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Citation:

LITTLER, Brenda Kimbembi Maleco, ALESSA, Tourkiah, DIMITRI, Paul, SMITH, Christine and DE WITTE, Luc (2021). Reducing negative emotions in children using social robots: systematic review. Archives of Disease in Childhood, archdischild-2020. [Article]

This article has been accepted for publication in ADC following peer review.
The definitive copyedited, typeset version is available online at 10.1136/archdischild

Reducing Negative Emotions in Children using Social Robots: Systematic Review

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Keywords: Anxiety. Distress.

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Hospital. Social Robots. Children

Word count: 2700

ABSTRACT

BACKGROUND: For many children, visiting the hospital can lead to a state of increased anxiety. Social robots are being explored as a possible tool to reduce anxiety and distress in children attending a clinical or hospital environment. Social robots are designed to communicate and interact through movement, music and speech.

OBJECTIVE: This systematic review aims at assessing the current evidence on the types of social robots used and their impact on children's anxiety or distress levels when visiting the hospital for outpatient appointments or planned admissions.

METHODS: Databases MEDLINE, PubMed, IEEE Xplore, Web of Science, Psych INFO and Google Scholar were queried for papers published between January 2009 and August 2020 reporting the use of social robots interacting with children in hospital or clinical environments.

RESULTS: A total of ten studies were located and included. Across these ten studies, seven different types of robots were used. Anxiety and distress were found to be reduced in the children who interacted with a social robot.

CONCLUSIONS: Overall, the evidence suggests that social robots hold a promising role in reducing levels of anxiety or distress in children visiting the hospital. However, research on social robots is at an early stage and requires further studies to strengthen the evidence base.

KEYWORDS: Anxiety · distress · Hospital · Social Robots · Children

INTRODUCTION

Social robots can potentially change the way professionals deliver interventions within the healthcare sector. Social robots are designed to interact with human beings through play, gestures, and movements. Studies have recently shown that they can provide companionship for the ageing population [1], as well as teach social cues to children with Autism Spectrum Disorder (ASD) [2]. Social robots can be personalised for each child's needs [3], giving them the potential to be a useful tool within the healthcare sector. Ways in which social robots have previously engaged with children in the healthcare setting are through music, games, and conversations [4]. This multifactorial sensory experience is known to be an effective form of intervention for distracting children from stressful situations [5,6]. This review aims to synthesise the existing evidence on the effectiveness of social robots for reducing anxiety or distress in children visiting the hospital or a clinical setting. The research questions were: what studies have been reported in the literature that used social robots in clinical and hospital settings to reduce anxiety and stress in children?; what robots were used in such studies and how were they used?; what are the results of using social robots in these settings in terms of effectiveness?; what lessons can be learned from reported studies for future research in this field?

METHODS

Eligibility criteria

The inclusion criteria were dependent on the PICOS framework [7] as described below:

Population

The population was children (age 0-18 years) who were visiting the hospital or clinical environment with any psychological or physical health condition. There was no limitation on the children's gender or socio-demographic characteristics.

Intervention

The intervention was a social robot that provided companionship with verbal or physical interactions. The interactions could occur at any point of the visit, before, during or after the treatment.

Comparator

The comparator was either usual care or another control intervention such as a teddy bear or a virtual character.

Outcomes

The outcomes of the studies included the effects each social robot had on anxiety, or distress on their participants.

Study Design

The eligible study designs included both qualitative and quantitative studies.

Information sources

Eight electronic databases were searched: MEDLINE (via OvidSP), PubMed (via OVidSP), IEEE Xplore Digital Library, Web of Science (via WoS), PsychINFO (via OvidSP), and Google Scholar.

Additionally, two grey literature databases were searched: BASE and Clinical Trials. Hand searches for studies were completed through scanning the references of automatically found studies.

Search Strategy

A building block approach identified search terms for each concept which were added using the Boolean AND operator [8]. All searches were limited to studies published between January 2009 and August 2020, due to the use of social robots in the hospital being a new area of research. The review was restricted to peer-reviewed English language. The following search strategy was used, and the pattern was adapted to suit each database: ((anxiety* OR distress* OR fear* OR worry*) AND (children* OR paediatric* OR infant*) AND (hospital* OR clinic* OR healthcare*) AND (social robots OR humanoid OR robotics*).

Study Selection

The first phase consisted of removing duplicates and reviewing the titles of the studies found on the electronic databases. Two reviewers (BL and TA) independently scanned titles against the eligibility criteria. Each study was assigned a score ranging from 0 to 2 by the two reviewers: 0 meant the study was irrelevant, 1 indicated that it might be relevant, and 2 meant it was relevant. If the study received a total of 2 points or more, it was included in the next phase. The second phase consisted of screening the abstracts of the selected titles. Cohen's kappa was calculated to determine the inter-rater reliability between the reviewers for each step of selecting titles and abstract. Then the full articles of the studies that had total scores of 2 points or more were reviewed. If there was any disagreement between the two reviewers, the authors (PD, CS, and LdW) were consulted to reach a consensus.

Exclusion Criteria

The studies that were excluded were based on the following criteria:

Studies that did not focus on children in a hospital or clinical environment.

Papers that solely focused on children with ASD, since this has been reviewed in the past [9,10].

Studies that did not have social robots as an intervention.

Studies that did not aim to reduce anxiety or distress.

Academic thesis papers and protocols were not included.

Data collection process

The data from the selected studies were extracted by two authors (BL and TA) independently. Information extracted includes the country in which the study was done, the study design, participants, the robot used, the purpose of the robot use, the intervention, data collection methods and the main outcomes. The Cochrane Collaboration's Risk of Bias Tool [11] was used to assess the risk of bias of each the studies, and a quality assessment was done using the Critical Appraisal Skills Programme (CASP) [12].

RESULTS

Identification and classification of studies

The identification and classification processes are summarised in Figure 1. The electronic databases yielded a total of 1598 titles. Duplicates were removed, leaving 1435 to be screened. Upon paper's title analysis against eligibility criteria, 1342 records were excluded. Cohen's kappa for agreement between the two reviewers (BL and TA) in this step was 0.75 (substantial agreement). Next, both reviewers screened the abstracts of the 93 remaining papers; Cohen's kappa for agreement in this step was 0.72 (substantial agreement). Of those, 58 papers were selected for full-text assessment, which led to 45 papers being excluded, due to not meeting the inclusion criteria. Thirteen papers remained for inclusion in the review and full-text evaluation. Both reviewers identified three papers that presented the same study in multiple journals which was resolved by selecting only the latest version for inclusion in the review. In total the review encompassed ten studies.

Study Characteristics

Four studies were conducted in the USA [18–20,23], two in Canada [15, 21] two in Italy [14,22], one in Iran [13], and another in the Netherlands [16]. Four of the studies were Randomised Controlled Trials (RCTs) [15,19,20-21], with the others classed as quasi-experimental [13], an observational study [14], a pilot study [23], and three explorative studies [16,18,22]. Risk of bias assessment was conducted for all studies, and the method of randomisation was examined. Two studies used a computer or central web-based programme to assign their participants into groups [15,20]. Two studies used block randomisation, where they divided their participants into blocks, depending on age [19,23]. Three studies reported that participants were randomly assigned but did not explain which randomisation method was used [13,14,21]. The remaining three did not report how allocations were made, and therefore, had a high risk of bias [16,18,22] (see Table 1).

Types of Robots

Four studies used the NAO robot, an autonomous humanoid robot that walks, talks, and has the functions to detect and produce sounds. NAO was personalised to perform a mix of tasks, such as performing gestures and interacting verbally and physically, alongside other activities depending on the objectives [13, 15, 20, 22] (see Table 2). Pepper and Sanbot ELF were both used in one study [14]. Pepper is a human-shaped autonomous humanoid robot that interacts with humans verbally and physically. Pepper expresses itself through changing eye colour and tone of voice. Sanbot Elf is a cartoonish built robot designed to be a health care companion. It expresses itself through body movement, different expressions in the display screen, and responds to touch.

Table 1: Characteristics of studies included in the systematic review

The first author *(Country)*	Study design and objective	Target population	Type of robot	Purpose of the Robot	Number and type of intervention	Data Collection Methods	Outcome and Key findings
The first author (Country)	**Study design and objective**	**Participants**	**Type of robot**	**Purpose of the Robot**	**Type of intervention**	**Data Collection Methods**	**Outcome and Key findings**
Alemi et al. (Iran) [13]	**Quasi-experimental** To explore the effect of utilising a social humanoid robot as a therapy-assistive tool in dealing with paediatric distress	11 children, aged 7 to 12, with cancer	**NAO Robot**	To help the kid get more acquainted with the hospital and its different sections, to establish positive images about the hospital	Randomly assigned to either: an intervention group (with social robot), or a control group (without a robot)	Self-report by children, with help from a psychologist and trained person if children needed support. The questionnaires were, MASC*, CDI* and CIA*. Taken before and after intervention	For the intervention group, anxiety level lowered, depression decreased, and anger levels came down. For the control group, anxiety level increased, depression had no change and anger level increased
Beraldo et al. (Italy) [14]	**Observational study** To use humanoid robots as a technique to manage negative feelings and promote positive moods in hospitalised children before sedation and analgesia	28 patients, aged 3 to 19, patients who stayed at Azienda Ospedaliera of Padua after a painful procedure	**Pepper robot and Sanbot Elf**	The purpose of the robots was to entertain the patients through interaction, in order to decrease negative feelings	Randomly assigned to either a group with Pepper or with the robot Sanbot Elf	Negative emotions via questionnaires designed by the team. They analysed twelve emotions, such as anxiety, fear, sadness and more	They found a significant decrease of the negative feelings and an increase of positive emotions in both groups. Overall the children enjoyed interacting with both robots, but Pepper appealed more to the older children
Beran et al. (Canada) [15]	**Randomised controlled trial** To study feasibility and collection effectiveness data on reducing child pain and distress during subcutaneous port accesses	57 children, age 4 to 9, who are receiving a flu vaccination	**NAO Robot**	Gives commands to blow and act as a supportive buddy for the child. A few times, the robot would say, "I will be here with you to help you feel brave"	Randomly assigned to either: the robot group, or the comparison condition group	Self-report by children, parents, nurse and researchers. They used FPS-R* video-taped and coded using the BAADS*	This study found that, when distractions are facilitated by a robotic device, children experience significantly less pain and distress compared to children who are given little or no distraction during a commonly performed medical procedure, vaccination

MASC – Multidimensional Anxiety Children Scale; CDI – Children's Depression Inventory; CIA – Children's Inventory of Anger; FPS-R – Face Pain Scale-Revised; BAADS - Behavioral Approach-Avoidance Distress Scale; CCLS – Certified Child Life Specialist; CFS – Children's Fear Scale; STAIC – State-Trait Anxiety Inventory for Children; STAI – State-trait Anxiety Inventory

The first author *(Country)*	Study design and objective	Target population	Type of robot	Purpose of the Robot	Number and type of intervention	Data Collection Methods	Outcome and Key findings
Okita (Canada)	**Randomised controlled trial**	18 children, aged 6 – 16, on the	**Paro the seal robot**	To act as a companion animal to reduce the pain and	Randomly assigned to either the condition alone	Children and parent completed two	For patients in the "together with parent" condition, there
Eind and Heerink (Netherlands) [16]	**Explorative study** To explore the potential of the baby dinosaur with children waiting to be seen at a consultation clinic	2 children 2 – 3 years old Child consultation clinic, visiting for a vaccination	**Pleo**	Pleo will distract children by performing behaviours that will request petting and nurturing	Each participant interacted with Pleo	Observations and interviews	Findings indicated that applications of Pleo are very useful in decreasing anxiety. Both children felt more relaxed during the interaction
Jeong et al. (USA) [18]	**Explorative study** To compare the effects of a social robot, a virtual character on screen and a plush teddy	4 children, aged 3 to 10, suffering from chronic and severe pain	**Huggable Robotic Bear**	Programmed to talk with a child about likes/dislikes, to sing nursery rhymes and play 'I Spy' games. Acts as a play buddy. With the intention to mitigate stress and anxiety	Assigned to either one of the three conditions, the teddy bear, the virtual Huggable Bear, or Huggable Robotic Bear	Qualitative analysis of child responses via videotaping	Both interventions modalities succeeded in entertaining participants; children who interacted with the robot appeared to be more physically and mentally motivated to engage with it
Jeong et al. (USA) [19]	**Randomised controlled trial** To study the impact of different embodiments on the socio-emotional engagement of child and co-present family members	54 children, aged 3 to 10, suffering from chronic and severe pain	**Huggable Robotic Bear**	Programmed to talk with a child about likes/dislikes, to sing nursery rhymes and play 'I Spy' games. Acts as a play buddy. Aimed to mitigate stress and anxiety	Block randomisation either to one of the three groups: the teddy bear, the virtual Huggable bear, or the Huggable Robotic Bear	Children were videotaped, and measurements of engagement were coded. CCLS* were given a questionnaire regarding their views and perspectives on social robots in paediatric care settings	They found evidence that children interacted longer and talked more when given a social robot than when given a virtual character or a plush toy. The result indicated a social robot might significantly impact a paediatric patient's socio-emotional engagement and wellbeing
Jibb et al. (USA) [20]	**Randomised controlled trial** To study feasibility and collection of effectiveness data	40 children, aged 4 to 9, actively undergoing cancer treatment	**NAO Robot**	Programmed to execute a series of vocalisations and movements that were consistent with evidence-based combined psychological interventions to migrate procedural pain	Children were randomised to either a cognitive-behavioural based group or an active control group. Both had a NAO robot as the intervention	Children self-reported using FPS-R*, CFS* and the observer used BAADS* to rate	This study demonstrated that it is feasible to test the clinical effectiveness of an interactive humanoid robot in treating children's pain and distressing during outpatient appointments.

MASC – Multidimensional Anxiety Children Scale; CDI – Children's Depression Inventory; CIA – Children's Inventory of Anger; FPS-R – Face Pain Scale-Revised; BAADS - Behavioral Approach-Avoidance Distress Scale; CCLS – Certified Child Life Specialist; CFS – Children's Fear Scale; STAIC – State-Trait Anxiety Inventory for Children; STAI – State-trait Anxiety Inventory

[21]	To explore if a robotic animal could reduce pain and emotional anxiety in patients and their parents	oncology unit and 18 parents		emotional anxiety the patient is experiencing	with a robot or together with parent and robot.	questionnaires: the Wong-Baker Faces Pain Rating Scale and the STAIC* for children and STAI* for the adults	was a significant decrease in negative emotional traits from patients and parents
Rossi et al. (Italy) [22]	**Explorative study** Trying to eradicate fear and pain sensation from the medical procedure	73 children 3 and 12 years Children receiving vaccination	**NAO**	To attract the children's attention by applying distraction strategies that are used in human-human interaction	Depending on the baseline test participant were assigned to one of two groups with a NAO (distraction with or without emotional cues) or a group without a social robot.	A questionnaire assessing anxiety and distress by parents. FPS-R * completed by the children, and the FLACC* by the nurse	The robot was able to supply actual relief to the children in a situation of discomfort. Robot distraction strategies were able to reduce fear and anxiety
Trost et al. (USA) [23]	**Pilot study** To test that empathic and distracting robots' interactions with children reduce pain and distress in children receiving an IV in a hospital setting	33 children, aged 4 to 14, children receiving a peripheral intravenous (IV) catheters	**IVEY**	To empathise with the patient and decrease pain and fear associated with peripheral IV placement	Block randomisation and participants were placed in either one of the three conditions: usual child life specialists (CCLS) and robot, usual CCLS and non-empathetic robot, or the usual distraction services provided by CCLS	Patient's parent (or legal guardian) completed the validated the Children's Behaviour Questionnaire (CBQ), and the Beck Anxiety Inventory and questions about previous experience with and pain/anxiety Children completed a baseline Medical Fears Scale and Wong-Baker Faces Pain Rating Scale, and the Children's Fear Scale	Children who were in condition 1 (empathy robot) had the lowest self-reported mean score on the FACES scale, which relates to the level of pain, immediately after interacting with the robot. There was no difference on the Fear scale. Overall the mean scores on all pain and distress measures were the lowest in the empathy group

MASC – Multidimensional Anxiety Children Scale; CDI – Children's Depression Inventory; CIA – Children's Inventory of Anger; FPS-R – Faces Pain Scale-Revised; FLACC – Face, Legs, Activity, Cry, Consolability scale; BAADS - Behavioral Approach-Avoidance Distress Scale; CCLS – Certified Child Life Specialist; CFS – Children's Fear Scale; STAIC – State-Trait Anxiety Inventory for Children; STAI – State-trait Anxiety Inventory

Alongside humanoid robots, there are animal-like robots, and one study used a baby dinosaur robot named Pleo. Pleo is a small robot that displays behaviours of a pet and encourages petting and nurturing. It responds to touch, enjoys being fed, and it is commercially available [16].

The Huggable Robotic Bear was used in two studies; it is an app-controlled robot that has been designed by the MIT Media Lab, for young patients at the Boston Children's Hospital. In both studies, it was operated by a Certified Child Life Specialist (CCLS) using a Wizard-of-Oz method to communicate [18-19]. The second animal-like robot used is a seal-like robot named Paro, which responds to touch and makes seal-like noises to capture users' attention. It has a tail that wiggles and eyes that blink [21]. In 2009 Paro was classed as a class II medical device in the United States. The last robot used is called Maki, a 3D printable robot, who's head, eyes and eyelids move using a six-servo motor. In the selected study, the robot was renamed to IVEY, and a mouth was added onto the robot to increase stimulation and interaction between the participants and the robot.

Table 2: Social Robots used in studies included in the Systematic Review

Robot	Picture	Description
a) NAO [13,15,17,20,22]	 © 2018 John Wiley and Sons	58cm tall Microphone and loudspeakers LED (Eyes, ears and feet) 21 degrees of freedom Communication and physical movement
b) Pepper [14]	 © 2020 Softbank Robotics	120 cm tall Microphone and loudspeakers LED (eyes, ears and shoulders) Human shaped Communication Sound localisation

c) Sanbot ELF [14]	 © 2020 Sanbot website	90 cm tall Microphone and loudspeakers LED (ears and arms) Cartoonish aspect Communication and people detection
d) Pleo [16]	 © 2012 Springer Science + Business Media	53 cm long, 15 cm wide, 20 cm high Dinosaur like robot Expresses emotions using body movement Makes sound to get attention
e) Huggable Robotic Bear [18-19]	 © 2017 IEEE	Teddy bear robot Express verbally through Wizard-of-Oz teleoperation Move arms through remote laptop device
f) Paro [21]	 © 2013 John Wiley and Sons	16 cm tall, 2.7 kg weight Seal like robot Tactile sensors Speech recognition Autonomous behaviour Reactive behaviour from tactile sensing
g) Maki (also known as IVEY) [23]	 © 2020 Margaret J Trost et al.	34.2 cm tall Light-emitting diode Used alongside a tablet device (Wizard-of-Oz operation) Webcam and microphone 6 degrees of freedom

Purpose and role of the Robots

In all included studies the purpose of these robots is to act as a companion and as a form of distraction to the child. In each study the robot acted in a variety of ways, through entertainment and play, to either reduce anxiety or distress. One study renamed the NAO robot to Nima, a Persian name, to appear more acceptable and friendly to the target population [13]. Another study tailored their robot depending on the participant's anxiety levels at the start. If the participant had low levels of anxiety, the robot would perform happy animations with green LED eyes, but if the anxiety levels were high, the robot would have blue LED eyes and act upset, shaking its head and having a closed pose [22]. Pepper and Sanbot Elf were both used in the same study to entertain the participants with gestures, animations, voices and displaying screens to interact. Pepper used its arms and hands more, whereas Sanbot Elf used its face display to express emotions and interact [14]. The Huggable Robotic Bear had a CCLS playing the role of tele-operator. They talked to the participants about their likes/dislike, sang nursery rhymes and played games [18-19].

Animal-like robots, like Pleo and Paro, are programmed to act as pets, and therefore do not speak but act out gestures and make animal noises. The study that used Pleo had participants care for it in order for their attention to be diverted and their anxiety levels to decrease [16]. This was similar to the study that used Paro. Paro was brought in to act as a companion to reduce participant's anxiety levels. It has multiple sensors, a coat of fur and autonomous behaviours that invite individuals to stroke and respond to it [21].

Outcome Measures

Anxiety

Four studies evaluated the levels of anxiety before and after the intervention and clearly reported a reduction in anxiety levels when using a series of robot interventions [13,14,21,22]. Alemi et al. used the Multidimensional Anxiety Scale (MASC) to measure anxiety levels and found a 15% reduction in anxiety levels when participants interacted with the NAO robot [13]. Beraldo et al. explored the use of two different robots (Pepper and Sanbot Elf) to reduce anxiety. Twelve feelings were measured by providing participants with a questionnaire before, during and after their interaction with each robot. They found a significant reduction in anxiety levels for participants using either robot: anxiety levels decreased by 50% with the Pepper robot and 44.44% with the Sanbot Elf robot [14]. Okita adopted the State-trait Anxiety Inventory for Children (STAIC) to measure anxiety after interaction with Paro. There was a significant decrease in emotional anxiety when the participant had a parent in the room, along with Paro [21]. In the study by Rossi et al., participants' parents filled in a questionnaire regarding their child's anxiety levels before and after their intervention with Nao. Parents recognised a decrease in anxiety levels among their children, especially children who had high levels of anxiety at the start [22]. These studies showcase the positive effect of robot intervention and its capability of reducing anxiety in a hospital or clinical settings, as well as the different approaches to measuring anxiety.

Distress

Three studies examined the level of distress among their participants, with two using the Behavioural Approach-Avoidance Distress Scale (BAADS) and the third using Observational Scales of Behavioural Distress-Revised (OSBD-R) [15, 20, 23]. Beran et al. used the NAO robot as a means of distraction whilst the child received an injection. NAO would instruct children to blow and purposely divert their attention to fun topics. The BAADS showed that children experienced less distress when they were intentionally distracted [15]. Jibb et al. adopted a similar approach using the NAO robot to distract a child while receiving an injection. Their two-armed study incorporated the social robot in both arms. The first arm was an active distraction comparator where the NAO robot conducted standard movements. The second arm was a cognitive-behavioural arm with the robot programmed to execute a series of actions based on evidence-based psychological interventions for reducing stress. Overall their results demonstrated a reduction in distress in both arms, and there was a positive reaction from the parents, children and nurses towards the robot [20]. In the third study, IVEY was used to distract children during an IV-line placement. Trost et al. found children enjoyed the robot that showed empathy a lot more than the IVEY that played dress up, and results from the OSBD-R scale displayed a lack of distress when children interacted with IVEY [23]. This suggests that having a social robot in a hospital room, despite the action and the verbalisation employed, can mitigate distress.

Discussion

This systematic review aimed to gather evidence on the effectiveness of social robots in reducing anxiety or distress in children within a hospital or clinical environment. The review identified ten studies that met the specified inclusion criteria. Despite finding a large number of titles, studies that did not take place in a hospital or clinical environment were removed, which lead to a small number being included.

Children receiving a vaccination or IV-line placement were the most common target population [15,16,22,23]. The NAO robot was the most frequently used robot in the selected studies. This could be due to NAO's autonomous abilities and the capability to personalise it. Programming features of the social robots were used in each study to adapt the robots to their target population needs, offering a multifactorial sensory experience. The studies presented changes to anxiety and distress in children with associated positive responses from parents and hospital staff, thus highlighting the opportunities for using social robots in a hospital environment to reduce anxiety levels in children.

The use of robots to reduce anxiety and disstress in children in a hospital setting is clearly in an early stage of development. The fact that studies were found in five different countries, using seven different robots with very different behaviours, however, demonstrates that there is serious interest in the research community. It is impossible to draw strong conclusions from the available evidence, but most studies show positive trends, indicating that social robots may be effective tools to reduce anxiety and disstress. What robot behaviours and other characteristics are the most effective or promising is a question that requires further research. More empirical and theoretical underpinning of robot interventions is needed to guide such research.

The studies included in this review provide a relatively low quality of evidence. Studies were generally small scale and taking place at a single site. Very different outcome measures were used and the study designs mostly had an explorative or pilot character. Increasing the quality of evidence is also an important focus area for future research.

This is the first systematic review that investigates the effectiveness of social robots on reducing anxiety or distress in children in a hospital or clinical environment and acts as a catalyst for the development of future studies in this field.

Conclusion

This review highlights the potential impact that social robots have on reducing anxiety or distress in children when attending hospital. Further research providing high-quality evidence is required within this field to gain further understanding of how social robots can add value to health intervention in children.

Author Considerations

BL created the systematic review protocol; conducted the data extraction, preparation, analysis and wrote the initial manuscript. TA assisted with the systematic review extraction, preparation, and analysis. PD, CS and LdW advised on the protocol, the data extraction, preparation, analysis, and reviewed the manuscript drafts. All authors contributed to the draft and approved the final manuscript.

Conflict of Interest

None declared

Acknowledgements

This research was supported by the NIHR Children and Young People MedTech Co-operative. The views expressed are those of the authors and do not necessarily reflect those of the NIHR, NHS of Department of Health and Social Care.

What is already known on this topic?

- Social robots have a positive impact on supporting an ageing population with dementia
- Socially interactive robots have proven to be a useful tool when conducting therapy in children with Autism

What does this study add?

- Compiles published studies on the use of social robots in clinical and hospital environments, showing their potential to reduce anxiety and distress in children undergoing painful and distressing procedures
- A variety of social robots exists with different functionalities
- Further and more in-depth research is required to understand the role of social robots in paediatric healthcare

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