstrated the efficacy of both research streams. However, an overlooked research aim is the generalization of SARs interventions to the child's everyday life, which represents one of the main aims of psychological treatments. Therefore, in the future, a further goal will be to verify the generalization of SARs, extending their effectiveness beyond the experimental setting, to clinical and daily-life contexts.

### **Robots and Adults**

Socially assistive robots for adults' care can be grouped in two main categories: therapeutic robots and rehabilitation robots. While research on therapeutic robot agents focuses on psychological, physiological, and social effects of robotic interactions, rehabilitation robots are designed to assist mentally and physically impaired people in performing activities of daily living. In general, rehabilitation robots are devised to assist disabled people by helping them to maintain their autonomy and self-efficacy through compensation, training or enhancement of their lacking abilities. In these instances, embodied technologies may be used to fulfill the patient's requirements, although the implementation of this technology, particularly when thinking of their psychological effects on the users, is still in its infancy. What we are witnessing at present are technological progresses specifically focusing on physical support. For example, it is very important to evaluate the parameters through which the robot movement is set in case of assistance.

By measuring the galvanic skin reflex through GSR sensor to evaluate the user's emotion during interaction with the robot, it is possible to evaluate interactional parameter, such as movement velocity toward the subject during care intervention on disabled persons who have difficulties with physical movement (Takahashi et al., 2001). The movement of an eating assist robot, for instance, which is used very close to a user, needs to have mild or gentle motion. In fact, high-speed movement may come as a surprise to the user, thus disfavoring maintenance of mental stability; luckily, the plastic human brain can adapt to new situations, also to unexpected or exceptionally rapid robot movements.

As far as therapeutic robots are concerned, attention is greatly paid to the psychological wellbeing of an individual rather than to her/his physical inability. To date, when speaking of assistive-clinical interventions, these are largely mediated by unembodied technological means, computational artifacts, such as mobile apps and online websites providing psychological support and scaffold to the patient. Research on relational agents (RAs), as they are called, is very important in psychological terms and clinical psychiatry because it helps understanding the dynamics that can promote the robot-user interface and dialog, as well as the factors that need to be taken into consideration for the modeling of a robot cognitive architecture that may be effective for intervention. And, not lastly, the emotional effect that these systems may have on the patients. RAs are typically designed based on ideal therapeutic relationships between human counselors and patients as role models. Model conversations are tailored to the type of patient and condition that RA will need to interface, taking into account the context, prior conversations, and the user's profile (Bickmore et al., 2010). Besides the psychological component, the more advanced research has further focused on the development of the physical features that these agents need to embed to aid conversational processes that would make the robot increasingly look anthropomorphic and effective in engaging with the patient. Eye gaze, look direction to indicate turn-taking, pointing at something being talked about, head nods, and emotional expressions (Rizzato et al., 2016) are some of the several features that developers look at when implementing such systems. BEAT – text-to embodied-speech system (Cassell et al., 2001), is an example of such attempts. BEAT is designed to associate phoneme production with mouth shapes, in addition to other sorts of nonverbal communication that give the impression of a most natural conversational situation.

These types of RA-based health interventions have been particularly developed for health care applications to promote, for example, antipsychotic medication adherence among adults with schizophrenia (Bickmore et al., 2010). As a matter of fact, research has shown that these patients often fail to take medication (Haynes et al., 2002), but also that a positive interpersonal relationship with a health care provider may lead to improved adherence rates (Zygmunt et al., 2002). A pilot study involving schizophrenia patients aged 19 to 58 years, who were on antipsychotic medication, used a system that run on a laptop computer as a stand-alone system (Bickmore et al., 2010). The system was designed for a one-month, daily-contact, intervention and involved a computer-animated humanoid agent able to simulate face-to-face conversation with patients. Use of both verbal and nonverbal (e.g., gesture, gaze) channels allowed to communicate therapeutic information and to establish and maintain a therapeutic alliance relationship. Before the actual intervention phase, an orientation phase was programmed to enable the consolidation of the relationship between the agent and the patients. During the intervention phase, the patient's self-reports informed the artificial agent about her/his medication-taking behavior, which was timely encouraged and reminded by the system. Also, daily physical activity, like for example walking, and regular interaction with the agent were encouraged by the system. For each of these behaviors, which were documented by the patient's self-reports, the agent provided feedback. At progress, new behavioral objectives were further negotiated. When approaching the end of the agent-mediated intervention (termination phase), the agent began instructing the patient in techniques for behavioral self-maintenance. Importantly, based on the literature on mental health nursing (Kidd, 2007), the dialogs and nonverbal behavior were tailored to specifically address patients with a schizophrenia profile. At termination, self-reports ratings of satisfaction about the patients' experience were very high, nearly to ceiling, and almost all patients (89%) self-reported medication adherence. This is a most representative example of how such systems are being implemented for inclusion into clinical assistance.

Along the same vein, CCBT (computerized cognitive-behavioral therapy) has proved successful in clinical psychiatry. The system was implemented for the treatment of a variety of mental illnesses (e.g., unipolar depression, generalized anxiety disorder, panic disorder; Newman et al., 1997; Titov, 2007; Kenardy et al., 2003) particularly in conjunction with the intervention of care providers. This type of computerized therapy showed to be able to increase patients' retention in an intervention, improving therapeutic outcomes by working especially on motivation. The advantage of using these at-home technologies are many, including access and cost effectiveness. Their value is mostly based on the fact that the systems are readily available to the patient on a constant base, therefore allowing monitoring the patients' conditions, as well as proving the necessary input and motivation to adhere to the therapy. Furthermore, not only do these systems aim to promote therapeutic treatment, such as medication intake, but also, and substantially, behavioral changes with application to an endless list of behaviors. These include substance abuse and eating disorders, which are common during adolescence as well as in full adulthood.

These RA systems have insofar proved to be effective in clinical care on a variety of illness or problematic psychological conditions. What is still missing, though, is to provide these virtual agents with a very natural property, which would bring them closer to an effective anthropomorphic relational process, and namely a body. Embodiment and anthropomorphism represent a great challenge for our roboticists today (Marchetti et al., 2018). Embodied agents are in fact assumed to be more engaging from a psychological perspective than equivalent unembodied digital systems. For example, in one of her studies, Kidd (2007) compared the effect of interactions between overweight teenagers and a social robot, which was designed to promote diet tracking by using essential social behavior, versus the use of a touch screen system. The participants to the study showed a clear relational preference toward the robot, although no actual difference was found in health improvement (weight loss). The presence of a real, physical robot has a noticeable effect on the perceptions that the user may have of the interaction. These differences are crucial to the potential success

of such social robot systems, especially in anticipation of the various types of applications for which they can be used. Therefore, the prospective scenario in which relational robots will play a growing and impactful role in the clinical sphere make us look toward the direction of an increasingly widespread use of embodied robotic agents.

As outlined by a recent systematic review of the literature (Scoglio et al., 2019), to date there is not much research related to the effects of interventions in the neuropsychiatric/clinical sphere in adults and young adults through the use of embodied robotic systems. As a matter of fact, most studies use populations of non-clinical subjects, evaluating, mostly, the effect of robotic agents on the improvement of some psychological difficulties, like anxiety, or aspects associated with quality of life, such as time spent exercising. Galvão Gomes da Silva et al. (2018), for example, developed a social robotic motivational interviewer, with the aim to evaluate if robot-mediated intervention can be effective in supporting behavior change. In this research, scripted motivational interview focused on increasing the physical activity of 20 participants, most of whom females aged between 18 and 33 years. The aim was to assess participants' qualitative experiences of a motivational interview, including their evaluation of usability of the social robot during the interaction. The type of robot used to the purpose of the study was the NAO humanoid robot, which is provided with multiple sensors for touch, sound, speech, and visual recognition. It is able to move and to interact with users via an audio system equipped with 20 language options. The results of the study are quite promising in that the respondents generally found the interface with the robot easy to manage and, given its unjudgmental nature, they found themselves at ease articulating and talking aloud about their personal considerations. NAO robot ultimately proved, in this research, to have the potential to be effectively used for interventions aimed at promoting motivation, also outlining advantages over more humanoid avatars designed to deliver virtual support. Another, non-specific clinical application of social robot use, but with impact on promoting dialog and reflection, was provided by implementation of CRECA (context respectful counseling agent). The embodied part of CRECA is a silicon-like human bust with head that works in conjunction with an on-screen counseling agent avatar. CRECA was developed with the aim to aid IT counselors to manage the several calls for help by people who suffer from socio-emotional or financial pressure (Kurashige et al., 2017). CRECA is connected to a computer and microphone to perform speech functions using natural language processing. It can create conversations with the users and respond to client verbalizations with prompts for continued discussion (Scoglio et al., 2019). An important feature of CRECA is that it can use body language and, more specifically, the "unazuki" (in Japanese), that is a sort of "nodding" which greatly promotes dialog by validating the user's responses. This feature, alongside the timely production of the word "exactly" in response to the user's speech, produces a sort of emphatic bond that encourages the user's communication and reflections. The newly developed multimedial nodding CRECA by Kurashige and colleagues behaves in a human-like, most natural manner, with appropriate double nodding in response to the speaker's verbal input. The experimental research, which was aimed at assessing the effectiveness of such behavior in a counseling setting, has proved to be successful in helping the user to deepen self-reflection and to reach additional solutions in response to perceived problems. The use of CRECA shows the benefits associated with accompanying an embodied agent to a computer interface, which include facilitation and promotion of dialog, reflection, and self-awareness.

Only a few recent studies have evaluated the effect of embodied robotic agents specifically on psychiatric patients. These studies are mostly pilot and carried out in controlled settings, therefore the generalizability of the findings remains limited. However, they prospect an effective and more systematic clinical use of robotic systems, which are tailored with respect to the specific pathology under consideration. In 2018, in a pilot study Loi and collaborators investigated the use and effect of a socially assistive robot, Betty, in a residential care facility that accommodates people aged under 65 years. The patients suffer specific medical and psychiatric conditions like, for example, acquired brain injury and younger-onset dementia. Betty is a cute small robotic agent, with the technological name of Partner Personal Robot PaPeRo, endowed of big eyes, legs, but no mouth or arms. It can walk and talk, and is provided with audio, touch, movement, and visual sensors. Interactions with Betty are viable through a voice recognition system and it can be programmed with the user's preferences, like books, games, music, etc. So, for example, one resident in Loi et al.'s study cheered on a particular football team, and this team song was programmed when interacting with that resident. Thanks to its human-like interaction modes, Betty is mostly used to motivate, entertain, for companionship, and it has proved to exert a calming effect on the interactive partners. Betty was introduced in the facility for 12 weeks, 3 hours a week. The effects of Betty on the residents' clinical condition was, of course, not direct and definitely not specifically aimed at the treatment of the psychiatric condition *per se*. However, by working on improving the general psychological well-being, this – like other similar – robotic agents are thought of facilitating the management of the clinical and medical condition, as also outlined by the studies described up to here.

In 2016, a group of researchers in Canada (Sefidgar et al., 2016) assessed whether providing an embodied robotic agent with a haptic system that allowed affective touch delivery could enhance efficacy in therapeutic applications. This idea, which was based on the proved efficacy of interacting with real animals as therapeutic adjuncts for mentally disordered populations (e.g., Levinson and Mallon, 1997), led the researchers to deploy a social robot, the Haptic Creature, in an interaction with adults aged between 19 and 45 years. The Haptic Creature is an expressive animatronic lap-pet (size of a large cat), which looks very much like a furry mouse, that responds to the user's movement and touch with visual cues, ear stiffness, vibro-tactile purring, and modulated breathing to mimic relaxed breathing. Because of these properties, the Haptic Creature was specifically designed to be calming, exerting beneficial effect on individuals' anxiety level. In particular, the receivers held the robot on their laps and stroked it as it was breathing. A review study by Shibata and Wada (2011) had already reported on several works which have used animal-like robot agents interacting with the elderly. The findings by Sefidgar et al. (2016) are in line with these researches in that the patient's that interacted with the Haptic Creature had heart and respiration rates significantly decreased relative to stroking a non-breathing robot, and also reported themselves as calmer and happier. Altogether, the findings suggest a possibility of mental health improvements exerted by such artificial creatures, which are comparable to those induced by real animals. Such improvements include, besides decreased anxiety, decreased

depression and its symptoms, enhanced coping skills, and increased social interactions. Given the great success of real animal therapeutic use, one may then wonder why not use a real animal instead and why bothering so much with an artificial “replica”. Surely these artifacts are easier to manage both in terms of care and cleaning, especially in clinical conditions and settings. They do not require extensive and costly training to become efficient assistive animals. Their feedback is constant on request and therefore always available. And, with the progress and development of programming possibilities, the responses of these agents can be increasingly specifically targeted to particular pathologies or problems.

A specific pathology that has received extensive attention in the life span in association with human-robot interaction is surely autism. As already discussed in the previous section for children, several studies have shown that the interaction between people with autism spectrum disorder (ASD) and robot agents produces different beneficial behavioral effects in autistic individuals. This appears to hold also true for adults. As for children, in fact, also young adults seem to be greatly engaged in a relationship with robots. Focusing on eye-contact, a prominent deficit recognized in ASD, the preliminary study carried out by Hiroshi Ishiguro’s team (Yoshikawa et al., 2019) aimed at developing, through use of robot intervention, a treatment method to increase frequency and duration of ADS individuals’ eye contact. Not only does the great challenge of these types of studies involve stimulating eye contact during intervention, but also to maintain it afterward and, in particular, to generalize it across communication partners. Moving the first steps toward these ambitious objectives, Yoshikawa and collaborators had four ASD adolescents aged between 15 and 18 years undertake an intervention session where they interfaced with a humanoid android, which looks very much like a human being. The humanoid robot used in the study was a female-like android robot called Actroid-F (Kokoro Co., Ltd.). It looks very much like a real female human, can pull some face expressions, such as smile, anger, and surprise, and utterance production is accompanied by a fairly congruent mouth movement. It has 11 degrees of freedom: neck (3), eyeballs (2), eyelids (1), cheek (1), lip (1), eyebrow (2), and bow (1). Additionally, this very innovative system, can be controlled based on target persons’ head and facial motion captured by a camera (Yoshikawa et al., 2011). Differently from the previous works with adults here described, the authors also compared ASD individuals’ behavior toward the robot with respect to a human being, and also with respect to a control group of healthy individuals matched by age and gender. During the five intervention sessions, the participants sat in front of either a human female or the android, while their eye gaze was monitored during interaction. The utterances of the human interlocutor and the android interlocutor were scripted in advance. In each script, they asked questions to the participants and, after waiting for a while, commented on the participants’ answers. The questions and comments in the scripts were chosen such that they could maintain consistency in the conversation after receiving various possible adolescents’ answers. In other words, participants’ experiences were designed to be interactive as well as equivalent among participants. The researchers found a significant increase in ADS individuals’ eye-contact toward the robot during the intervention sessions with respect to eye-contact to the human. Greater eye-contact to the robot was also with respect to the control group. Generalization of eye-contact to the human over training was, on the other hand, quite poor, thus not supporting the idea that eye-contact can be generalized across agency. However, the participants tested were only four and the intervention session limited in number. Possibly a greater sample size or intervention duration could bring alternative results. Also, the target age could make a difference. Children are more plastic than adults, so this target age could more successfully address the experimental question. Nevertheless, this study, though only preliminarily, reinforces the idea that robot use may be more successful in the ASD human-robot interaction than interaction with humans, also for young adults. Furthermore, it does not come as a surprise to find that both ASD and healthy control attended longer to the android’s face than to the human’s face. The experience of interfacing with an android can be defined, at least, curious. We may suppose that, when interacting with an android we may get very close to the uncanny-valley effect, and namely to rejecting the experience because it causes discomfort and unease. It is interesting to find, though, that ASD individuals were nevertheless keener toward attending the android’s face than the healthy control, thus indirectly supporting that androids are not properly perceived as humans, and are still treated as tools, with which ASD’s are most at ease.

Encouraging results with respect to the use of android agents in ASD come also from a previous study carried out by Kumazaki et al. (2017). In this study, ASD young adults aged between 18 and 25 years showed to moderately feel more self-confident and less stressed during a mock job interview lead by an android-robot with respect to a psycho-educational approach human interview. The participants were unemployed workers who were actively seeking employment. Their self-confidence level was evaluated by self-reports, whereas stress levels were assessed through analysis of salivary cortisol. Again, the android robot used in this study was Actroid-F (Kokoro Co. Ltd), a similar female type of humanoid robot used in the study described above. An advantage of using an android robot is that people can be exposed to a three-dimensional learning experience that closely resembles the situation of a real job-interview, which is classically challenging and potentially anxiety-provoking. This was supported by the participants’ behavioral and psychophysical responses recorded during the actual interview with a real human, which followed the android training or independent study. This study preliminary shows how an android-system mediated-learning can be improved for ASD subjects with practical consequences on the assessment of self-efficacy at work.

Although these series of studies outline the potential effectiveness of robotic agents in improving psychological and psychiatric conditions, their result have to be necessarily regarded only as preliminary and circumscribed to controlled experimental settings and to a specific culture. The Japanese culture is, more than many other cultures – both Easterners and Westerners – already accustomed to using robot-mediated services and assistance. Therefore, the results found with Japanese participants would necessarily need to be replicated in other cultural frames. What is certain, though, is that important first steps have been taken to demonstrate that social assistive robots can help in the management and, at least partially, in the treatment of patients with behavioral and/or psychiatric problems. To date, we can prospect implementation of humanoid robots, as the ones described above, only in specific controlled high-tech settings. Their accessibility and actual use is in fact quite far in time, requiring it high level expertise and further

architectural implementation. No to speak of their extremely costly acquisition, implementation and maintenance. On the other hand, the prospective opportunity of home-assistance mediated by less technologically advanced solutions, like the Haptic Creature or Betty, is more within reach. Use of these technologies would practically solve, in a nearer future, problems, such as the intervention time-continuum, costs containment, and continuous monitoring, assistance, and support.

The last question to be addressed, not less important than the previous ones, concerns the level of comfort of adults in interacting with robotic technologies in care settings. It is of course important to know whether these new technological tools, in their various forms, are welcomed by the potential users, both in the clinical and in an at-home setting. To interact with someone, or something, from early in life we need to trust in the relationship (Di Dio et al., 2020a,b) and in the efficacy of the help that the other, person or thing, can provide us. Our health is everything after all and we want to put it in good hands. Likewise, it is vital that these artificial systems are accepted by people that classically provide care assistance. A joint “group effort” is the best way to provide more comprehensive care for the benefit of those in need. Additionally, as assessed through the Technology Acceptance Model (TAM; Venkatesh and Davis, 2000), nurses can actively help in the process of patients’ acceptance of technology. They can in fact facilitate integration of robotic technologies into patient care by understanding patients’ attitudes toward robots. To investigate individuals’ attitude toward robots, two surveys were carried out by Backonja et al. (2018) on nearly 500 adults that were segmented into age groups based on the US Census Bureau groupings: age 18–44 years (young adult), 45–64 years (middle aged), and >65 years (older adult) (Howden and Meyer, 2011). Most of these respondents did not report a chronic condition. They also reported that had no knowledge of robots or had not used a robot. Therefore, the sample was mostly representative of a population of adults that were not particularly familiar with 2015 robotic technology. The survey included the Negative Attitudes Toward Robots Scale (NARS; Nomura et al., 2006; Syrdal et al., 2009; Tsui et al., 2010) and two questions taken or modified from the European Commission’s Autonomous System 2015 Report (European Commission [EU], 2015, p. 14). The survey revealed that, regardless of age, adults are quite comfortable prospecting the use of robots as social partners. Additionally, findings dissipate views according to which older adults are not as welcoming to robots as younger adults. On the contrary, elderly are eager to accept robot-mediated assistance, possibly to also make up for the lack of human presence, attention, and care. In general, evidence suggests that nurses and practitioners are likely to encounter similar attitudes toward robots among adults of all ages for whom they develop or deploy robotic interventions: respondents were generally supportive of or neutral toward robots. Also, respondents on average indicated that they thought robots were useful and disagreed that robots were dangerous. It has to be outlined that data were obtained from a US population. Other studies carried out in New Zealand (e.g., Stafford et al., 2014b), Korea (Shin and Kim, 2007), and Europe (e.g., Ray et al., 2008) present controversial findings that would need to be dug into more deeply. Cross-cultural differences may be searched into differences in cultural norms, such as, for example, roles and tasks deemed acceptable for robots (Lee et al., 2012; Wang et al., 2010). This observation leads to a major issue: we need to be careful generalizing results across cultures, environments, ages and even across types of robots. The implementation and design of robots needs to be user-tailored in light of these, and other, factors, such as the clinical condition or psychological problem under consideration.

A brief parenthesis needs to be opened for Actroid-F, our special female android robot developed by Ishiguro’s team. Its peculiar human-like features, although appealing, could be felt as threatening. This idea is somewhat dispelled by evidence (Yoshikawa et al., 2011) suggesting that most of adult patients evaluated at a pain clinic reported a positive impression about the android robot. Some (about 30%) even declared a preference toward the android compared to the human. These patients were Japanese and one may argue in favor of a cultural bias in the patients’ judgment, as also discussed above. One needs to bear this in mind before generalizing the findings, though they undoubtedly provide evidence in support of acceptance of android care-mediated assistance from ASD individuals.

Not less significant is the question of if and how care staff accepts socially assistive robots to be included as part of their activities. Referring back to the pilot work by Loi et al. (2018) with residential in care facilities describe above, the authors assessed, through pre and post questionnaires, the degree to which the staff accepted Betty. Not only did the staff, that was mainly composed of middle-aged females nurses, report an overall improvement of the residents’ engagement with Betty, but also a general personal acceptance of, and positive attitude toward Betty as a companion to residents. It has to be noted that the staff’s attitude toward the introduction of a novel “entertaining” tool for the resident’s use was quite positive from the very start. Not only did its actual inclusion confirmed their expectations, but also revealed to exert a greater positive influence on the resident’s engagement than anticipated. These results are quite consistent also with findings from other studies here described, as well as with previous findings by Moyle et al. (2016), who also used Betty as a novel companionship to their elderly residents.

In summary, as far as adults’ care and assistance is concerned, a picture emerges according to which, in recent years, artificial intelligence (in many different forms) has been increasingly tested and deployed for clinical and therapeutic use. In the next few points, we summarize this scenario.

### The Great Variety

The various forms of SARs used with adults can be broadly grouped into *therapeutic robots* and *rehabilitation robots*, the latter mainly designed to assist physically impaired people. To provide physical support, these agents have to be necessarily embodied and most research is devoted to the regulation of these system’s physical performance in interaction with patients, not forgetting to consider the patients’ psychological response to such interventions. The most advanced forms of therapeutic robot agents are also anthropomorphic, like the Pepper robot. Rehabilitation robots, on the other hand, are built to support the psychological wellbeing of individuals rather than their physical inability. A number of these systems is unembodied, i.e., digital. Their application focuses

on robot-user interface and dialog based on ideal therapeutic relationships between human assistants and patients. Embodied therapeutic robots have also been designed, from the zoomorphic haptic-creature or the semi-anthropomorphic robot Betty, to more sophisticated ones, like humanoid robots or even androids.

### **Anthropomorphizing**

The most used humanoid robots nowadays are Pepper and NAO, whose advanced sensor-systems and human-like physical features and behaviors enable them to assist patients by interacting with them in close proximity, safely and efficiently (e.g., [Bolotnikova et al., 2019](#)). Independent of whether therapeutic or rehabilitation, digital or embodied, implementation of anthropomorphic systems revolves around the replication of human-like mental and behavioral features: from coordination of eye gaze, look direction and pointing, to head nods, and verbal and non-verbal emotional expressions. Nevertheless, in the expectation of enabling these artificial agents to manage long-term relationships, relations between humans and robots are still confined to short interactions, the only ones that today's robots can actually support.

### **Attitude vs. Experience**

Attitude toward the employment of SARs is typically measured through questionnaires, of which the most used internationally are the Negative Attitudes Toward Robots Scale (NARS) and Technology Acceptance Model (TAM). Evidence generally supports adults' poor acceptance of these systems in daily activities and, in particular, health care. However, it has to be remarked that most surveys are carried out with healthy adult participants, with no actual experience of artificial intelligence. Opposite, the level of user's (either patients or caregivers) welcoming of and satisfaction with artificial intelligence after actual experience is generally positive. This data somehow brings up a gap with results from assessments of attitude toward artificial systems, and highlights the greatest limit of the latter. In fact, people's attitudes reflect more their mental projection and imagination associated with the concept of robotic systems than their actual, realistic potential. This observation is supported by the fact that, where there is experience and/or need, the divergence between adults' imaginary and actual potential narrows in favor of greater acceptance of robotic systems.

### **A Costly Investment**

While digital systems can be deployed at the user's home, are constantly available and relatively cost effective, embodied anthropomorphic robots are quite expensive in terms of manufacturing and programming. Additionally, their use is limited to controlled settings under careful clinical and technical human supervision. Therefore, for the time being, their use is inevitably limited, although we may expect a rapid technological growth and a large-scale employability in the next decade or so.

### **Robots and Elderly**

In the movie entitled "Robot and Frank", released in 2012, an elderly man, who begins to show the first signs of Alzheimer's disease, strikes up a peculiar friendship with a robot. His sons, worried about his father's health, decides to buy a humanoid robot that could take care of him. Frank, albeit with some initial perplexity, takes advantage of the presence of the robot, which keeps him company and keeps his house clean. Over time the friendship grows and strengthens to the point of pushing Frank to rediscover an ancient and illegal passion for theft. We are facing with a robot that not only becomes a social companion but an accomplice in transgressive undertakings.

As often happens, it is the art that makes us imagine possible future worlds. In this case, it is a movie that lets us a glimpse, in an ironic and at times irreverent way, at a not too distant future, where robots could become so sophisticated social partners as to be able to establish a real friendship with an elderly person.

The use of social robots for assistance, care, and companionship for the elderly is probably one of the areas in which this specific social declination of robotic agents spread earlier. It is parallel to the use of social robots in children's care settings (especially with children suffering from autism spectrum syndrome but not only, as already illustrated and detailed in this chapter regarding several clinical conditions). Some elements that characterize the elderly may justify the interest in robotic companion implementation: a greater risk of pathological solitude, a greater need for promoting well-being choices, a greater need for continuous medical-assistance interventions. If the favorable employment prospects seem consistent, some critical issues persist. First of all, the lack of motivation for older people to interact with this type of agent. In fact, without disturbing the phenomenon of "Uncanny Valley" - the sense of repulsion that can accompany interaction with humanoids ([Mori, 1970](#); [Mori et al., 2012](#)), the elderly may not show any interest or even feel mistrust for this technology, preferring more traditional assistance and entertainment tools. The distrust could be due to a lack of motivation to approach "too advanced" technology and of doubtful utility for those who have grown up relying on less sophisticated cultural instruments and, also, for this reason, perceived as less "active" and/or "autonomous." That is, robots would be seen as potentially dangerous, arousing distrust and perplexity in the elderly. In this sense, [Walden et al. \(2015\)](#) highlighted how those same people who could benefit from interacting with robotic agents, feel contradictory feelings toward them. In particular, they showed interest and appreciation for the mechanical help that robots could offer them and, at the same time, they declared themselves very worried about decisions that robots could autonomously make.

The analysis of the literature shows that, as early as 2009, a review that focused on SARs in elderly care (Broekens et al., 2009) identified a large number of works on this topic, the first of which dates back to 2001. This information helps us to understand how this research theme, although strongly constrained by technological advances, is at the same time perceived as extremely interesting to the point of determining a sudden growth in research work and consequent publications.

A crucial aspect of the elderly-robot interaction is the perception of the robot as an entity with its cognitive activity and, therefore, capable of original mental states that could lead to decisions that humans would struggle to predict.

A review that focused on the possibility that humans attribute mental states to robots has highlighted how - especially for the elderly - this attribution is particularly challenging because closely linked to the problem mentioned above of preference/acceptability (2018).

Furthermore, Stafford et al. (2014a), working on the relationship between robots and the elderly in a nursing home, showed that older people preferred to interact with robots to which they attributed few mental states. The elderly were somewhat frightened by robots due to an overestimation of their cognitive abilities. Sabelli et al. (2011) introduced a conversational robot into an elderly care environment for 3.5 months and analyzed its main interactive exchanges with the elderly and staff using an ethnographic methodology. Three of the six identified trends (basic social interaction, information about robots, and emotional elements) concerned the socio-relational/mentalistic dimension. Iwamura et al. (2011) focused on the use of a robot by a group of elderly customers in a supermarket: they found elderly preferring a robot that also engaged in a non-shopping-oriented conversation to a robot only capable of functionally oriented conversation. Gross et al. (2012) delved into the possibility of using robots in the context of treating people with neurodegenerative diseases. Preliminary results of the implementation of a care robot for the elderly with mild cognitive impairment (MCI) show how satisfied the elderly were when interacting with a robot capable of supporting them in carrying out daily activities. It also placed the importance of evaluating the effectiveness of these long-term interventions (weeks or months) and promoting relationships with a truly autonomous robotic partner (equipped with a very powerful behavioral system), as the first item on the agenda of future research.

That the times are ripe or, in any case, fertile to tackle the question of the use of social robots for the elderly more and more seriously and concretely is also documented, albeit indirectly, by the increasingly consistent use that older people make of new technologies. In 2017, the Pew Research Center stated that, at least in the US population, the group of the elderly were more digitally connected than ever (the percentage was more than duplicated compared to 2013), revealing itself increasingly inclined to approach technological-digital artifacts.

On the technological advancement front, research is taking substantial steps forward, further reducing the gap between humans and robots in terms of versatility and rapidity of behavior. One of the most critical aspects of social assistance robots is the limited ability to complete even simple actions (such as filling a glass of water) in times and ways comparable to human ones. In this regard, Lee et al. (2020) have developed a new butler humanoid robot that promises particularly rapid perception, planning, and execution times. This project, according to the authors, was born precisely in response to the growing average aging of the population, and the consequent need to have robots capable of providing satisfactory daily assistance. The authors start from the observation that the level of technological sophistication of the robots is still rather limited. Robots are particularly slow and increasingly unreliable as the originality and complexity of the contexts arise. The authors propose a new 3D object detection pipeline with a kinematically optimal manipulation planner to significantly reduce the overall manipulation execution time for their butler. The result is interesting because it combines an increase in execution speed (which, however, reaching 24% of human speed, remains significantly lower) with reliability equal to 80% in almost ecological contexts.

In the review mentioned above (Broekens et al., 2009), two types of SARs were identified: robot providing services to support the daily activities of elderly and robot keeping company to improve the physical and psychological well-being of the assisted people.

Although the authors highlighted many critical issues transversal to all the works considered (limited variety of social robots, almost exclusively carrying out investigations in Japanese culture, almost exclusive involvement of elderly people placed in nursing homes, methodological problems) the results were equally very promising and concerned mainly "(i) increased health by decreased level of stress, (ii) more positive mood, (iii) decreased loneliness, (iv) increased communication activity with others, and (v) rethinking the past" (p. 98).

This possible classification of robotic agents is intertwined with at least one other way of categorizing robots for assisting elderly people. It is the one that distinguishes anthropomorphic robots from robots for personal use. The formers are aimed at replicating human functions, shape, and even reasoning and therefore more easily attributable to the wider category of company assistance robots; the seconds are the robots that try to respond to the need to implement useful machines that could help human beings in real-life conditions and alleviate their working conditions. Personal robots are more similar to those described above as robots capable of providing services to support the carrying out of daily activities by older people (Dario et al., 2001).

This second classification, already widespread in specialist literature from the early years of the new millennium, has the merit of underlining the great interest and great charm practically always recognizable in the possibility of developing a robot agent very similar in appearance and ability (especially psychological skills) to the human being with the main intention of making him a socially effective partner. The goal of anthropomorphization pushes the possibility that this type of humanoid robot can support the human being also in a series of behavioral activities. This second objective, which is also crucial in the assistance of elderly people, then flows into the personal robot, which is designed to assist the elderly in terms of actions in the best possible way and, therefore, without necessarily having a human appearance. In truth, until a few years ago, it was believed that it could be above all personal robots that offered greater possibilities for application development and relapse; humanoid robots, on the contrary, seemed as fascinating as difficult to achieve. If for the first, the development difficulties were mainly mechanical engineering, the challenge for humanoid robots was the



development of artificial structures capable of simulating the functioning of the human mind in the best possible way. Today the challenge reappears on both fronts, also thanks to the great developments that have occurred in the design of artificial intelligence capable of real autonomy and, therefore, of learning sequences not programmed in advance. The renewed challenge proposes the possibility of creating a humanoid robot that encompasses not only human-like psychological abilities but which also behave to support human activities: in short, a complete robot, that would have almost nothing to envy humans. In concrete terms, there is still a long way to go to develop a robotic entity that integrates all these peculiarities into itself.

A crucial topic for future research is the cultural influence: it is intertwined with the issue of the acceptability of the insertion of the robot in care settings, with a focus on the different caring figures of the elderly. In fact, in the study of [Coco et al. \(2018\)](#), the attitude of the Japanese nursing house staff toward robots offering assistance and care services to the elderly is compared to the attitude of the Finnish staff. The results highlighted a strong effect related to culture. Japanese recognized robots capable of fundamental services in assistance and personal care. On the contrary, the Finns were reluctant to recognize that robots could actually prove useful; they appeared more frightened by the possibility of their introduction into assistance and care practices.

Another interesting systematic review ([Bemelmans et al., 2012](#)) focuses on the effects and effectiveness of the use of social assistance robots in the care of elderly people, especially if they are affected by some form of cognitive impairment. This review includes 41 articles that include 17 original empirical research. The evidence did not substantially differ from what was highlighted a few years earlier by the review by [Broekens et al. \(2009\)](#). In fact, the authors declare that, although the opportunities and interest in the use of robots capable of assisting elderly people at various levels are very high, there is still a lack of consistent scientific production that can reliably return the real potential of this eventualities. Nonetheless, the available works show how older people interacting with robotic agents experience positive effects on (socio) psychological (e.g., mood, loneliness, and social connections and communication) and physiological (e.g., stress reduction) parameters. The authors are critical, noting that the results reported so far indicate effects on an individual level and suggest to identify the psycho-social care needs of all the people involved in order to provide targeted assistance interventions for their multiple needs through the available SARs. The authors conclude by warning against the risk that the use of social assistance robots is limited to providing advantages comparable to those that would be obtained by introducing an entertainment gadget in the relationship with the elderly person and remembering how future research developments cannot but go through the use of more rigorous strategies and methods.

A short time later, [Kachouie et al. \(2014\)](#) carry out a new systematic review of the literature on this topic by including 82 publications in their analysis, for 34 research groups involved, extracted from the initially identified number that counted 816 of them. Previously, most of the studies had taken place with samples from the Japanese population. Instead, the variety of robots used increases. The main results shared by most of the works taken into consideration concern: Improvement in feeling and mood, improvement in emotional states, increase in activities, increase in social interactions, decrease in depression. The authors criticized the impossibility of generalizing the results. They also highlighted the most significant problems: absence of an evaluation of the cultural background, absence of an evaluation of the features of the robotic agent, prevalence of studies conducted in care facilities, majority of female participants, poor consideration of the expectations of the elderly person called to use the robotic agent, absence of a systemic approach that also takes into account the perspective of the other figures involved in the care of the elderly and, finally, poor consideration of the elderly as a person and therefore as a recipient of customizable care.

A systematic review focuses on the use of SARs in mental health and well-being research and identifies 12 works that investigate the well-being and mental health of people against the use of a robotic agent through an experimental research design ([Scoglio et al., 2019](#)). Seven of the twelve pieces of research involved older people with medium to severe dementia. The most consistent (and transversal) results concern an overall improvement in mood, a reduction in negative or aggressive behavior, an increase in gratification and positive social relationships. The authors declare SAR-interventions may constitute a promising treatment. They also stress that existing studies are limited in generalizability, scope, and measurement.

A latest systematic literature review ([Pu et al., 2019](#)) performs a meta-analysis of randomized controlled trials. Only 9 of the 2202 articles initially identified were included in the meta-analysis for a total sample of 1042 elderly people, of whom 80% had been diagnosed with dementia or cognitive impairment. The meta-analysis does not seem to highlight any statistically significant effect related to the use of robots in terms of quality of life, cognitive level, apathy, and depressive symptoms, agitation, anxiety, and neuropsychiatric symptoms. If we look at the indicators that could not be treated through the meta-analysis, a reduction in the levels of loneliness and an increase in social relationships were common positive outcomes. An improvement in sleep quality, a reduction in anxiety and stress levels, and a reduction in the use of psychotropic drugs were also found.

The review of the works that have focused on the use of social robots with the elderly describes an extremely varied picture where medium-long term potential and critical issues, sometimes even very significant, are inexorably intertwined.

It seems that robots can be of great help both in those situations where limited support is needed in order to continue guaranteeing the elderly an almost total autonomy and in those situations where the social robot supports elderly with a consistently compromised health condition. These two extremes of application circumscribe an incredibly wide field of intervention within which it seems possible to outline some elements of transversal synthesis.

### **Explainability of the Mind**

We have seen how people can perceive robots as intruding entities and how, above all, the elderly can fear their use in everyday life because they perceive them as entities with incredibly greater (and even dangerous) capacities than a human being. One of the goals of future research should be to make the “thought processes” of the robotic mind more readily intelligible. This might seem

counterintuitive when compared to what happens in relationships between humans, where the opacity of the mind is a fundamental feature of interpersonal relationships. On the other hand, it is highly understandable how, faced with an exceptionally performing artificial mind, people wonder about similarities and differences with the human one. A better understanding of what level/kind of “opacity” should be implemented in the robot without compromising the need for its explainability could significantly contribute to this disambiguation.

### Relational Sustainability

Social robots are as exciting as they are capable of suddenly betraying our expectations. The extent of this problem is, to some degree, directly proportional to the complexity of behaviors that need to be implemented, and which will eventually enable these non-human entities to sustain medium-long term relationships. Research in the elderly shows how the use of robots is particularly useful in the context of short-term interactions. However, criticalities emerge as the duration of the exchange lengthens. The research will have to identify operational methods to endow these entities with the ability to effectively manage the complexity of human relationships in order to “bear” the exchange with the human even in the medium to long term.

### Generality vs. Specificity of the Support

An element strongly connected to the one just mentioned relates to the type of support that the robot can offer. The idea of a robot capable of “replicating” human conduct in all respects - becoming a real 360° companion - is very vivid. However, the research will have to evaluate the opportunity to develop robots tailored to perform specific functions. They will be specialized social robots that do not respond to all possible requests (with the risk of being approximate and unreliable) but rather able to react exceptionally reliably to specific problems.

### Simplicity is the New Complexity

Despite the very high level of sophistication of the most performing social robots, it is not guaranteed that - especially with the elderly - the best results can be obtained only with sophisticated social robots. Current research shows how very simple and not necessarily anthropomorphic companion robots can be effectively used to improve and/or contain cognitive impairment with a consequent increase in the quality of life. For the future, the development of more performing robots for targeted interventions with people, who progressively lose their autonomy, will have to deal with the necessary implementation of robots capable of placing themselves in a sort of “proximal development zone”.

### Future Research Directions\*

What evolution of social assistive robots can we expect in the future? First, future studies should prepare more rigorous research designs that include multimethod approaches and pay more attention to sampling strategies together with a better definition of expected constructs and outputs. With specific reference to the clinical samples, they must be defined based on homogeneous and systematic diagnostic criteria, which also contain precise information about previous and/or ongoing pharmacological and non-pharmacological treatments. Secondly, future studies will have to consider intercultural variability associated with acceptability and effectiveness of the interventions: cross-cultural research is currently very limited. Thirdly, the research should focus on the specific type of robot (Manzi et al., 2020a) and its humanoid vs. non-humanoid nature as a potentially relevant variable. All the results from these works could provide further data for guidelines and useful applications. Last but not least, most of today’s observations about the effectiveness of, or satisfaction with SARs are based on having the user interfacing the artificial system that performs pre-programmed tasks and routines, thus creating the temporary illusion to be real relational agents (Wizard-of-Oz). When the illusion eventually vanishes, the “assistive agent” soon returns becoming a soulless machine. As a matter of fact, SARs are only able to sustain brief interactions, whereas enduring relationships require endowing the robot of learning algorithms which would enable it to flexibly adapt to new situations by evolving from past experiences. This is exactly what research is focusing on at present. Besides, situations such as the recent spread of the Corona Virus is providing an important and tangible signal urging the scientific world to shift toward, and invest in this type of technology, now more than ever necessary for clinical, therapeutic, preventive and diagnostic purposes (Yang et al., 2020).

While not aiming to address the Cartesian dichotomy body and mind, it is quite clear that robotics has achieved incredible levels of complexity and precision of action that far exceed human capabilities. Just to give two examples, think of the algorithms for managing and analyzing big data and the da Vinci technology used in the medical field. On the other hand, robots are far from being able to socially act by offering answers even remotely similar to human ones. It will therefore be necessary to aim at the refinement of the robots’ capacities to make decisions also with relevance for social interaction, similarly to what has already happened for the evolution of non-social robots.

Even more than for non-social artificial intelligence, the SARs – within the multidimensionality and heterogeneity of the clinical setting - will have to be equipped with powerful encyclopedic knowledge together with rich episodic knowledge enabling them to calibrate diagnosis and/or interventions on the single patient. As a matter of fact, the ability of artificial intelligence to handle a myriad of different types of data far better than humans has already been proven. On the other hand, robots still seem to lack

the ability to manage the “here and now” of the specific relationship (episodic knowledge). Both aspects are equally fundamental to think that a helping relationship can be successful. The encounter between encyclopedic and episodic knowledge will allow a tailor-made intervention, approximating the most complete and profound nature of the human-human clinical relationship. We can imagine the SAR as the meeting point between what is now, in our imagination, the maximum expression of robots with an incredible speed and ability to calculate, and what is the maximum expression of us as human beings: creativity, originality and spontaneity in the management of relational complexities, often through a mental functioning of a heuristic nature.

Finally, it seems appropriate to remark that artificial intelligences are precisely intelligent systems. In every intelligent system a new property does not emerge for summative properties, but for emerging ones. No artificial intelligent system is currently able to do what we have just briefly described the abilities of a SARs - that should arise from the hypothesized meeting point - will be an absolute novelty because their performances will be emergent. All this must be achieved through a careful ethical attention to the transparency and explainability of the operating algorithms of the agents, which are the basis of acceptance and trust.

### **Clinical Applications and Recommendations\***

In light of what has been argued so far, it appears necessary to establish a closer connection between research results and intervention practices. The latter particularly lack globally shared protocols, which could instead emerge from the organization of the Consensus Conference aimed at implementing Evidence-Based interventions. Each intervention should be preceded by, and comply with feasibility studies that not only involve those directly affected by the intervention, but also the various protagonists of the assistance and care network. These methodological precautions could allow a more targeted and shared nudging toward the acceptability and the effectiveness of the intervention. The implementation of SARs should take into great consideration the issue of explainability. Explainability is a fundamental requirement for effective artificial agents, whose decision-making processes are not automatically understandable in terms of typical human decision-making and communication processes (e.g., [Di Dio et al., 2019](#); [Manzi et al., 2020b,d](#); [Marchetti et al., 2020a](#)). We are quite far from reaching this perspective, and this is why psychologists, health therapists, and engineers are increasingly tightly working together to fine-tune the robot’s architecture to the endless variety of people’s needs in the clinical setting.

### **Conclusion\***

This chapter reviews and offers a critical reflection based on evidence from the literature on the use of SARs in various care settings. By framing the topic in the life span perspective enabled us to highlight the wide range of potential for robot use. The psychological and behavioral outputs that can be obtained through the use of these artificial agents are evident in all the development phases considered. Artificial agents are ductile: although they appear behaviorally and/or psychologically imperfect, SARs outline their deployment potential in different contexts and pathologies. This evidence gives us hope that technological progress can further increase their effectiveness by filling the limits mentioned above. Another issue transversal to age and clinical situations is the poor generalizability of the results that a more careful methodology will be able to address. If we look in more detail at the three age phases considered, the following emerges. As for children, the most transversal and relevant issue associated with intervention contexts and pathologies is embodiment (preference for humanoid social robots) vs. the opportunity to make a careful cost-benefit analysis that, considering the specific pathological condition, could put into play less expensive non-embodied technological devices. In addition, for this specific age group, a further aspect to be taken into account is the potential of SARs as mediators of the relationship between child, caregiver and clinician within each specific therapeutic intervention. As for adults, the most interesting aspect that emerges is that of anthropomorphizing, which recalls some aspects already underlined for children with respect to embodiment. Specifically, embodiment and anthropomorphism confront us with the challenge of the replication of human-like mental and behavioral features, which in turn are connected with acceptability and preferences toward these possible virtual therapists. Finally, with respect to the elderly, the promising use of non-humanoid social robots poses a specific challenge: the implementation of social robots combining the high quality of specialized intervention through very simple appearances and behaviors.

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