Robotic Psychology

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Although the contribution that social robots have made to healthcare is recognized, much less attention has been given to the role that social robots can play in a specific healthcare application domain, namely psychology-based interventions. Robotic psychology, or robopsychology, is a research field not yet fully exploited in regards to the study of compatibility between people and robotic creatures on multiple levels (i.e., sensory–motor, emotional, cognitive, and social). The proper use of social robots in the psychological field would exploit their potential even more, since relationality is a fundamental aspect for any intervention aimed at affecting people's psychological dimensions.

social robot | robot-based psychotherapy | robotic psychology | robopsychology

1. Introduction

The technological advancements seen in recent years and the new paradigm in robotic sciences emphasizing the "human-oriented" values of engineering design led researchers to equip some of these artificial entities with a physical embodiment [1] and, therefore, let them interact in a more typically human fashion (e.g., proxemics, kinesics, tactile and multisensory stimulation) [2]. Personal service robots' growth allowed them to be robust enough to be deployed in a plethora of settings, including healthcare, where they have been particularly beneficial [3][4][5]. Nonetheless, personal service robots had to learn to process social information and interact in a socially adequate and refined way to properly function and serve the purposes of the healthcare interventions. In other words, they evolved into social robots. Both scientific and non-scientific definitions see social robots as being capable of interacting with and working for humans [6]. More specifically, social robots are expected to meet various criteria, although to different degrees [7]. Social robots should: (i) avoid generating false expectations due to their shape, size, and material qualities; (ii) recognize, respond to, and employ. where possible, all modalities that humans naturally use to communicate; and (iii) be aware of human social rules and norms and behave accordingly.

Although the contribution that social robots have made to healthcare is recognized, much less attention has been given to the role that social robots can play in a specific healthcare application domain, namely psychology-based interventions [8][9]. Robotic psychology, or robopsychology, is a research field not yet fully exploited in regards to the study of compatibility between people and robotic creatures on multiple levels (i.e., sensory–motor, emotional, cognitive, and social) [10]. The proper use of social robots in the psychological field would exploit their potential even more, since relationality is a fundamental aspect for any intervention aimed at affecting people's psychological dimensions [11][12][13]. Indeed, the effect that artificial entities have on human beings is not limited to mere instrumental support. Individuals may also satisfy relational needs through artificial entities [14][15] and, in general, such entities appear able to influence some aspects of people's psychic life with relative ease [16][17][18]. Human beings are naturally inclined to attribute mental states to inanimate objects and animals through processes known as anthropomorphization, mind perception, and emotional attachment [19][20][21][22]. In this case, however, social robots are not just a passive receptacle of this human trend, but they have been developed to facilitate this attribution process through the implementation of human-like features that mimic human mental state representations and actions [23][24]. Thus, social robots appear particularly interesting for the purposes of psychological intervention due to their perceived similarity with human beings or other life-like creatures. In particular, researchers have used them for interventions with children with autism spectrum disorder (ASD) and to promote wellbeing (i.e., lowering stress and anxiety), topics that are of interest in this paper. ASD is characterized by persistent deficits in social communication and interaction skills, but also repetitive and restricted behavior patterns, activities, and interests [25].

The evidence about robot-based intervention effectiveness in psychology has not yet been systematized to account for the multiple types of social robots employed. The aim of this article was to offer a systematic review of social robot empirical findings regarding psychological intervention to (a) identify psychological pathologies/disorders/conditions that may benefit from robot-based intervention, together with (b) the specific psychological areas targeted by them, and (c) describe the types of robots most used for each domain of intervention.

The paper is organized as follows. In the Method and Procedures section, the systematic review methodology will be explained, including the search and selection strategy, together with the description of inclusion/exclusion criteria. In the Results section, the included studies will be presented in two separate paragraphs. The first one will summarize the characteristics of the studies in terms of robots and activities proposed, target samples, and psychological dimensions addressed. Meanwhile, the second section will report the outcomes obtained in all the selected works. Moreover, the Risk of Bias paragraph will give an overview on the potential biases affecting the studies. Finally, the last section will present a critical discussion.

2. Autism Spectrum Disorder (ASD)

Social robots have been usually introduced in therapy settings basing on the fact that for children with ASD, interacting with humans is often difficult as they can be overburdened by social stimuli [26]. On the contrary, computer-like interventions can offer predictable and enjoyable social training opportunities [27]. According to this framework, indeed, social robots' embodiment allows a balance between the possibility of providing, simultaneously, human-like cues and object-like plainness in social interactions, offering a controllable and safe environment in which children can train target behaviors, gradually increasing their complexity [27]. Therefore, in the studies included in this review, the robots have been used to foster social and emotional competencies, since these are core symptoms in ASD [25]. For this purpose, NAO and PROBO are the most commonly used robots. Overall, studies showed mixed results, but most of the selected reports found improvements in social skills. From the point of view of behavior, children particularly improved in turn taking [28][29], eye gaze [30][31][32][33][34], imitation [28][35], play skills, fostering collaboration [36], and communication [35] thanks to the interaction with robots as compared to human agents. Moreover, a reduction in autistic behaviors [32][36] and an increase in adaptive ones were also found [31]. Considering emotional domains, studies underlined the opportunity to promote socio-emotional understanding learning [37], while interfacing with the robot, resulting in the possibility to facilitate emotion recognition [33] and improve positive affect [38]. Interventions also addressed cognition, showing higher levels of attention [38][39] when the children interacted with robots compared with humans, and improvements in visual perspective taking [40].

By contrast, in a number of studies, no significant differences were identified while analyzing these domains across robot and human conditions [28][41][31][33][42][36][43], suggesting how robots can have the same performance as human operators.

3. Cancer

Based on the results showed by using social robots in therapies for children with ASD, authors like Alemi and colleagues [44][45] tried to employ them to relieve typical distress symptoms displayed by pediatric patients suffering from cancer. In their research paradigm, indeed, the use of a humanoid robot, like NAO, capable of communicating sympathetic emotions through different channels could facilitate the relief of distress involving the children and encouraging their self-expression. The findings in this field reported an overall significant decrease in children's levels of anxiety, depression, and anger [44][45].

4. Anxiety

Selected reports targeting anxiety disorders mainly used animal-like robots, like Paro or a Haptic Creature. The reason for their use is grounded on the framework of animal-assisted therapy [46] and the social cognitive theory in human–animal interaction [47]. Specifically, authors claimed that some animal-like robots were designed to mime the effect of animals used in therapy settings, which have been shown to positively affect anxiety levels [48]. However, the access to animal-assisted therapy is often limited by a range of difficulties, including allergies, availability, and costs [47]. Therefore, the idea of overcoming these limitations with animal-like robots that are easy to find and use has inspired studies in this field. Here, authors have also built the hypothesis that calming effects provided by the robots could help children replace anxiety with pleasant stimuli, based on the systematic desensitization process described by cognitive behavioural therapy [47]. Hence, studies included in this review targeted the overall score of anxiety and some specific aspects, such as physiological parameters and the affective experience. Selected reports provided mixed results. Half of the reports underlined a decrease in anxiety levels both in children at risk [47] and in young adults [49] after interacting with the robot, improving also physical indicators (i.e., heart rate) and emotional experience [47]. By contrast, the other half of the studies did not identify significant effects on anxiety in children, students, and professionals [46], nor in their levels of arousal, but it underlined only an improvement in positive affect while performing stressful tasks [46].

5. Wellbeing

To promote wellbeing, most of the included reports tried to investigate the possibility of building a relationship between a robot and a human agent, based on the fact that socio-emotional support and the creation of a strong rapport between patients and different agents have been shown to improve people's ability to cope with difficulties [50][51]. Following this theoretical background, authors believed the robots to be suitable for building a relationship, since their physical embodiment and ability to interact socially make them resemble human agents. In the studies considered, overall improvements were found in psychological wellbeing [52], mood [53][52], readiness to change [52], responses of empathy [54], and socio-emotional wellbeing with the elicitation of positive affects [51] in different groups of children, students, adults, and elderly. In just one study, outcomes did not show effects on physiological measures of arousal nor prosocial behaviors [50].

6. Mixed Target Disorders

More other disorders and dimensions have been targeted by selected studies, including intellectual disabilities, depression, self-disclosure, or studies that have provided robot-based mindfulness interventions and protocols for emotions and behavior change. In these fields, different frameworks explain the use of social robots with animal or human features. For example, some interventions are, again, based on the paradigms of animal-assisted therapy [55] or they sink the roots in a body of research showing how social robots can facilitate interventions [53] and convey a sense of presence while eliciting positive social responses [56][57]. In the selected studies, social robots showed the potential to improve mood in intellectual disabilities [55] and depression [58], foster positive behaviors in the elderly with dementia [59], increase sensory awareness and mood during meditation [60], and promote healthy eating behaviors [61]. Moreover, social robots were also able to create an amusing setting [62] and elicit self-disclosure, but less so than a human interaction partner [63].

7. Discussion

Advances in new technologies and, in particular, robots are an opportunity for a positive revolution in the human ability to cope with problems. Social robots can enhance human performance in education [64] and foster the health of older adults [65] and hospitalized children [66]. However, the contributions of social robots have not yet been fully exploited if we consider the relational skills inherent in this technology that would be particularly useful in the psychological domain. This contribution, therefore, aimed to systematize the current and emerging literature on the use of social robots for psychology-based interventions.

From these findings, it is possible to gather some guidelines for the effective use of social robots, although these directions cannot be too solid considering how the existing body of research is limited and mixed. Specifically, to conduct interventions for patients with ASD, the robot's embodiment seems to be particularly relevant, while other features, like anthropomorphism, appear to have a weaker effect on target dimensions. This is in line with other studies that have already explained the importance of embodiment to convey a sense of social presence [67]. Furthermore, in the treatment of anxiety, animal-like robots seem to be preferable. Indeed, studies that promote their use follow in the footsteps of animal-assisted therapy, which has shown its potential benefits in the reduction of anxiety across different patients [48]. Finally, in interventions addressing wellbeing, the robots' features do not appear to be particularly relevant beyond of a minimum degree of interactivity necessary to establish an immersive social interaction between human and robot.

Consequently, it is important to select the appropriate robot according to the characteristics that therapy needs and **Table A3** can be useful for this purpose, since it describes the main features of each one.

Thus, overall, social robots appear to be suited to act as an aid to affect psychological dimensions or disorders. Indeed, social robots seem to have comparable and sometimes even better performance than human operators [28][31][32][42][36][34][62] and, therefore, they can expand the availability of psychology-based interventions, both towards the general population and people that otherwise will be difficult to intervene on (e.g., hospitalized people, rural communities, disadvantaged people). Indeed, the possibility to conduct smart therapies or interventions at home or in healthcare settings has the potential to increase both the accessibility and availability of treatments [68] due to the flexibility of time and places in which they can be carried out. On the one hand, the robot can act autonomously, where an expert or an artificial intelligence system enables the robot to effectively manage the intervention and any emerging problems [46][55][59][47]. On the other hand, through remote control [31][45][50][58], psychologists may have the possibility of having an easily accessible embodiment for their activity while being physically far away. These considerations are particularly relevant in the light of restrictions faced worldwide during the COVID-19 pandemic, which has rapidly posed important challenges in different fields, including the necessity to encourage innovative and more dynamic approaches to support people's mental health.

Apart from the reduction of accessibility barriers and costs, robots can be functional also in overcoming problems with cleanliness and sterilization in delicate environments, such as hospital wards and clinics. However, while some robots, like NAO, are more easily cleanable, others like Paro have raised concerns as they have fur. Researchers have already tried to define cleaning protocols for infection prevention to make safe use of these kinds of robots. Preliminary results are positive since it seems possible for the robots to meet infection prevention and control standards, such as those defined by the National Health Service [69]. Similarly, issues with allergies that are reported in animal-assisted therapies [70] can be easily avoided, as the use of animal-like social robots has shown its benefits across the selected reports.

Considering the potential underlined by most of the studies, it is worthwhile and necessary to deepen the research in the field of robot-based interventions in psychological domains. Both research needs and future directions can be pointed out.

Firstly, among the selected reports, only a few specified the use of randomized control trials. Thus, it seems necessary to expand and systematize the body of work in order to have strong evidence to promote the use of social robots in actual clinical practice. Future research should define clear protocols to combine the standard therapy and robot-assisted interventions, as this is shown to be potentially beneficial. Secondly, future studies should involve larger samples, considering also follow-up sessions to assess long-term benefits. At the same time, it will be important to consider increasing ecological validity of studies [37][41]. Thirdly, some technical limitations pose challenges for the future. For instance, in some studies, the story played by the robot during the intervention could not be stopped by the therapist [71], some robotic movements were too quick or rigid [71], and sometimes the robot was not capable of reacting to social advances made with the children's gestures [36]. Therefore, technical improvements are desirable because adjusting the robots' abilities could improve not only the interaction but also the validity of the studies. Moreover, a possible future direction could be the analysis of the differences in human-robot interaction between young and the elderly. Indeed, in one of the selected studies, the latter reported communication issues and lower level of confidence as compared to younger participants [53]. This investigation could contribute to improving their experience and, hopefully, the benefits they can obtain from the robot intervention.

Speaking of therapy, it is known that self-disclosure is an essential element for the effectiveness of any therapeutic path, along with the creation of an alliance. Some of the studies included in this review tried to build a relationship between a human agent and a robot, but just one study targeted the dimension of self-disclosure [63]. The findings highlighted the possibility to elicit self-disclosure through the interaction with robots, but robots were less effective than human operators. Interestingly, the embodiment was found to influence the quantity and quality of self-disclosure. For future therapeutic perspectives, this element could be further explored, even comparing the outcomes coming from robot- and virtual-reality-based interactions, since researchers have shown how users feel comfortable to disclose personal experiences in social virtual reality [72]. Thus, future research could explore the possibility of integrating robots and virtual reality to move towards updated and more effective therapeutic and teletherapeutic pathways. In order to address these future challenges, interdisciplinary research teams should be fostered worldwide, including professionals from different fields: engineering, psychology, neuropsychology, medicine (e.g., pediatricians and geriatricians) for constant and ever-improving development.

In the end, to seed a new robotic revolution beneficial for people's health and wellbeing, it is necessary to go beyond the application of (social) robots strictly limited to rehabilitation paths or specific medical conditions [73][74][75]. Social robots should not only avoid people being injured or harmed (as in the first Laws of Robotics envisaged by Isaac Asimov) and support them in their recovery, but also promote their wellbeing all-round, thus answering their psychological needs and demands.

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