Co-design of a Social Robot for Distraction in the Paediatric Emergency Department

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ABSTRACT

We are developing a social robot to help children cope with painful and distressing medical procedures in the hospital emergency department. This is a domain where a range of interventions have proven effective at reducing pain and distress, including social robots; however, until now, the robots have been designed with limited stakeholder involvement and have shown limited autonomy. For our system, we have defined and validated the necessary robot behaviour together with children, parents/caregivers, and healthcare professionals, taking into account the ethical and social implications of robotics and AI in the paediatric healthcare context. The result of the co-design process has been captured in a flowchart, which has been converted into a set of concrete design guidelines for the AI-based autonomous robot system.

CCS CONCEPTS

• Social and professional topics → Children; **• Human-centered computing → Participatory design**; **• Computer systems organization → Robotics**.

KEYWORDS

Socially assistive robots, Child-robot interaction, Co-design

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1 INTRODUCTION

Children regularly experience pain and distress in clinical settings, which can produce negative effects in both the short term (e.g., fear, distress, inability to perform procedures) and the long term (e.g., needle phobia, anxiety) [29]. A range of techniques have been shown to help manage such situations, delivered through a variety of means [7], including several recent studies that have shown that social robots can also be used to manage child pain and distress [1, 32]. This clinical context represents a highly dynamic, complex, and challenging deployment context for a social robot, requiring a carefully designed scenario involving the healthcare providers (HCPs), the patient, parents/caregivers, as well as the robot.

We are developing an AI-enhanced social robot [12] to meet the needs and desires of HCP and other stakeholders to deliver distraction therapies in the paediatric emergency department. The scenario for this robot has been developed through an iterative, ethically informed co-design process involving children, parents/caregivers, and HCPs together with members of the technical and clinical teams. The result of this co-design study is a detailed flow diagram that meets all requirements of the HRI intervention, including the role of the robot, the level of autonomy, the goals of the intervention, social cues, and social stimuli, as well as a translation of the flow diagram into concrete technical requirements. The scenario is being implemented through a set of technical components, including a vision system designed specifically to work in the target deployment location; an automated planning system that dynamically selects spoken, non-verbal, and task-based actions to be taken by the system; as well as a control panel that supports the sensing system and the action selections to ensure that the robot provides the necessary level of robustness in the real-world clinical context.

2 RELATED WORK

Socially Assistive Robotics (SAR) [11] provides a unique opportunity to use human-like social communication to support embodied interaction with the goal of providing concrete assistance to the user.

This type of HRI is considered potentially useful to create a shared relationship by using characteristics such as expressiveness, personality, dialogue, empathy, and adaptation skills. Numerous SAR studies have reported benefits in various domains, such as social, behavioural, physical, and cognitive well-being in different populations [3, 14], in applications such as such as robot-assisted education [17], autism diagnosis and therapy [13, 22, 26], and Alzheimer therapy and elder care [30, 33].

Paediatric healthcare is an increasingly active deployment context for SAR [9], particularly with the goal of reducing patient pain and/or distress [21, 32]. Several studies have compared robot-delivered distraction to standard care in the context of needle-based procedures, with generally positive effects. Ali et al. [1] found that the addition of a robot reduced distress and, to a lesser extent, pain compared to standard care in the context of needle-based procedures in an emergency department. In a similar study, Smakman et al. [28] found that a robot reduced pre-procedure pain and stress for a subset of the children in their study, while Rossi et al. [25] also found a similar result for children undergoing vaccinations.

Rather than directly comparing outcomes with and without the robot, other studies have examined the impact of different robot behaviours. For example, Jibb et al. [16] compared user responses to a robot that used Cognitive Behavioural Therapy to one that used distraction: the children did not experience different levels of pain, but did feel less stress in the distraction condition. In addition to measuring the impact of the robot, Rossi et al. [25] found that adapting the robot's behaviour to the child's perceived anxiety level had a positive impact on distraction. Trost et al. [31] compared two versions of their robot, one that used empathic SAR and one that used distractive SAR: while they reported no significant difference on the mean scores of pain and distress, they do suggest that empathic SAR could be clinically more effective since children were more willing to receive the medical procedure in this condition.

While most of the systems outlined above are designed to alleviate short-term pain and distress during a single procedure, stress reduction interventions involving social robots have also been explored in more long-term clinical contexts. For example, Ligthart et al. [18, 19] have developed a storytelling robot to support children in hospitals for a long term in an oncology ward. Although the robot has not yet been tested in a clinical context, the storytelling intervention has been shown to be engaging in a series of longitudinal studies involving primary-school children.

Design practices such as co-design and user-centred design are well established in the HRI community [8]. These techniques balance the decision-making power between researchers and stakeholders, resulting in appropriate technology that also meets the needs of the target users [24]. These techniques are especially important when we want to approach real-world practices in complex scenarios such as the one considered here. All of this work takes place in the context of an increasing push in the HRI community to establish best practice standards to strengthen the evidence supporting the advantages of social robotics in different domains [34].

In summary, the emerging consensus from the increasing number of studies in this area is that a social robot has the clear potential to reduce patient pain and distress through distraction. A significant limitation in most of these studies is that the autonomy has been extremely restricted: most have used fully scripted behaviour or a Wizardo-of-Oz approach. While the storytelling system developed by Ligthart et al. is designed to be autonomous, it is designed for a long-term, relationship-building context rather than the emergency department, and has also not yet been tested in a clinical setting. Indeed, limited autonomy was identified as one of the limiting factors in a recent survey of social robotics in the clinical context, [32], and is one that we aim to explicitly address in this work by analysing and collecting, through co-design, properties of trustworthy and ethical HRI that should incorporate AI-based adaptive action selection into the execution of the robot's behaviour.

3 CO-DESIGN

We target the procedure of intravenous insertion (IVI) in the paediatric emergency department: inserting an intravenous tube into a patient's vein so that infusions can be delivered directly into the patient's bloodstream. This is one of the most commonly performed procedures on children seeking medical care, and also one that can be painful and distressing for the child and for their parents or caregivers, so a standard procedure in a paediatric setting is to provide distraction before and during the procedure to alleviate pain and distress. To develop the appropriate general roles and specific behaviour for a social robot in this context, we have carried out a series of co-design studies, including HCPs, parents/caregivers, and children, together with the clinical and technical team members.

3.1 Ethical considerations

Integrating novel technology into healthcare settings must be guided by a moral commitment to patients' interests, which requires considering ethical issues inherent in this technology. The use of SARs in healthcare uniquely touches on core values in medicine such as humanism, therapeutic alliance, and interpersonal connection. Additionally, the use of AI methodologies for SARs requires additional ethical inquiry given AI's particular set of ethical challenges. From a literature review into ethics-related questions on the use of SARs in paediatric pain management, we learned that issues such as efficacy and beneficial conditions need to be considered from the start [2, 4–6, 16, 27]. These factors relate specifically to the perceived benefits of the SAR in a complex environment against the notion of *efficacy*, which is typically operationalised into measurable data related to features like trust, safety or likeability. Perceived benefits for the stakeholders are a different dimension calling for different measures and approaches.

Notions of bias and equity must also be considered, even at the early stages of SAR design. For example, there are documented problems related to machine-based prioritisation of certain accents, skin tones and bodies, which could lead to children feeling stigmatised or 'othered' [10, 15, 23]. Notions of privacy often go hand in hand of trust, which is a central feature in HRI and SAR design, although note that children tend to have very minimal understandings of privacy compared to their parents/caretakers, and HCP needs for privacy differ as they would be with the SAR for a longer time.

3.2 Co-design process

To model the IVI domain using stakeholders' inputs, a two-cycle co-design study was carried out, taking the above ethical considerations into account both in the design of the questions as well as the guidance of the overall discussions. In the first co-design cycle, we carried out a qualitative assessment of the needs of children, parents/caregivers, and HCPs in two paediatric emergency departments (EDs). Semi-structured virtual individual and focus group interviews were conducted with 11 health professionals (5 nurses, 4 physicians, 2 child life specialists), who were predominantly female and had different years of experience in paediatric emergency care (1-21 years). In parallel, semi-structured virtual individual and focus groups were completed with 19 children and 11 parents/caregivers from the same two paediatric EDs. In the second co-design cycle, workshops were held between the technical team and clinical staff to analyse and interpret the findings of the focus groups and to turn them into technical HRI requirements.

3.3 Co-design cycle 1 findings

The findings from the first co-design cycle can be divided into three main categories: predicted benefits based on procedure phases, potential robot behaviours, and risks and constraints. In this section, we outline the findings in each category; Section 4 shows how these findings were converted into technical system constraints.

3.3.1 Procedure phases. The HCPs classified the predicted benefits of the robot-based intervention based on the three main phases of the IVI procedure. **Before** a pain-related procedure, HCPs stated that the ideal aim of the robot intervention is to provide emotional support and promote coping strategies. **During** a procedure, participants identified a change in the primary aim, i.e. the robot could behave as a distraction based on the child's anxiety and engagement level and adapt to the child's age-related preferences. **Following** the procedure, HCPs emphasised the importance of framing the medical procedure experience as positive for the child through positive reinforcement, rewards, and debriefing conversation by having the robot remain to support the child. Children and caregivers also highlighted the role of the robot-based intervention based on the three main phases. Caregivers emphasised the role of the robot during IVI procedure where it would cater distraction activities based on the child's needs and preferences. Children highlighted the importance of the robot before and after the IVI procedure. They suggested the robot build rapport with them prior to the painful procedure by engaging in conversation and playing games, then focusing on positive reinforcement and de-briefing following the completion of the procedure.

3.3.2 Robot behaviours. HCPs felt that the proposed SAR should be equipped with a diverse range of actions to suit children's needs, including encouraging dialogue, positive reinforcement phrases, humour, and cognitive behavioural strategies (e.g., breathing techniques, guided imagery, meditation). HCPs also felt that the proposed SAR should allow the user (i.e., child) to choose from a selection of options for distraction. In addition, the proposed SAR should also have the ability to estimate social signals and generate responsive social stimuli accordingly as children exhibit affective states (verbally, physically, and emotionally). Caregivers advocated for tailored language and distraction activities to match the child's developmental level and recommended the robot have the ability to adapt to the child's needs and respond in situationally appropriate ways. Children suggested physical enhancements for the robot including the colour of the robot, the voice of the robot, and preferred to robot remain in a standing position instead of sitting.

3.3.3 Risks and constraints. HCP highlighted two main constraints on the system reliability. First, it must never speak over an HCP while information is being delivered; in other words, the system must maintain proper turn-taking between HCP and the robot. Second, the proposed SAR must not act inappropriately. This includes both emotional insensitivity (e.g., telling a joke when a child is crying), as well as situations where there is a lack of awareness of clinical deterioration (e.g., seizures, loss of consciousness). Caregivers were mainly concerned about the ability of the robot to respond in socially complex setting (such as the ED) and protecting their child's privacy with regards to the robot videotaping and photographing the interaction. Children highlighted the technical failure of the SAR and its implications, such as losing control, as their main concern.

4 FROM CO-DESIGN TO SYSTEM DESIGN

In the second co-design cycle, two workshops were held where the team's clinical and technical specialists, together with four additional HCPs (3 nurses and 1 child life specialist), discussed the previous focus groups' findings from a technical perspective. As a first step, the entire procedure was divided into six steps as suggested by most of the HCPs. Subsequently, in each stage, an objective related to psychological exercises to reduce distress was assigned. Then the whole group defined the role of the robot at each stage, the plausible activities for each role, and their relationship with the child's emotional state. Likewise, the total time of each stage and its distribution between the HCP and the Robot was established. The result of the discussion is summarised in Table 1. In addition, decision and bifurcation points were identified to help refine the system design into a concrete scenario to be implemented in the AI system. For example, to execute the child's preference, increase cognitive exercises and engagement or rethink alternate pathways to end the intervention. The result of the scenario modelling process was concluded with a final, detailed version of the flow chart as shown in Figures 1 and 2.

The technical HRI requirements and scenario flowchart have been used as the basis to implement the initial version of the robot system. The system includes components for vision-based social signal processing, interaction management, action planning, and output generation. The planning domain is based on the information from the detailed flowchart, and the system chooses its actions based on a combination of properties that may be directly sensed, provided through a GUI, or directly modelled as part of the world state. Full technical details of the system are provided in [20].

Robustness and accountability are crucial for appropriate interaction in this real-world scenario, as identified by all co-design stakeholders. We have therefore included a GUI-based mechanism that allows HCPs to take control when necessary while maintaining accountability for the procedure. The GUI can be used by an operator to monitor and, if necessary, update the system state to ensure system behaviour is appropriate. Note that the GUI is not used to select actions; rather, it is used to supplement the sensors to ensure that the system is making decisions based on the best

Table 1: Co-design findings translated into technical HRI requirements

	Stage	Intro	Preprocedure	Site Check	Procedure	Debrief	End
HCP Requirements	**Psychological exercises**	Positive expectation	Coping exercises	Normalize experience	Distract	Positive reinforcement	Form positive long-term memories
	Stage Goal	Engage the Child	Manage anxiety keeping engagement	Keep Engagement	Divert	Re-engaged the Child	Inform/Educate
	Robot Role	Robot Peer	Robot Tutor	Robot mediator	Robot Assistant	Robot Peer	Robot Interviewer
	Timing	HCP: 2-3 min R:2-3 min	HCP: 10-15min R:5-10min	R:2-3min	R:2-8min	HCP: 2-3 min R:2-3 min	HCP: 2-3 min R:2-3 min
Technical Requirements	**Planning Goal**	Establish role Set up positive expectation	Manage anxiety Divert Make plan for procedure	Re-enforce strategy Calm Keep patient still	Implement diversion plan Respond to delays	Congratulate Reward	Recount key points Finish interaction
	Metrics	Attention Level	Attention and Anxiety Level	Attention and Anxiety Level	Anxiety Level	Attention Level	Attention Level
	Data Sources	Gaze Direction	Gaze Direction Head/Facial features User Input/queries Child choice	Gaze Direction Head/Facial features User Input/queries Child choice	Head/Facial features User Input/Queries	Gaze Direction	Gaze Direction

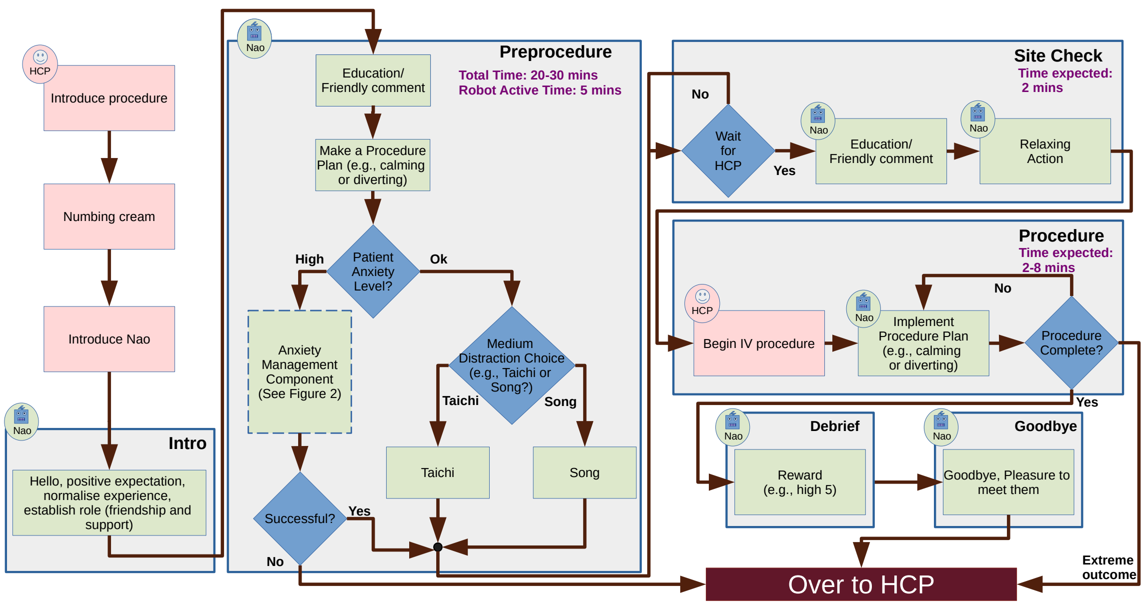

Figure 1: Flowchart illustrating a possible scenario incorporating HCP and Social Robot

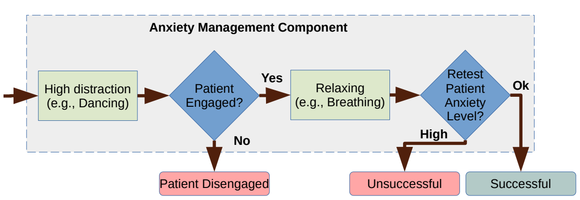

Figure 2: Anxiety management component

possible estimate of the world state. The design of the system also provides a clear and direct way for the operator to start and stop the robot whenever necessary through the GUI.

5 CONCLUSIONS & FUTURE WORK

We are developing a social robot that can collaborate with a HCP to alleviate patient pain and distress during IV insertion in the emergency department. This scenario combines a dynamic and uncertain environment, complex social interaction that is difficult to specify in advance, and a real-world deployment location where robust and appropriate behaviour is crucial. To establish the details of the robot's role and behaviour, we have carried out an ethically-informed co-design with a range of stakeholders, generated guidelines based on the findings of that process, and implemented a prototype system based on those guidelines. The prototype is currently undergoing usability testing as we continue to develop the system components, interaction model, and appropriate social signal prediction models. The final system will be evaluated in a two-site randomised clinical trial in paediatric emergency departments.

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REFERENCES

[1] S Ali, R Manaloor, K Ma, M Sivakumar, B Vandermeer, T Beran, S Scott, T Graham, S Curtis, H Jou, et al. 2019. LO63: humanoid robot-based distraction to reduce pain and distress during venipuncture in the pediatric emergency department: a randomized controlled trial. *Canadian Journal of Emergency Medicine* 21, S1 (2019), S30–S31.

[2] Samina Ali, Mithra Sivakumar, Tanya Beran, Shannon D Scott, Ben Vandermeer, Sarah Curtis, Hsing Jou, and Lisa Hartling. 2018. Study protocol for a randomised controlled trial of humanoid robot-based distraction for venipuncture pain in children. *BMJ Open* 8 (12 2018), e023366. Issue 12. https://doi.org/10.1136/bmjopen-2018-023366

[3] Aida Amirova, Nazerke Rakhymbayeva, Elmira Yadollahi, Anara Sandygulova, and Wafa Johal. 2021. 10 Years of Human-NAO Interaction Research: A Scoping Review. *Frontiers in Robotics and AI* 8 (11 2021). https://doi.org/10.3389/frobt.2021.744526

[4] Christoph Bartneck, Dana Kulić, Elizabeth Croft, and Susana Zoghbi. 2009. Measurement Instruments for the Anthropomorphism, Animacy, Likeability, Perceived Intelligence, and Perceived Safety of Robots. *International Journal of Social Robotics* 1 (1 2009), 71–81. Issue 1. https://doi.org/10.1007/s12369-008-0001-3

[5] Tanya N. Beran, Alex Ramirez-Serrano, Otto G. Vanderkooi, and Susan Kuhn. 2013. Reducing children's pain and distress towards flu vaccinations: A novel and effective application of humanoid robotics. *Vaccine* 31 (6 2013), 2772–2777. Issue 25. https://doi.org/10.1016/j.vaccine.2013.03.056

[6] Colleen M Carpinella, Alisa B Wyman, Michael A Perez, and Steven J Stroessner. 2017. The Robotic Social Attributes Scale (RoSAS): Development and Validation. *2017 12th ACM/IEEE International Conference on Human-Robot Interaction (HRI*, 254–262.

[7] Christine T Chambers, Anna Taddio, Lindsay S Uman, C Meghan McMurtry, and HELPinKIDS Team. 2009. Psychological interventions for reducing pain and distress during routine childhood immunizations: a systematic review. *Clinical therapeutics* 31 (2009), S77–S103.

[8] Vicky Charisi, Daniel Davison, Dennis Reidsma, and Vanessa Evers. 2016. Evaluation methods for user-centered child-robot interaction. *2016 25th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*, 545–550. https://doi.org/10.1109/ROMAN.2016.7745171

[9] Julia Dawe, Craig Sutherland, Alex Barco, and Elizabeth Broadbent. 2019. Can social robots help children in healthcare contexts? A scoping review. *BMJ Paediatrics Open* 3, 1 (2019), e000371. https://doi.org/10.1136/bmjpo-2018-000371

[10] Rashmi Dyal-Chand. 2021. *Autocorrecting for Whiteness*. Technical Report. Northeastern Public Law and Theory Faculty Research Papers Series. https://papers.ssrn.com/abstract=3800463

[11] D. Feil-Seifer and M.J. Mataric. 2005. Socially Assistive Robotics. In *9th International Conference on Rehabilitation Robotics, 2005. ICORR 2005.* IEEE. https://doi.org/10.1109/icorr.2005.1501143

[12] Mary Ellen Foster, Samina Ali, Sasha Litwin, Jennifer Parker, Ronald P. A. Petrick, David Harris Smith, Jennifer Stinson, and Frauke Zeller. 2020. Using AI-Enhanced Social Robots to Improve Children's Healthcare Experiences. In *Social Robotics*. 542–553. https://doi.org/10.1007/978-3-030-62056-1_45

[13] Pablo Gomez Esteban, Paul E Baxter, Tony Belpaeme, Erik Billing, Haibin Cai, Hoang-Long Cao, Mark Coeckelbergh, Cristina Costescu, Daniel David, Albert De Beir, Yinfeng Fang, Zhaojie Ju, James Kennedy, et al. 2017. How to Build a Supervised Autonomous System for Robot-Enhanced Therapy for Children with Autism Spectrum Disorder. *Paladyn Journal of Behavioral Robotics* 8, 1 (2017), 18–38. https://doi.org/10.1515/pjbr-2017-0002

[14] Anna Henschel, Guy Laban, and Emily S. Cross. 2021. What Makes a Robot Social? A Review of Social Robots from Science Fiction to a Home or Hospital Near You. *Current Robotics Reports* 2 (3 2021), 9–19. Issue 1. https://doi.org/10.1007/s43154-020-00035-0

[15] Ayanna Howard, Cha Zhang, and Eric Horvitz. 2017. Addressing bias in machine learning algorithms: A pilot study on emotion recognition for intelligent systems. *2017 IEEE Workshop on Advanced Robotics and its Social Impacts (ARSO)*, 1–7. https://doi.org/10.1109/ARSO.2017.8025197

[16] Lindsay A. Jibb, Kathryn A. Birnie, Paul C. Nathan, Tanya N. Beran, Vanessa Hum, J. Charles Victor, and Jennifer N. Stinson. 2018. Using the MEDiPORT humanoid robot to reduce procedural pain and distress in children with cancer: A pilot randomized controlled trial. *Pediatric Blood & Cancer* 65, 9 (2018), e27242. https://doi.org/10.1002/pbc.27242

[17] Wafa Johal. 2020. Research Trends in Social Robots for Learning. *Current Robotics Reports* 1 (9 2020), 75–83. Issue 3. https://doi.org/10.1007/s43154-020-00008-3

[18] Mike Ligthart, Koen Hindriks, and Mark A. Neerincx. 2018. Reducing Stress by Bonding with a Social Robot: Towards Autonomous Long-Term Child-Robot Interaction. In *Companion of the 2018 ACM/IEEE International Conference on Human-Robot Interaction* (Chicago, IL, USA) *(HRI '18)*. 305–306. https://doi.org/10.1145/3173386.3176904

[19] Mike E.U. Ligthart, Mark A. Neerincx, and Koen V. Hindriks. 2022. Memory-Based Personalization for Fostering a Long-Term Child-Robot Relationship. In *Proceedings of the 2022 ACM/IEEE International Conference on Human-Robot Interaction (HRI '22)*. 80–89. https://doi.org/10.5555/3523760.3523775

[20] Alan Lindsay, Andrés A. Ramírez-Duque, Ronald P. A. Petrick, and Mary Ellen Foster. 2022. A Socially Assistive Robot using Automated Planning in a Paediatric Clinical Setting. In *Proceedings of the AAAI Fall Symposium on Artificial Intelligence for Human-Robot Interaction (AI-HRI)*. https://doi.org/10.48550/arXiv.2210.09753

[21] Clara J Moerman, Loek van der Heide, and Marcel Heerink. 2018. Social robots to support children's well-being under medical treatment: A systematic state-of-the-art review. *Journal of Child Health Care* 23 (Nov 2018), 596–612. https://doi.org/10.1177/1367493518803031

[22] Paola Pennisi, Alessandro Tonacci, Gennaro Tartarisco, Lucia Billeci, Liliana Ruta, Sebastiano Gangemi, and Giovanni Pioggia. 2016. Autism and social robotics: A systematic review. *Autism Research* 9, 2 (2016), 165–183. https://doi.org/10.1002/aur.1527

[23] Inioluwa Deborah Raji, Timnit Gebru, Margaret Mitchell, Joy Buolamwini, Joonseok Lee, and Emily Denton. 2020. Saving Face. *Proceedings of the AAAI/ACM Conference on AI, Ethics, and Society*, 145–151. https://doi.org/10.1145/3375627.3375820

[24] Andrés A. Ramírez-Duque, Luis F. Aycardi, Adriana Villa, Marcela Munera, Teodiano Bastos, Tony Belpaeme, Anselmo Frizera-Neto, and Carlos A. Cifuentes. 2020. Collaborative and Inclusive Process with the Autism Community: A Case Study in Colombia About Social Robot Design. *International Journal of Social Robotics* (2020). https://doi.org/10.1007/s12369-020-00627-y

[25] Silvia Rossi, Marwa Larafa, and Martina Ruocco. 2020. Emotional and Behavioural Distraction by a Social Robot for Children Anxiety Reduction During Vaccination. *International Journal of Social Robotics* 12, 3 (Jan 2020), 765–777. https://doi.org/10.1007/s12369-019-00616-w

[26] Brian Scassellati, Laura Boccanfuso, Chien-Ming Huang, Marilena Mademtzi, Meiying Qin, Nicole Salomons, Pamela Ventola, and Frederick Shic. 2018. Improving social skills in children with ASD using a long-term, in-home social robot. *Science Robotics* 3, 21 (2018), eaat7544.

[27] Amit G Singal, Peter D R Higgins, and Akbar K Waljee. 2014. A Primer on Effectiveness and Efficacy Trials. *Clinical and Translational Gastroenterology* 5 (1 2014), e45. Issue 1. https://doi.org/10.1038/ctg.2013.13

[28] Matthijs H. J. Smakman, Koen Smit, Lotte Buser, Tom Monshouwer, Nigel van Putten, Thymen Trip, Coen Schoof, Daniel F. Preciado, Elly A. Konijn, Esther M. van der Roest, and Wouter M. Tiel Groenestege. 2021. Mitigating Children's Pain and Anxiety during Blood Draw Using Social Robots. *Electronics* 10, 10 (May 2021), 1211. https://doi.org/10.3390/electronics10101211

[29] Bonnie J Stevens, Laura K Abbott, Janet Yamada, Denise Harrison, Jennifer Stinson, Anna Taddio, Melanie Barwick, Margot Latimer, Shannon D Scott, Judith Rashotte, et al. 2011. Epidemiology and management of painful procedures in children in Canadian hospitals. *Cmaj* 183, 7 (2011), E403–E410.

[30] Adriana Tapus, Cristian Tapus, and Maja J Mataric. 2009. The use of socially assistive robots in the design of intelligent cognitive therapies for people with dementia. In *2009 IEEE International Conference on Rehabilitation Robotics*. IEEE. https://doi.org/10.1109/icorr.2009.5209501

[31] Margaret J Trost, Grace Chrysilla, Jeffrey I Gold, and Maja Matarić. 2020. Socially-Assistive Robots Using Empathy to Reduce Pain and Distress during Peripheral IV Placement in Children. *Pain research & management* (2020), 1–7.

[32] Margaret J Trost, Adam R Ford, Lynn Kysh, Jeffrey I Gold, and Maja Matarić. 2019. Socially assistive robots for helping pediatric distress and pain: a review of current evidence and recommendations for future research and practice. *The Clinical journal of pain* 35, 5 (2019), 451.

[33] K. Wada, T. Shibata, T. Saito, and K. Tanie. 2004. Effects of robot-assisted activity for elderly people and nurses at a day service center. *Proc. IEEE* 92, 11 (2004), 1780–1788. https://doi.org/10.1109/jproc.2004.835378

[34] Megan Zimmerman, Shelly Bagchi, Jeremy Marvel, and Vinh Nguyen. 2022. An Analysis of Metrics and Methods in Research from Human-Robot Interaction Conferences, 2015-2021. In *Proceedings of the 2022 ACM/IEEE International Conference on Human-Robot Interaction (HRI '22)*. 644–648.