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Socially Assistive Robots As Mental Health Interventions For Children: A Scoping Review

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ABSTRACT

Socially Assistive Robots are promising in their potential to promote and support mental health in children. There is a growing number of studies investigating the feasibility and effectiveness of robot interventions in supporting children's mental wellbeing. Although preliminary evidence suggests that Socially Assistive Robots may have the potential to help address concerns such as stress and anxiety in children, there is a need for a greater focus in examining the impact of robotic interventions in this population. In order to better understand the current state of the evidence in this field and identify critical gaps, we carried out a scoping review of the available literature examining how social robots are investigated as means to support mental health in children. We identified existing types of robot intervention and measures that are being used to investigate specific mental health outcomes. Overall, our findings suggest that robot interventions for children may positively impact mental health outcomes such as relief of distress and increase positive affect. Results also show that the strength of evidence needs to be improved to determine what types of robotic interventions could be most effective and readily implemented in pediatric mental health care. Based on our findings, we propose a set of recommendations to guide further research in this area.

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1. INTRODUCTION

The World Health Organization defines mental health as “a state of well-being” that allows a person to lead a fulfilling and productive life and contribute to society [1]. Supporting mental wellbeing is especially important in children as many mental health disorders have their onset in childhood or adolescence [2]. Untreated mental health issues such as anxiety and depression in children are associated with poorer education outcomes [3] and development of mental illness later in life [4]. Socially Assistive Robots (SAR, also “Social Robot”, “Companion Robot”) have emerged in recent years as potential tools to promote and support mental health in children. The goal of this study was to describe the current landscape of SAR research and identify critical research gaps in the context of mental health. For the purposes of this paper, we use a definition of mental health that focuses on emotional regulation and coping with adverse events, key aspects of mental well-being as a “dynamic state of internal equilibrium” as per the proposed definition by Galderisi *et al*.[5]. This scoping review was formulated to focus on mental health-specific outcomes as defined through the lens of the medical model (e.g., measures of anxiety, depression, distress) rather than social and cognitive skills as to specifically capture this novel and growing application area for social robotics [6].

Polanczyk et al. [7] in a meta-analysis of prevalence of mental disorders published in 2015, found that based on studies from 27 countries, 13.4% of youths suffer from at least one mental health issue, with anxiety being the most common. Despite the prevalence of mental health needs among children and young adults, they often remain unaddressed [8–11]. Diagnosis and treatment of mental health conditions in children are associated with unique challenges, as children and youths undergo rapid physical and emotional development and may present with different symptoms than the adult population. In addition, investigating children’s mental health separately from adults’ is important, as this distinct population presents childhood-specific mental disorders, such as disruptive mood regulation disorder, and is a subject to age-specific diagnostic criteria and therapy [12].

Current evidence-based mental health therapies include psychosocial therapies, such as cognitive behavioral therapy (CBT), and pharmacological therapies (i.e. medications). CBT focuses on changing thought and behavioral patterns and is typically carried out in clinical setting as individual or group sessions with a therapist. The nature and duration of treatment largely depends on the mental health issue addressed and its severity, but typically consists of no less than 6 sessions [13]. Successful treatment requires commitment of time and effort. Supporting mental health in children is difficult because of stigma and poor mental health literacy among youth [14] as well as various barriers to access to services that differ between rural and urban settings [15]. SARs, created with the purpose of assisting people by means of social interaction, have the potential to help address some of children’s and youths’ mental health needs. An indication of this potential is the evidence on the use of SAR in adult and older adult populations. SARs such as the robotic seal Paro have shown promise in their potential to support the mental health of older adults [16, 17]. A recent systematic review of controlled trials analyzing the impact of social robots on the well-being of older adults suggests that social robots can significantly improve nine quality of life outcomes, including reducing loneliness and medication use, but also mental-health specific outcomes such as decreasing stress and anxiety [18].

For children, the potential benefits of SARs in mental health care are facilitated by the high acceptability of robots by this demographic [19–22]. A recent review by Dawe and colleagues mapped the publications related to supporting children in the healthcare context [23]. The authors report that SAR are generally readily accepted by children and their use in healthcare is promising. Examples of application areas include supporting the well-being of pediatric patients by means of distraction, emotional support, and social support during a hospital stay. SARs are also being explored to address social isolation in hospital settings. Csala, Németh and Zainkó [24] used the robot Nao to develop an entertainment program for children who suffer from leukemia and have to remain in isolation. In this pilot study the use of a robot received positive feedback from parents and patients and demonstrated an application of SAR in a scenario where employing other social agents, like Child Life Specialists or pets, would be difficult or impossible due to child's compromised immune system.

Beyond acute settings, SARs have also been investigated as social interventions for children with Autism Spectrum Disorder (ASD). A large body of work has established usefulness of robots such as Nao, Rovio [25] and My Keepon [26] to deliver interventions aimed at improving social skills in children. A systematic review of SAR for ASD from 2015 concluded that robots are generally beneficial in ASD interventions and have the potential to improve sociability, attention, language skills and reduce unwanted repetitive behaviours [27]. These findings of clinical outcomes were supplemented by a comprehensive review of the challenges of research into robotics as ASD interventions [28]. These contributions are important in developing a systematic understanding of the effectiveness of social robot interventions in ASD as well as improving experimental methods of inquiry into SAR interventions for children. While social skills and social functioning can play a role in children's mental health, SAR interventions to support mental health outcomes specifically in children differ substantially than those aimed at improving social skills and have not yet been rigorously characterized.

The goal of this scoping review is to describe the current landscape of SAR as tools to improve mental health outcomes in children and to identify critical gaps in the research in this field through an interdisciplinary approach at an intersection of robotics and medicine. Thus, we use a definition of mental health outcomes informed by medical research. We define mental health outcomes as changes in mental well-being and mental illness symptoms as a result of treatment or intervention [29]. These changes can be quantified using specific measures or described using qualitative methods and can be used as evaluation tools to determine the effectiveness of a particular intervention. For the purposes of this review, we focused on outcomes specific to mental well-being, rather than social outcomes, which have been reviewed recently [27, 30]. In line with our interdisciplinary approach, the present scoping review focuses on social robots as assistive technologies. The theoretical framework we use to guide the research is the Human Activity Assistive Technology Framework (HAAT)[31]. The HAAT framework places context as an integral part of an assistive technology system formed by the user, technology and the activity performed [32]. It is ideally suited to research that examines robots as therapy in contexts such as mental health that have important social and cultural components. In line with an interdisciplinary approach to scoping review methodology informed by the HAAT framework, this review focuses on characterizing current literature based on elements from the HAAT model: robots used (assistive technology), intervention type (activity, context) and the outcome measures used to evaluate this interaction.

2. METHODS

We conducted a scoping review of the available literature based on the methodology by Arksey and O'Malley [33]. The scoping review is a review method used to broadly characterize an area of research to better understand key concepts, the types of research designs that are used and identify any gaps [34]. This type of review differs from a systematic review in that it is not aimed at synthesizing the findings in the field, but rather providing a "map" of existing studies to guide future efforts. We selected this method over other types of reviews as it is ideally suited to provide an overview of a new field of study which may not yet have yielded sufficient harmonizable data sets to quantitatively assess the effects of interventions [35], as is the case in the area of SAR for pediatric mental health.

2.1 **Search strategy**

As the field of SAR is dynamic and rapidly evolving, we limited the scope of our literature search to publications from the past 10 years (2009 – Nov 6th 2019). In consultation with an academic librarian, we used a combination of keywords: "robot", "robotics" and terms related to "child" in order to prevent omissions of publications that do not specifically mention mental health or socially assistive robots. These search terms were used in the following databases: EMBASE, PubMed, MEDLINE, PsycINFO, which together capture content from additional databases such as IEEE Xplore. Additionally, the research team conducted a manual search of Google Scholar to identify any relevant studies using the same keywords. Complete search strings are available in Table 1. The settings of search engines were set to retrieve only peer-reviewed publications.

2.2 **Selection of relevant publications**

The titles and abstracts of database search results were screened by two members of the research team based on the following criteria.

Inclusion criteria:

- The publication is a peer-reviewed study or a conference proceeding;
- The intervention reported focused on children (0-18 years old);
- The publication is in English;
- The study assesses aspects of mental health outcomes, defined as changes in mental well-being and mental illness symptoms as a result of treatment or intervention that can be quantified or described qualitatively.

There were no inclusion restrictions on the mental or health status of participants, i.e. studies reporting on mental health outcomes of SAR intervention in children with ASD, cancer, diabetes and other conditions were included.

Exclusion criteria:

- Publication does not report on a mental health intervention;
- Publication solely describes robot development;
- The robot is used for diagnosis of a mental health disorder;
- Publication examines only social outcomes of robot intervention (e.g., gaze, social skills, communication skills).

Conflicts during screening were resolved by a third member of the research team. After the initial screening, a member of the research team conducted citation linkage search to identify potentially relevant studies that could have been omitted. The relevant research articles selected through the process of title and abstract screening were read in full by a member of the research team to establish their suitability. In instances when the inclusion of an article was unclear, the full article was read and discussed by two members of the research team until consensus was reached.

2.3 **Data extraction**

One researcher extracted data from all included publications. Information extracted from the publications included dimensions identified by Baxter et al. [36], that are also consistent with the HAAT framework such as participants (characteristics of the user), level of autonomy of the robot used (characteristics of the assistive technology), robotic intervention type, length and environment (context in which the assistive technology is being used). Additionally, based on HAAT we extracted country of origin to further describe the context of the intervention, as well as goals of the study and measures employed to characterize the outcomes of the user-technology interaction. To aid in developing actionable recommendations we also extracted limitations reported in the studies. Information regarding each of the studies was charted using Microsoft Excel. Publications reporting on the same study were grouped together to avoid confusion during the analysis stage.

2.4 **Search results**

The databases search yielded 6861 results (EMBASE: 2698, PubMed: 1295, Medline: 2033, PsycINFO: 835). The results were then pooled using EndNote software and the duplicates were removed. For each of the keyword combinations, 100 pages of Google Scholar results were reviewed until the results no longer met inclusion criteria (e.g., no English-language results). An additional 22 articles resulting from the manual search of Google Scholar were added. The list of relevant entries retrieved through Google Scholar is available in Supplemental Table 1. After the removal of duplicates, the total number of studies was reduced to 3616 unique results. The initial screening of titles and abstracts carried out by two researchers led to 35/3616 conflicts in screening (99% agreement; Kappa = 0.984, CI [0.978, 0.989]). Screening of abstracts and titles resulted in 40 articles for full text screening. After full-text screening, 16 publications reporting on 12 research studies were included in the analysis. The details of the studies included in this review (citation, country, goal, participants, robot used, intervention type, intervention length and control used) are reported in Table 2.

The research articles in the sample reported mostly on studies conducted in North America with four publications from the USA and three from Canada. Other countries represented in the sample included Iran (2), Germany (1), the Netherlands (1) and Japan (1). In total, publications from six different countries were included in this review.

3. RESULTS

3.1 **Robots used**

Five different robots were used in the studies from the sample (Fig. 1). The most frequently used robot for interventions was **Nao** (6/12). Nao is a programmable humanoid robot developed by a French company, Aldebaran Robotics (now Softbank Robotics) [37]. Nao has seven touch sensors located throughout its body, four microphones and speakers used for speech detection and interaction, and two cameras for face detection. It is also capable of autonomous behaviours. The second most popular robot was **Paro** (3/12). Paro is a robotic baby seal developed by AIST in Japan [38]. It is autonomous and capable of learning new behaviours using user feedback through reinforcement-like mechanisms. It has touch, sound, vision, motion and temperature sensors, can recognize whether it is being held and can express emotion through movement of its head, flippers and eyes. Another robot used in one of the interventions was **Huggable** [39, 40], an Android phone-based social robot modelled after a teddy bear. Huggable was developed by Personal Robots Group at the Massachusetts Institute of Technology. In the study, Huggable was remotely controlled and used a pitch-shifting software to communicate with the children [40]. Personal Robots Group also developed the social robot **Tega** [41] that was used in one of the studies. Tega was designed to provide companionship for children and as a research platform in SAR. **Pleo** [42] is a pet dinosaur robot developed by Innovo Labs based in Hong Kong and Nevada. It is capable of autonomous actions including exploration and play. It is equipped with a camera, two microphones, beat detection, touch sensors, foot sensors, orientation sensor, infrared mouth sensor. Three articles out of the sixteen included in the review mentioned what types of sanitation the robot require between interactions with children, two reporting on Nao being wiped down [43, 44] and one reporting on Huggable's fur being removed, wiped down and washed between interactions [39]. Sanitation methods are important, as the ability to sanitize the robot may determine its appropriateness to use in a hospital setting.

Fig. 1 *Social robots used in the identified studies: Nao (a), Paro (b), Huggable (c), Tega (d) and Pleo (e)*

3.2 **Intervention type**

Intervention types relate to how SARs were used in a particular setting. We summarize the nature of interactions described in included articles. The interaction types each study were categorized into free and guided/structured interaction. The intervention length ranged from a single five minute session to unlimited access to a SAR over a period of three months. Full interaction details as well as duration of specific interventions are reported in Table 2.

3.2.1 *Free interaction*

Five studies included in the review used different models of free interaction with a robot as an intervention. In the design of Crossman and colleagues [45] children underwent the Trier Social Stress Test for Children and subsequently interacted with the robot Paro for 15 minutes. While interaction with the robot was encouraged, the participants remained in the room with the robot on their own, observed through a two-way mirror [45]. Similarly, in Okita et al.'s study [46], children were able to interact with Paro freely, either taking turns with their parent or while being alone in the room. In Jeong et al.'s study [39, 40, 47], hospitalized children were able to freely interact with the robot Huggable at their bedside, without a time limit while being video-recorded. There was a Child Life Specialist present during the interaction to provide loose guidance [39]. In a study by Nakadoi et al. [48], the robot Paro was placed in an accessible location in a psychiatric ward and could be freely accessed by inpatients after obtaining permission from the staff. Children in focus groups carried out by Ullrich et al. [49] could also freely interact with the robot Nao after watching a video demonstration of a possible intervention. The children in this study interacted with the robot as a group [49].

3.2.2 *Guided/structured interaction*

Two of the studies retrieved used a guided interaction model, with the robots being pre-programmed to deliver an intervention. In the first study, a psychological intervention for pain reduction was pre-programmed on the robot Nao [19]. The statements uttered by the robot were based on psychological evidence and practice [19]. In the study by Park and colleagues [50], the robot Tega was pre-programmed with a set of reactions in each of the conditions and the interaction consists of playing tablet-based puzzles. Additionally, the robot selected the next puzzle based on an algorithm unique to each of the experimental groups [50].

Four studies reported on using robots as distractions for children during a medical procedure. Ali et al. [44] in their RCT protocol described a plan to use pre-programmed Nao robot to distract children during venipuncture procedure at a hospital. The robot will engage the child in conversation and activity and will invite the child to blow during intravenous needle insertion (IVI) to minimize the pain. A similar procedure is reported in Beran et al.'s study [43] during which Nao was used as a distraction during flu vaccinations. Eind and Heerink [51] report in their study the use of Pleo as a distraction for younger children during a vaccination consultation. In their study young children were introduced to Pleo and the procedure could be demonstrated on the robot. The nurse helped children interpret Pleo's behaviours and made sure they were engaged in play with the dinosaur. Previously mentioned study by Jibb et al. [19] used a pre-programmed robotic distraction and a robot delivering an evidence-based psychological intervention during a needle insertion procedure. These two interventions were compared.

In a study by Ferrier, Pearson and Beran [52], the robot Nao was programmed to deliver various structured interventions, including distraction, breathing exercises, motivational story-telling and others to customize the intervention to different medical procedures, children's age and psychological well-being at the time of intervention.

Alemi and colleagues [53, 54] deployed a robotic intervention that consisted of multiple sessions for children with cancer. During the course of the study, children took part in 8 group sessions with the robot Nao. The robot was remotely controlled and performed a pre-programmed script that was aimed at informing children about medical procedures, improving coping and reducing distress. Nao was portrayed during the sessions as a patient undergoing treatment such that children could sympathize with it.

3.3 **Intervention outcomes**

Intervention outcomes are the mental health variables that the studies were aimed at improving. All mental health-related results from the sample of studies are reported in Table 2. Half of the thirty reported tests in all of the studies combined resulted in a statistically significant result. The most frequently used outcome measure was Faces Pain Scale-Revised, followed by State-Trait Anxiety Inventory for Children. Specific validated outcome measures used by the different studies are summarized in Table 3.

Anxiety: Among the studies included in this review, four examined the impact of robotic interaction on anxiety in children. The results reported are mixed – while Alemi et al. found a significant reduction in anxiety in the robotic intervention group compared to psychotherapy control group, in which anxiety remained the same [53], Crossman et al. found no significant effect when comparing free robot interaction with waiting condition and robot turned off [45], Jeong et al. did not report anxiety measure results [39, 40], and Logan et al. [47] were not able to collect enough electrodermal activity readings to complete analysis.

Depression/anger: In addition to anxiety, Alemi et al. examined the impact of the robotic intervention on depression and anger. They reported a significant reduction on both measures in the intervention group [53].

Pain: The impact of SAR interaction on perceived pain was investigated by two studies. One of the studies reported reduction in pain [55], while the other one found no difference between the robotic and non-robotic groups [19]. Additionally, in the study by Jibb et al., children experienced only moderate pain relief compared to expectations in the robotic conditions.

Distress: Studies that reported on the effect of SAR on distress are in agreement and both suggested that SAR reduce distress in children [19, 55]. Jibb et al. reported a decrease in distress in the robotic distraction group compared to robotic cognitive-behavioural therapy group.

Affect/mindset: Similar positive results are also tied to measures of affect. Crossman et al. reported a large effect of the SAR use on positive affect compared to non-robotic and waiting control conditions [45]. Beran and colleagues found that both parents and children smiled significantly longer in the robotic condition [43]. Further supporting this finding, Jeong et al. measured the sentiment of verbal utterances of children and reported a significant positive effect of the robotic intervention on joy, agreeableness and decrease in sadness [39, 40]. Additionally, based on the same intervention, Logan et al. reported improvement in positive affect in the robotic condition compared to plush toy condition [47]. Another positive result was reported by Park and colleagues who found that interaction with a peer-like robot increased children's growth mindset and made them more resilient to failure as they attempted a difficult task more times than in the control condition in which children interacted with a peer robot that did not exhibit a growth mindset [50].

Emotional responses to the robots: Findings about the impact of SAR on different measures of psychological wellbeing were supplemented by behavioural observations. Jeong et al. observed that participants were eager to hug the bear-shaped robot and responded emotionally when it was time for the robot to be put away [40]. Moreover, children in the robotic condition were more likely to show shared attention than in control conditions [39]. In Eind and Heerink's pilot study [51] there were only two participants, but both children showed interest in the robot. Additionally, the authors report a potential problem which resulted from being overly absorbed by play with the robot as one of the children stopped following the instructions provided. Mixed reactions were observed by Nakadoi and colleagues as well, as while some participants responded very well to Paro, some were distressed by its sounds and appearance or even expressed aggression [48]. Ullrich, Diefenbach and Butz noted a positive attitude of children to the robot. Two of the children in this study expressed the opinion that a robot like Nao would be a valuable distraction during stressful procedures. Several children also mentioned that having a robot companion at school would help in reducing stress [49].

3.4 Study limitations

Here we report limitations identified by the authors of the studies in the review sample in any section of the manuscripts. Commonly reported limitations are summarized in Table 4.

Despite promising intervention outcomes, the results of the studies in this review need to be interpreted with their limitations in mind. Three studies described in three articles reported small sample sizes [19, 52–54]. Examination and measurement of only short-term effects of the robotic intervention, which may only capture novelty effects, was cited as a limitation in two studies [19, 45]. Another limitation reported by two of the studies was recall bias in children, as they were asked to recall their past experiences with medical procedures [19, 49]. Other limitations appearing in the papers include: recruitment difficulties [53, 54], self-selection of participants [53, 54], limited follow-up with the participants/their parents [43], raters of behaviour not being blinded to the intervention type [43], the brevity of interaction with the robot, technical difficulties interrupting the flow of the interaction [19, 47], single site of intervention [19] and lack of objective measurements [48] or controls [48]. Three studies did not report any limitations [39, 40, 50, 51] and one paper described a study protocol [44].

4. DISCUSSION & CONCLUSION

4.1 Summary of findings

Overall, the impact of SAR interventions on mental health outcomes is mixed, and highly dependent on the context of the interventions. These findings are consistent with the key tenants of the HAAT framework [31], which stipulates that context (e.g., place, culture) influences the relationship between the user (e.g., population of interest), activity (e.g., intervention) and technology (e.g., robot). Some positive outcomes such as relief of distress and increase in positive affect were consistently reported by a number of studies regardless of robot used [19, 40, 43, 45], results which are consistent with a recent review of SAR interventions for pediatric pain and distress [56]. However, the disparities in outcome measures, robots used and study quality in this sample make it challenging to draw patterns or relationships within the data, as others conducting similar work have also found [56]. Based on our findings, we can nonetheless build on the work uncovered in this scoping review and extract the similarities and limitations of the studies to provide a list of recommendations to consider when designing studies of the impact of SAR on mental health outcomes (Table 5). These recommendations are divided into themes of improving the quality of research design, using appropriate controls, considering device-specific barriers for the use of SAR, improving transparency of reporting studies and greater awareness of the social and ethical impact of SAR interventions.

4.2 **Country**

Our sample contained articles published mainly in North America, which could be explained by the fact that robotics research is associated with high costs. Thus, it is more likely to be carried out in highly developed countries. The search result of 16 articles from 6 different countries shows that the interest in SAR interventions is spread internationally. Having a varied perspective from multiple cultures is important, as cultural elements greatly contribute the context in which robotic assistive technologies are used, and influence how children interact with the robots. Some dimensions of child-robot interaction that may be influenced by culture are attitude towards the robot [57], evaluation of the robot [58] as well as robot acceptance [59]. For instance, Shahid *et al.* carried out a study aimed at comparing playing a game alone, with a friend and playing with a social robot with Dutch and Pakistani children as participants. Their results suggest that Pakistani children appreciated the robot more as a game partner and reported a greater willingness to play with the robot again than Dutch children [60]. Considering context and culture during the development phases of SARs and SAR interventions is critical to promote successful interactions, especially in the context of mental health interventions [60]. In behavioural interventions, evidence suggests that patient characteristics such as sociocultural factors may influence the outcomes of a psychological intervention [61]. To make sure that SAR interventions are appropriate for a particular cultural context, user-centered initiatives are recommended. When developing a mental health intervention or conducting a study, the researchers should consider consulting relevant stakeholders, such as therapists, potential participants and their parents, to inform study design and outcome measures.

4.3 **Robots used**

According to the HAAT framework, there is a reciprocal relationship between the technology, its user and the activities performed. Accordingly, the decisions about which type of robot is appropriate for a particular study depend largely on the desired type of child-robot interaction. The frequent use of the humanoid robot Nao may stem from its ability to interact verbally, as well as its commercial availability. Robots that are verbal and have limbs could potentially be easier adapted to deliver mental health therapy, such as Cognitive Behavioural Therapy. Additionally, some interventions are based on children identifying with the robot, e.g., during demonstration of a medical procedure. In such cases, the use of a humanoid robot may be especially desirable. Studies included in our sample that used the robot Nao tended to be better controlled that the ones using different robots. The fact that Nao is a well-established robotic platform may contribute to the rigour of the research performed that uses this robot. It is reasonable to expect that more refined robots contribute to more sophisticated interventions. While humanoid robots can provide instructions or reassurance to children in stressful situations, pet-like robots are well-suited for distracting children, providing comfort and emotional support. The setting of robot application to a large extent determines the type of robot that is the best fit for the role. In a hospital situation or during a medical procedure it may be easier to have an agent that can engage with or distract the child verbally, as the freedom of movement of the child is usually limited when they are undergoing medical treatment. An aspect of robot choice that also needs to be considered in use with children in health care is proper sanitation. Most of the studies included in the review did not mention sanitation techniques used to sanitize or clean the robots between interventions. This finding is consistent with the results of a 2016 literature review on sanitizing robotic animals which reported limited information available on procedures applicable to the field of robotics [62]. This finding could be due to the fact that in many studies children interacted with the robot verbally, which reduces the need for sanitation after each use.

4.4 **Intervention type**

Most of the study designs included in this review used free interaction with the robot, robotic distraction and structured interaction. Currently, there is limited evidence on the effects of different robotic interaction types on mental health outcomes. Based on the HAAT framework, assistive technology system includes the technology and the user in a specific context, therefore there is a need to explore which interaction types are appropriate for different care scenarios and what is the extent of their effects, as children may have different needs and preferences depending on the situation. For instance, during a game of chess with a social robot, children preferred esteem support and emotional support over receiving clues or information [63]. Only one intervention included in this review used robot-assisted therapy as means of improving children's wellbeing [53, 54]. There is space for development in this area, as previous research suggests that robot-enhanced psychotherapy would be accepted by children and parents [64]. A meta-analysis from 2014 [65] suggests that robot-assisted psychotherapy may be useful in improving behavioural symptoms, however, the results it presents are based mainly on psychotherapy for individuals with dementia and autism spectrum disorder. The authors point out that application of robot-enhanced therapy to other common mental health problems such as anxiety and depression remains open for investigation [65], which our findings also support with only one study identified in this area.

4.5 **Intervention outcomes and outcome measures**

An important consideration when interpreting outcomes of SAR mental health interventions is the control condition. The selection of the control condition affects the internal validity of the study and determines the strength of conclusions that can be drawn from its results [66]. Using a waiting condition as control (e.g.,[45]) allows for detecting a large effect size, which may be appropriate for preliminary studies with a small number of participants [67]. Three of the studies in the sample used standard care as a control condition. In these cases, if no difference between the groups was detected, the SAR intervention effect could be interpreted as equivalent to that of the standard of care, rather than as having no effect at all. These types of control conditions are usually more appropriate for interventions in later stages of testing, to detect a smaller effect size in adequately powered studies [67]. As the field of SAR mental health interventions moves from development and feasibility studies to clinical trials aimed at determining efficacy, the control conditions used should become more specific and allow for the evaluation of the impact of the unique features of robots being tested.

While the potential benefits that could result from the use of SAR are broad and varied, there is a number of challenges in research involving children's interaction with socially assistive robots. The specific context of mental health treatment and prevention interventions is unique. Mental health interventions are typically used are time-consuming, tailored to the needs of the child and distributed over a longer period of time. Meanwhile, most of the robotic interventions in the sample were one-time interaction studies. Establishing feasibility of SAR mental health interventions is needed, however, determining whether reliable effects of interactions with robots are present would require a greater number of interactions over a longer period of time. The discrepancy between the experimental paradigms of mental health studies and the nature of child-robot interaction studies may contribute to a low number of studies in this intersection of fields at this time.

Unique challenges are also tied to conducting research with children as participants. Children are prone to suggestion and have the tendency to want to please the experimenters which makes choosing valid outcome measures difficult. Compounding this challenge, there is a lack of consensus and standardization of outcome measures and many studies use different scales and instruments. Most of the selected studies used various validated measures to determine the impact of robotic interventions on mental health constructs. In addition, many studies included qualitative measures of investigated constructs which enabled them to capture the perceptions of participants alongside mental health outcomes. The combination of measures provides insight into the end-user perspective on the intervention which is important. Since the field is still in development, different control conditions are used across studies which makes comparison between them or generalization of the results difficult. Some studies report no change on one measure, but significant results on related measures. This finding suggests that researchers should be more specific in selecting their outcome measures. For instance, Logan *et al.* report a significant pre -post intervention difference in parents' perceptions of their child's pain (Numerical Rating Scale), but no significant effect on child's self-report of pain (Numerical Rating Scale or Faces Pain Scale – Revised)[47]. Additionally, SAR are not readily available across countries, which results in different regions relying on particular robotic solutions. There is also limited knowledge about cultural differences in perception and use of robotics. Finally, published articles are subject to reporting bias, which may explain why robots seem effective as mental health interventions.

4.6 **Limitations of studies in the sample**

Most studies included in the review did not extensively report the limitations of research. We noticed that there is limited discussion on the recruitment process [53], the potential impact of study procedures on children's stress level [45] or in-depth descriptions of the observational protocol [48]. Additionally, most studies only described the assent process very generally. According to Kyriakidou et al. [68], there are four necessary features for every study that includes child-robot interaction: 1) child's assent, 2) description of the robot prior to interaction, 3) introduction of the robot to children prior to the interaction and 4) explanation of the robots' mode of operation (e.g. whether it is remotely controlled or autonomous). However, different designs may need to be employed when this procedure runs counter to the goals of a study, for example when Wizard-of-Oz methods are used. Children's beliefs about the animacy of robots should be considered at the outset of study design [69]. In terms of reporting, a systematic literature review of peer-reviewed articles published between 2004 and 2014, revealed that only 10 of 27 articles described relevant ethics procedures, and only six described robot-specific ethical considerations [68]. These findings are still relevant when considering articles included in this review, published since 2009. It is crucial that scientists who deploy SAR in studies with children implement ethical guidelines in order to minimize participant burden and avoid unnecessary deception and attachment issues. It is equally important to report on the ethics procedures included in the study, as well as openly discussing study limitations, as it is key to improving study designs and generating stronger results especially in a field that develops so rapidly.

The current, early stages of SAR interventions' development for mental health could be seen as parallel to the beginnings of robot-assisted therapy for children with ASD over ten years ago (e.g. [70, 71]). Much like the studies in the sample, early studies were focused on the feasibility of robotic interventions for ASD and often used single-case examples. In recent years, tremendous work has been done in the field of robotics research for ASD, which has been summarized and analyzed in multiple reviews [30, 72, 73]. As the field of SAR and mental health interventions matures, it is likely that it will follow the pattern of ASD literature, with an increasing number of randomized controlled trials and intervention studies with more participants and over longer time periods. Acknowledging the limitations in research to-date can catalyze improvement in research rigour. In turn, focusing on the quality of SAR intervention evaluations will help ensure that the field development in the next years brings decisive evidence on appropriateness of SAR interventions for mental health in children.

4.7 **Proposed recommendations**

Based on analysis of studies in our sample we propose a set of recommendations to address common shortcomings and promote development of quality evidence in the field of SAR interventions to support children's mental health. While several recommendations apply to research on robots as health interventions more broadly, we highlight below areas of special importance in mental health research.

Studies in our sample were mainly focused on establishing feasibility and acceptability of SAR interventions for mental health, as well as exploration of possible effects. Since SAR interventions for mental health are situated at the intersection of several different fields, prioritizing research outcomes may be challenging. While for some researchers, human-robot interaction outcomes are important, others may be interested in health outcomes. These interests require different research design approaches. To evaluate whether SAR could be used to improve mental health, more strictly controlled clinical studies are needed. The American Psychological Association identifies two dimensions that are used to evaluate treatment: efficacy and clinical utility [61]. While different types of research evidence are used to answer different questions, randomized controlled trials (RCTs) are considered necessary to establish a causal effect of an intervention [61]. Through randomization and strict controls, RCTs evenly distribute confounding factors between the experimental groups and minimize the risk of introducing systematic errors, thus increasing internal validity of the study. One of the studies in the sample described a proposed RCT protocol, which suggests that the field is moving towards establishing higher quality evidence that could inform clinical practice.

A well thought-out study design is crucial for the quality of the resulting findings. We suggest that future studies focus on a well-defined goal (e.g., anxiety management, distraction) and select appropriate outcome measures that will not only accurately capture the construct under investigation, but also allow for comparison with other studies in the field. In pediatric mental health research specifically, researchers conducting quantitative work should consider using child- or youth-specific validated instruments (e.g., State-Trait Anxiety Inventory for Children [74], Children's Depression Inventory [75]). Quantitative studies should also be adequately powered to determine a meaningful effect.

Another important aspect of SAR studies that needs to be mindfully selected is the control or comparison condition. Currently, the control conditions range from no controls and non-robotic toys to differently programmed robots. In mental health research, where early evidence suggests a potential benefit of robotic interventions, researchers must consider the potential harms of not providing any intervention to a control group, and ethical alternatives such as cross-over designs can be explored. As the field progresses from feasibility and exploratory studies to clinical trials, the research designs should incorporate standard care as control conditions to increase validity. Comparisons between different robot designs are equally important, as they promote understanding of how the specific features of a robot help or hinder mental health interventions. This knowledge will allow health care professionals and researchers to use evidence-based decision-making when selecting therapy robots.

Beyond design, a commonly encountered issue is transparency in reporting. Being thorough in reporting of ethics procedures, negative outcomes and study limitations aids other researchers in implementing study designs that limit participant burden and in mitigating problems that were encountered by other groups. Lastly, going forward, it is important to consider the social and ethical impact or SAR. Child-robot interaction poses unique challenges that need to be anticipated, such as the emotional impact of taking the robot away [76] and children's perceptions of the ontological and moral status of the robot [77]. Both of these considerations are especially salient in the mental health context and researchers should prepare support resources for their participants who may experience adverse effects from the withdrawal of an intervention. Based on the findings of this scoping review, we recommend following robot ethics for children, as described by Kyriakidou *et al.*[68], which include obtaining informed assent from children taking part in the study, describing and showing the robot prior to the study as well as explaining the mode of operation of the robot to the child. The full set of recommendations is summarized in Table 5.

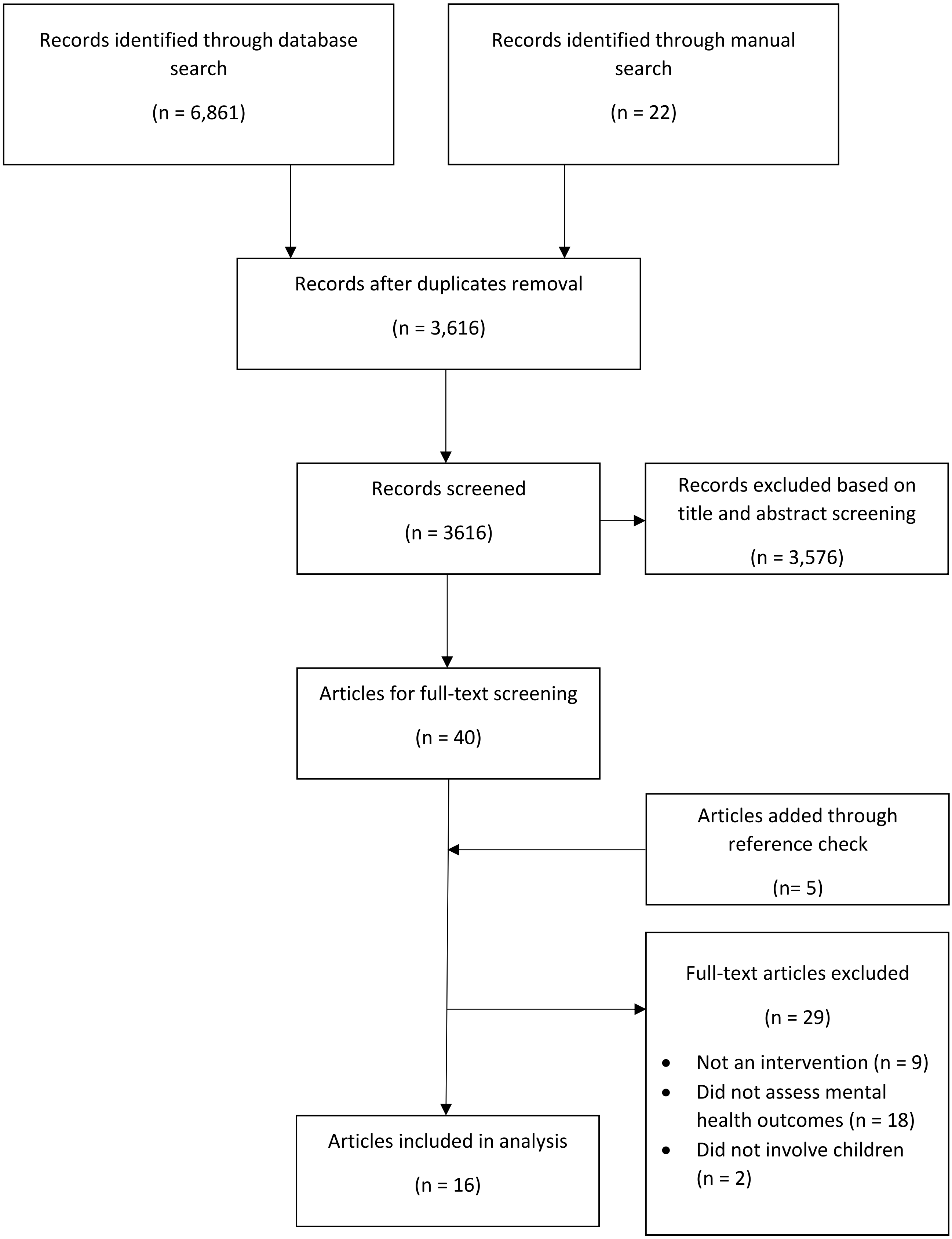
4.8 **Limitations of the present study**

This study is not without limitations. Our search was supplemented by using Google Scholar. While it provides an opportunity to explore backward and forward citations that yielded additional results, the fact that Google Scholar searches were based on keyword terms, as opposed to search strings, limits the replicability of this component of the search. Our search strategy yielded a small sample size of publications which limits our ability to generalize the results, but highlights the need for more research in this area. Due to diverse measures, interventions and controls in the studies, the comparability between studies in the sample was limited. Additionally, we acknowledge that exclusion of studies examining social skills from our search with the goal of limiting overlap with recent reviews in the area of ASD resulted in excluding SAR interventions that may improve mental health outcomes through better socialization of children.

4.9 **Conclusions**

Results from this scoping review of SAR interventions for pediatric mental health support the potential of SAR in this context. Future directions in this field should build on the recommendations proposed in Table 5 to address current limitations and knowledge gaps and add high quality evidence to this body of work. Specifically, while many studies control for SAR interventions with standard treatment procedures, there is a need to compare the impact of SAR in comparison with other interventions with a potential novelty effect, such as less advanced interactive toys. Additionally, the use of SAR for mental health support should be investigated with children in different age groups and with different diagnoses of mental health conditions to determine contexts in which SARs are most effective. Finally, there is a need for more randomized controlled trials in the field to determine whether social robots can be effective in supporting mental health based on standardized and replicable outcome measures. As the international robotics research community continues to grow and investigations into novel mental health care application areas emerge, high quality evidence about the impact of SARs on mental health will propel the development of translational solutions for the benefit of children worldwide.

Appendix 1 – Review flow chart.



Compliance with Ethical Standards

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

Table 1 Search strategy details

Ovid search string (EMBASE, MEDLINE)	
Search target	**Search terms***
“robot”, “robotics”	(robot? or robotics/).tw,kw.
“child”	juvenile/ or exp adolescent/ or exp child/ or exp postnatal development/ or (pediatric* or paediatric* or child* or newborn* or congenital* or infan* or baby or babies or neonat* or pre term or preterm* or premature birth or NICU or preschool* or pre school* or kindergarten* or elementary school* or nursery school* or schoolchild* or toddler* or boy or boys or girl* or middle school* or pubescen* or juvenile* or teen* or youth* or high school* or adolesc* or prepubesc* or pre pubesc*).mp. or (child* or adolesc* or pediat* or paediat*).jn.
PubMed, PsycINFO search string	
Search target	**Search terms***
“robot”, “robotics”	robot* OR robotics/
“child”	Infant OR infan* OR newborn OR newborn* OR new-born* OR baby OR baby* OR babies OR neonat* OR perinat* OR postnat* OR child OR child* OR schoolchild* OR schoolchild OR school child OR school child* OR kid OR kids OR toddler* OR adolescent OR adoles* OR teen* OR boy* OR girl* OR minors OR minors* OR underag* OR under ag* OR juvenil* OR youth* OR kindergar* OR puberty OR puber* OR pubescen* OR prepubescen* OR prepuberty* OR pediatrics OR pediatric* OR paediatric* OR peadiatric* OR schools OR nursery school* OR preschool* OR pre school* OR primary school* OR secondary school* OR elementary school* OR elementary school OR high school* OR highschool* OR school age OR schoolage OR school age* OR schoolage* OR infancy OR schools, nursery OR infant, newborn

*The terms were connected by “AND”. Search was restricted to dates from 2009 to November 6th, 2019. Only peer-reviewed publications were considered.

Table 2: Summary of studies included in the review

Authors, Year	Country	Goal/s	Participants	Robot used	Intervention	Intervention length	Control/s
Alemi et al., 2014 **Alemi et al., 2016**	Iran	To reduce **distress** in children diagnosed with cancer. To determine whether there is a difference in the levels of **anxiety**, **anger** and **depression** levels pre and post SAR intervention	11 children (10 female, 1 male) receiving cancer treatment, aged 7-12	Nao	Pre-programmed robot-assisted therapy. Cognitive WoZ (commands to perform sets of actions sent to the robot by experimenter). **Interaction type**: Verbal interaction.	8 group sessions over 3 weeks. Duration of each session not reported.	Psychotherapy
Ali et al., 2018	Canada	To compare the reduction of reported **pain** and observed **distress** of IVI procedure with and without SAR intervention	80 children undergoing venipuncture, aged 6-11	Nao	Pre-programmed robotic distraction. **Interaction type**: Verbal interaction.	Single session, length will depend of procedure (5-8 minutes).	Standard procedure
Beran et al., 2013 **Beran et al., 2015**	Canada	To explore the effects of SAR distraction during a flu shot on children's and parents' **emotions.**	57 children (27 female and 30 male) undergoing vaccination, aged 4-9	Nao	Pre-programmed robotic distraction **Interaction type**: Verbal and physical interaction.	Single session, based on the duration of flu vaccine administration	Standard procedure
Crossman et al., 2018	USA	To demonstrate the capacity of SARs to alleviate clinically relevant symptoms in children (**affect**, **anxiety**, **stress**)	87 children (46 female and 41 male) undergoing Social Stress Test, aged 6-9	Paro	Autonomous pet robot. **Interaction type:** Free interaction.	Single, 15-minute interaction with the robot after the Stress Test.	Robot turned off Waiting condition

Eind & Heerink, 2018	The Netherlands	To explore feasibility of using SAR in interaction with children in a medical setting. Focused on distraction during vaccination.	2 children (a girl and a boy) aged 3 years and 9 months	Pleo	Robot was introduced before vaccination consultation. **Interaction type:** guided interaction with the robot	Single session, duration depended on length of vaccination consultation.	None (observational study)
Farrier, Pearson & Beran, 2019	Canada	To determine the effects of SAR intervention on children's **pain** and **fear** during medical procedures.	46 children aged 2-15 undergoing medical procedures	Nao	Pre-programmed with different behavioral modes to accommodate children in different types of treatment. **Interaction type:** varied depending on child's procedure	Single session with multiple robot behaviors. Session length depended on procedure (3-10 minutes).	Standard care
Jeong et al., 2015 **Jeong et al., 2018** **Logan et al., 2019**	USA	To compare the effects of an embodied SAR to a virtual character and a plush teddy bear. To determine the influence of the interactions on pediatric patients' **affect**, **joyful play**, **social interactions**.	54 children, pediatric hospital patients, aged 3-10	Huggable	Wizard-Of-Oz (all aspects of robot behavior were controlled by an experimenter). **Interaction type**: Free interaction with the robot	Single session. Length determined by the patient (mean 26.4 minutes).	Free interaction with a virtual agent or a puppeteered teddy bear.
Jibb et al., 2018	Canada	To determine preliminary effectiveness of a SAR in reducing child's **fear, pain** and **distress** during a needle port insertion.	40 children (16 female, 24 male) undergoing cancer treatment, aged 4-9	Nao	Pre-programmed interaction with a robot using evidence-based cognitive behavioural intervention during subcutaneous port needle insertion. **Interaction type:** Verbal interaction.	Single session, length determined by the length of procedure.	Pre-programmed robotic distraction (dancing and singing) during subcutaneous port needle insertion

Nakadoi et al., 2015	Japan	To assess the effectiveness of SAR-assisted therapy for ASD. Focused on observing **mood**, **anxiety**, **impulsivity**.	9 inpatients of a psychiatric ward, aged 8-19	Paro	Autonomous pet robot. **Interaction type:** Free interaction with the robot	Inpatients were free to interact with the robot over the course of 2 months.	None (observational study)
Okita et al., 2013	USA	To examine whether using SAR decreases **pain** and emotional **anxiety** in paediatric patients and their parents	18 children (all female), hospital patients, aged 6-16	Paro	Autonomous pet robot. **Interaction type:** Free interaction, with or without parent present.	Single session of 30 minutes.	No non-robotic controls.
Park et al., 2017	USA	To explore the impact of social interaction of children with a SAR on **growth mindset**	40 children (17 female, 24 male) aged 5-9	Tega	Autonomous robot pre-programmed to exhibit a growing-growth mindset during games. **Interaction type:** Playing pre-determined games with the robot	Single session, duration not reported.	Play time with robot programmed to exhibit a neutral mindset
Ullrich, Diefenbach & Butz, 2016	Germany	To evaluate the concept of using a SAR for psychological benefit of children in a stressful situation (waiting room).	5 children (1 female, 4 male) aged 5-12	Nao	Fully autonomous robot. **Interaction type:** Fully scripted video prototype presentation and free interaction with the robot.	Single session, interaction within a focus group. Duration not reported.	None (focus group study)

Table 3: Outcome measures used to investigate mental health constructs

Construct Investigated	Outcome Measures	Studies	Statistically significant effect? [a] (control/s)
Anxiety	Multidimensional Anxiety Children Scale	Alemi et al., 2014, 2016	**Yes** (Psychotherapy)
	State-Trait Anxiety Inventory	Ali et al., 2018 Okita et al., 2013	**N/A** **Yes** (Parent present vs absent)
	Heart rate recordings	Ali et al., 2018	**N/A**
	State-Trait Anxiety Inventory for Children	Crossman et al., 2018 Logan et al., 2019; Jeong et al., 2015, 2018 Okita et al., 2013	**No** (Robot turned off, waiting condition) **Not specified** **Yes** (Parent present vs absent)
Depression	Children's Depression Inventory	Alemi et al., 2014, 2016	**Yes** (Psychotherapy)
Anger	Children's Inventory of Anger	Alemi et al., 2014, 2016	**Yes** (Psychotherapy)
Fear	Children's Fear Scale	Jibb et al., 2018 Farrier, Pearson & Beran, 2019	**N/A** **Yes** (Standard care)
	Numerical Rating Scale (11-point)	Jibb et al., 2018	**N/A**
Pain	Faces Pain Scale-Revised	Ali et al., 2018 Beran et al., 2013, 2015 Logan et al., 2019; Jeong et al., 2015, 2018 Jibb et al., 2018 Okita et al., 2013 Farrier, Pearson & Beran, 2019	**N/A** **Yes** (Standard care) **No** (Free interaction with a virtual agent or a puppeteered teddy bear) **No** (Pre-programmed robotic distraction: dancing and singing) **Yes** (Parent present vs absent) **Yes** (Standard care)
	Electrodermal Activity Sensor	Logan et al., 2019; Jeong et al., 2015, 2018	Missing data, no comparison possible.
	Numerical Pain Rating Scale	Logan et al., 2019; Jeong et al., 2015, 2018 Jibb et al., 2018	**Yes** - parents' rating (Free interaction with a virtual agent or a puppeteered teddy bear) **No** (Pre-programmed robotic distraction: dancing and singing)
Distress	Observational Scale of Behavioural Distress	Ali et al., 2018	**N/A**

	Behavioural Approach-Avoidance Distress Scale	Beran et al.,2013, 2015 Jibb et al., 2018	**Yes** - Distress and Avoidance subscales (Standard procedure) **Yes** - Approach-Avoidance subscale (Pre-programmed robotic distraction: dancing and singing)
	Salivary cortisol	Crossman et al., 2018	**No** (Robot turned off, waiting condition)
	Electrodermal Activity Sensor	Logan et al., 2019	Missing data, no comparison possible
Engagement with the robot	Intrinsic Motivation Inventory	Ali et al., 2018	**N/A**
Affect	Positive and Negative Affect Schedule for Children, Short Form	Crossman et al., 2018 Logan et al., 2019; Jeong et al., 2015, 2018	**Yes -** positive affect (Robot turned off, waiting condition) **Yes** - positive affect (Free interaction with a virtual agent or a puppeteered teddy bear)
	Facial Affective Scale	Logan et al., 2019; Jeong et al., 2015, 2018	**Yes** (Free interaction with a virtual agent or a puppeteered teddy bear)

[a] Reports on any statistically significant effect measured (pre-post or between groups) in any of the experimental conditions.

Table 4: Limitations reported by studies included in the review

Limitations reported	Studies
Limited sample size or composition	Alemi et al. 2014, 2016 Jibb et al. 2018 Okita et al., 2013 Farrier, Pearson and Beran, 2019
Recruitment difficulties	Alemi et al. 2014, 2016
Self-selection of participants	Alemi et al. 2014, 2016
Limited follow-up	Beran et al. 2015
Raters not blinded	Beran et al. 2015
Only examined short-term changes	Crossman et al. 2018 Jibb et al. 2018
Interaction with robot was short	Crossman et al. 2018
Technical difficulties	Jibb et al. 2018 Logan et al., 2019
Single-site study	Jibb et al. 2018
Recall bias in children	Jibb et al. 2018 Ullrich, Diefenbach & Butz, 2016
No objective measurements	Nakadoi et al. 2015
Lack of control	Nakadoi et al. 2015
No limitations reported	Eind & Heerink, 2018 Jeong et al. 2015, 2018 Park et al. 2017

Table 5: Recommendations for designing studies on the impact of SAR on mental health outcomes in children

Main themes	Recommendations
Quality of study design	Carefully define the goal of intervention as it relates to mental health *(e.g., distraction, emotional support)*
	Select outcome measures that: 1) address the goal, 2) maximize the ability to compare with other mental health studies, 3) are validated
	Adequately power study
Appropriate controls	Use appropriate controls *(e.g., robot turned off, robotic toy)* and ensure the potential benefits of the intervention are equally distributed to participants experiencing mental health issues
	Use longitudinal or repeated measures designs to account for novelty effects
	Consider using automated or blinded scoring procedures
Device considerations	Use and report proper sanitation procedures *(e.g., washing the fur, sanitizing the shell)*
	Have strategies in place to mitigate the effects of the robot not working or breaking during the interaction, and prepare alternative support resources for interventions in which the robot is hypothesized to support mental health.
	Consider implications of availability status and price of the robot
Transparent reporting	Carefully consider the robot-specific ethics of your design and state the ethical procedures employed, consult relevant best practice documents such as Ethics in Action[a] *(e.g., privacy, deception, assent and consent processes)*
	Report details of participants' sociocultural background as culture can influence attitudes towards both robots and mental health
	Be transparent about the limitations of the study
	Measure and report negative outcomes
Social and ethical impact	Take into account the impact of robot on human-human interactions *(e.g., caregiving, trust)*
	Anticipate the emotional impact of taking the device away at the end of the study
	Consider how children's perspectives may impact research and well-being *(e.g., whether the child thinks the robot is alive, autonomous)*
	Describe and introduce the robot to children prior to interaction and explain its mode of operation (*e.g., if it is remotely controlled or autonomous*).

[a]https://ethicsinaction.ieee.org/

Supplemental Table 1: Google Scholar search results. Shaded articles were identified only through Google Scholar and were included in the study.

#	Article Title	Author(s)	Date
1	Children's behavior toward and understanding of robotic and living dogs	Melson et al.	2009
2	Clinical application of a humanoid robot in pediatric cancer interventions	Alemi et al.	2016
3	THERAPIST: Towards an Autonomous Socially Interactive Robot for Motor and Neurorehabilitation Therapies for Children	Calderita et al.	2014
4	A Social Robot to Mitigate Stress, Anxiety and Pain in Hospital Pediatric Care	Jeong et al.	2015
5	Huggable: The Impact of Embodiment on Promoting Socio-emotional Interactions for Young Pediatric Patients	Jeong et al.	2018
6	Reducing Stress by Bonding with a Social Robot	Ligthart, Hindriks and Neerincx	2018
7	How do diabetic children react on a social robot during multiple sessions in a hospital?	Looije, Neerincx & Peters	2015
8	Hygiene and the Use of Robotic Animals in Hospitals: A Review of the Literature	Scolten, Vissenberg & Heerink	2016
9	Self–Other's Perspective Taking: The Use of Therapeutic Robot Companions as Social Agents for Reducing Pain and Anxiety in Pediatric Patients	Okita et al.	2013
10	Trial of robot-assisted activity using robotic pets in children hospital	Kimura et al.	2004
11	Robots Learn to Play: Robots Emerging Role in Pediatric Therapy	Howard	2013
12	Assistive Robotic Technology to Combat Social Isolation in Acute Hospital Settings	Sarabia et al.	2018
13	Adapting a General-Purpose Social Robot for Paediatric Rehabilitation through In Situ Design	Carrillo et al.	2018
14	Murphy Miserable Robot - A Companion to Support Children's Well-being in Emotionally Difficult Situations	Ullrich, Diefenbach & Butz	2016
15	Reporting Robot Ethics for Children-Robot Studies in Contemporary Peer Reviewed Papers	Kyriakidou, Padda and Parry	2017
16	mediRobbi: An Interactive Companion for Pediatric Patients during Hospital Visit	Lu, Blackwell & Do	2011
17	Evaluating the child–robot interaction of the Naotherapist platform in pediatric rehabilitation	Pulido et al.	2017
18	A Motivational Approach to Support Healthy Habits in Long-term Child-Robot Interaction	Ros et al.	2016
19	Building up child-robot relationship: From initial attraction towards social engagement	Diaz et al.	2011
20	A field study with primary school children on perception of social presence and interactive behavior with a pet robot	Heerink et al.	2012
21	Application of the NAO humanoid robot in the treatment of marrow-transplanted children	Csala, Németh & Zainkó	2012

22	Reducing children's pain and distress towards flu vaccinations: A novel and effective application of humanoid robotics	Beran et al.	2013

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6. COMPLIANCE WITH ETHICAL STANDARDS

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