

# Use of a humanoid robot to reduce distress in autistic children undergoing paediatric cardiology visits: a pilot study

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## ABSTRACT

Children with autism spectrum disorder (ASD) often experience distress during medical procedures due to sensory sensitivities and communication challenges. We conducted a pilot study assessing whether a humanoid robot (NAO) could reduce distress during cardiology assessments. 24 children with ASD were evaluated during NAO-assisted visits. Distress levels were significantly lower compared with previous routine non-robot-assisted visits involving the same patients. Reduced motion artefacts and shorter diagnostic procedures were also observed. These results support the feasibility and potential benefit of integrating social robots into outpatient paediatric settings for patients with autism, paving the way for more inclusive and neurosensitive healthcare experiences.

Children with autism spectrum disorder (ASD) present significant challenges during clinical assessments due to communication difficulties, sensory sensitivities and rigid behavioural preferences. Paediatric cardiology procedures, which require cooperation and stillness, can be especially demanding for this patient population. Anxiety, irritability and refusal to cooperate may lead to prolonged assessments, reduced diagnostic quality and elevated caregiver distress. Recent literature suggests that socially assistive robots (SARs), such as NAO, may reduce distress and improve medical compliance in children with ASD due to their predictable, non-threatening interaction style and ability to engage attention without overwhelming stimuli.<sup>1–3</sup>

We conducted a pilot study to evaluate whether integrating NAO, a humanoid robot, into cardiology visits could improve tolerance and reduce stress in children with ASD. 24 patients (mean age 9.4±3.3 years; 87.5% male) with confirmed ASD diagnoses underwent outpatient cardiological evaluation at our tertiary paediatric centre. Importantly, the comparison between NAO-assisted

and routine visits was performed within the same group of patients, with distress during previous non-robot-assisted visits assessed retrospectively.

NAO was programmed to perform simple interactive sequences, including greetings, songs, movement games and procedural explanations using child-friendly language. The robot also provided positive reinforcement and encouraged participation during diagnostic steps.

Distress was assessed retrospectively for previous routine visits and again after the current NAO-assisted session using a validated 5-point Smiley Scale designed for paediatric self-assessment of discomfort and emotional state.<sup>4</sup> Procedural times for ECG, echocardiogram and total visit duration were also recorded. Data were analysed using descriptive statistics, Pearson correlation and Cohen's kappa for agreement between distress scores.

NAO-assisted visits were associated with a notable reduction in distress: 70.8% of children exhibited no observable distress compared with 25% in prior routine visits. Severe or very severe distress was reported in only 4.2% of the NAO-assisted group, compared with 20.8% in conventional visits. Moderate agreement was observed between distress scales (weighted kappa=0.26,  $p=0.0028$ ), with lower average distress during robotic visits (Table 1). According to caregiver feedback, NAO helped redirect children's attention, reduced resistance to physical contact and added a playful and predictable structure to the visit.

Procedural times were also reduced (ECG: mean 2.1±0.9min; echocardiogram: 5.6±1.8min), likely reflecting better cooperation (table 2). NAO interactions helped guide the child through the visit in a calm and



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**Table 1** Distress levels during visits

Distress level	Routine visit (%)	NAO visit (%)
No distress	25	70.8
Mild distress	20.8	16.7
Moderate distress	33.3	8.3
Severe distress	8.3	0
Very severe distress	12.5	4.2

structured manner, potentially decreasing motion artefacts and the need to repeat acquisitions. Additionally, staff reported lower perceived workload and improved time efficiency during NAO-assisted sessions.

Importantly, while these procedural times reflect actual measurements obtained during NAO-assisted visits, comparable timing data from previous routine non-robot-assisted visits were not systematically recorded in the medical charts. As a result, no direct quantitative comparison can be performed. Nevertheless, the absolute times documented in this pilot study are consistent with established ranges for paediatric outpatient cardiology procedures reported in the literature. For example, outpatient cardiology consultations often last between 20 and 45 min, depending on complexity, as shown in international workflow analyses; ECG acquisition can typically be completed within minutes, and echocardiography guidelines provide benchmark durations supporting the plausibility of our findings. These consistencies reinforce the interpretation of our time data as meaningful feasibility indicators even in the absence of a contemporaneous control group. Future studies should prospectively collect procedural times during both robot-assisted and standard cardiology visits to enable direct comparison and quantify potential efficiency gains. Larger multi-centre cohorts and randomised study designs will be essential to validate these initial findings.

Although our study was limited by its small, non-randomised sample and reliance on caregiver-reported distress, these preliminary results suggest that SARs may enhance the clinical experience for neurodiverse children and support diagnostic efficiency. This aligns with previous reports,<sup>5</sup> suggesting that SARs can reduce anxiety and enhance cooperation in paediatric care. Social robots may offer particular advantages in autism care. According to the intense world theory, individuals with ASD process

**Table 2** Procedural times (mean±SD)

Procedure	Duration (min)
ECG	2.1±0.9
Echocardiogram	5.6±1.8
Total visit	14.3±3.1

sensory and emotional input with heightened intensity.<sup>6</sup> Robots offer structured and emotionally neutral interactions, reducing potential overload and enabling greater predictability. NAO's embodied presence and capacity for consistent, calm responses appear to be especially suited to the unique needs of autistic children.

In conclusion, the NAO humanoid robot appears to be a useful adjunct in paediatric cardiology for patients with ASD. Following ethical approval and written informed consent obtained from parents or guardians, this pilot study demonstrated that integrating humanoid robots into outpatient care is feasible, well accepted and potentially beneficial. Further multicentre studies are warranted to confirm these preliminary findings and explore their applicability across broader clinical contexts.

**Contributors** EL contributed to the conception and design of the study, coordinated data analysis and drafted the initial manuscript. MLP contributed to data collection, data curation and interpretation of results. MGM provided critical revision of the manuscript for important intellectual content and contributed to the clinical interpretation of findings. FB assisted in the acquisition of data, performed statistical analyses and contributed to data visualisation. PAG contributed to the study design and methodology and supervised the overall research process. ER contributed to patient recruitment and clinical data management and provided critical review of the final manuscript. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for all aspects of the work. MGM accepts full responsibility for the overall content as guarantor. She had access to all the data, took responsibility for the integrity of the data and the accuracy of the data analysis and controlled the decision to publish.

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**Patient consent for publication** Consent obtained from parent(s)/guardian(s)

**Ethics approval** This study involves human participants and was approved by the Ethics Research Committee of the University of Modena and Reggio Emilia (CEAR, protocol number 298082/2024). Participants gave informed consent to participate in the study before taking part.

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#### REFERENCES

- Trost MJ, et al. Socially Assistive Robots in Pediatric Care: A Review. *Clin J Pain* 2019;35:451–8.
- Hamdan SZ, Bennett A. Autism-Friendly Healthcare: A Narrative Review of the Literature. *Cureus* 2024;16:e64108.
- Puglisi A, et al. Social Robots for Autism: A Review. *Children (Basel)* 2022;9:953.
- Gazal G, et al. Visual vs. Verbal Anxiety Reduction in Children. *Saudi Dent J* 2016;28:80–5.
- Alemi M, et al. Humanoid Robots in Therapy: Anxiety Reduction. *ICRoM* 2014;2014:748–53.
- Markram H, Markram K. The Intense World Theory. *Front Hum Neurosci* 2010;4:224.