Enhancing Autism Spectrum Disorder Screening: Implementation and Pilot Testing of a Robot-Assisted Digital Tool

DI NUOVO, Alessandro <http://orcid.org/0000-0003-2677-2650> and KAY, Adam

Published version

DI NUOVO, Alessandro and KAY, Adam (2024). Enhancing Autism Spectrum Disorder Screening: Implementation and Pilot Testing of a Robot-Assisted Digital Tool. In: ICMI Companion '24: Companion Proceedings of the 26th International Conference on Multimodal Interaction. ACM, 31-35. [Book Section]

Copyright and re-use policy

Enhancing Autism Spectrum Disorder Screening: Implementation and Pilot Testing of a Robot-Assisted Digital Tool

Alessandro Di Nuovo
Computing, Sheffield Hallam University
United Kingdom
a.dinuovo@shu.ac.uk

Adam Kay
Computing, Sheffield Hallam University
United Kingdom
adam.kay@shu.ac.uk

Abstract

Autism Spectrum Disorder (ASD) is a significant lifelong condition. Without early identification and intervention, it can lead to issues such as social isolation and mental health problems. This report presents the initial implementation and pilot testing of a digital version of the M-CHAT-R/F screening tool for assessing the risk of ASD. This version utilizes the multimodal interaction capabilities of a humanoid robot to prompt social behaviour in children, thereby assisting caregivers in identifying anomalies. The advantage of the robot-assisted version over the standard administration is that it allows real-time prompting and observation of children's behaviour for each question of the M-CHAT, rather than relying on parents' recollection. This approach enhances objectivity and reliability in the analysis and scoring. The report details the technical implementation of a prototype, which includes a graphical user interface (GUI) and 20 robot behaviour prompts designed to elicit appropriate responses to the M-CHAT-R/F. It concludes by presenting results of a pilot usability study with parents of children with ASD.

Keywords

Human-Robot Interaction, Humanoid Robots, Graphical User Interface, Digital Cognitive Assessment, Autism Screening

ACM Reference Format:
Alessandro Di Nuovo and Adam Kay. 2024. Enhancing Autism Spectrum Disorder Screening: Implementation and Pilot Testing of a Robot-Assisted Digital Tool. In *INTERNATIONAL CONFERENCE ON MULTIMODAL INTERACTION (ICMI Companion '24), November 04–08, 2024, San Jose, Costa Rica.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3686215.3690150

1 Introduction

Timely identification of ASD is crucial for effective treatment. However, there are long waiting lists, sometimes up to two years, for diagnostic appointments due to limited resources and the availability of the multidisciplinary diagnostic team required to physically meet and analyse children's behaviour for assessment.

Self-reported parental information can aid in screening and reduce waiting times, though it may be incomplete and biased. It has been demonstrated that innovative AI and digital technologies can perform data collection for screening and perform preliminary analyses for assessment of the subject performance [1], [2].

Recent interdisciplinary research has revealed high potential benefits of using social robots in the care of individuals with ASD. Therefore, there is a growing interest in integrating social robots into clinical practice [3]. A systematic review of the literature on the robot, comprehensive of both therapy and assessment, can be found in [4].

Digital tools have become a popular approach to support professionals in the data collection for both physical and mental health problems over the last few decades [5], [6]. Due to the potential false positive rates in diagnostic tools for ASD and other intellectual disabilities, researchers have started to see whether human-robot interaction can support data collection and preliminary scoring for diagnosis and large-scale screening [2], [7]. With the nature of ASD, it can be a common problem that child sufferers are less likely to engage and pay attention to human interaction [8]. However, when interacting with a robot like the NAO, 90% of children were more likely to stay engaged and pay attention to the robot over a human counterpart [9] suggesting that robotics can be used to increase interaction levels. Automated assessment can also help to accurately determine a child's level of attention within therapy sessions and then be tailored to that attention status. Deep learning techniques have been used to analyse attention rates in videos from ASD therapy sessions captured by the onboard camera within the NAO robot. One of the techniques, which measures visual attention, gathered an 88.2% accuracy score [10]. The researchers of this study believe that automated assessment could be an accurate way of helping to improve ASD early diagnosis and therapy sessions with the potential for improving children's lives. It should be considered that the success with either the diagnosis or treatment of ASD this may depend on the severity of the disorder. For children with lower levels of ASD the use of robot-assisted assessment can be beneficial for children who suffer from worse cases of the disorder found that levels of imitation when interacting with a robot are much lower due to their psychological condition [11]. However, cases with highest severity of the disorder are easily recognizable and therefore there is less need of new screening tools for identifying them early.

The aim of the authors of this report is to develop a digital version of the M-CHAT-R/F [12] diagnostic tool used in conjunction with the humanoid robot NAO. These purpose to increase the level of interaction that the child being diagnosed will show for each question asked. With the use of both a proven 2-stage diagnosis form and the added level of interaction due to the NAO robot, the overall aim is to help improve rates of valid ASD diagnosis in young

ICMI Companion '24, November 04–08, 2024, San Jose, Costa Rica

ACM ISBN 979-8-4007-0463-5/24/11
https://doi.org/10.1145/3686215.3690150

children to ultimately allow sufferers to get the correct support as early as possible.

2 Materials and Method

The most important requirement for this research is to have an application that implements a digital version the M-CHAT-R/F paper-based diagnosis form allowing users, either parents, teachers, nurses or doctors, to easily carry out a successful ASD diagnosis with the appropriate follow up [12]. To this end, it is a requirement that an intuitive UI design is implemented making it simple for users with all levels of computer literacy to use, sticking to a professional design with a single running theme applied throughout. This tool must also have some method of storing diagnosis results that can be reviewed at another time. This is important as the application is aimed for both clinicians and carers, with parents potentially needing to have the results examined by a professional to get a diagnosis. The last major requirement is to implement the use of robot-assisted assessment by using a NAO robot, creating 20 scripted behaviours to prompt children's response and support each question from the first stage of the diagnosis, enhancing the level of interaction of the child involved. Overall, all these requirements aim to easily collect more objective data as the robot will allow direct observation of the children behaviour associated with the M-CHAT-R/F question instead of recalling it from memory.

2.1 Tool Design

For the design and implementation, we adopted a Software Process Improvement (SPI) methodology, in which several prototypes were built upon the previous prototype to create a nearly complete product by the end of development. After each prototype was ready, a meeting was set up with the end user so that feedback could be gathered and then incorporated into the next prototype.

2.1.1 Application Tools and Methods. The technologies selected for this research were chosen with the main purposes of professional design quality, multiplatform use and ease of accessibility. The chosen platform was for a desktop application written in Java using the JavaFX extension with an SQLite database implemented for the back end.

2.1.2 Chosen GUI Toolkit. Due to the nature of this study a strong GUI would be needed in order to make the application look professional and ensure a well-structured user interface that could be understood and used by anybody. Java was also chosen due to its two built in GUI toolkits, Swing and JavaFX with JavaFX being picked as the toolkit to be used. JavaFX was picked over Swing due to it being the up-and-coming GUI toolkit for Java making it easier to implement professional and modern designs. Swing is an older more deprecated method of developing desktop applications as Xamarin is overtaking WinForms for C#.

2.1.3 Choice of Back End. To develop an efficient digital diagnosis application, it is a necessity to have a well-designed back end that can easily be written to and read from for storing the required question data and results needed by any basic paper-based diagnosis. The variety of database platforms ranges from large scale server-based databases like SQL Server to much smaller scaled local databases like SQLite. The choice of which database should be used is again very project dependent with many large companies sticking to a server-based option due to the greater amount of traffic that needs to be handled.

2.2 Robot Platform for behaviour prompts

One of the fundamental aims of this project is to use robot interaction to enhance the level of engagement of children under diagnosis. The robot used in the study was the Aldebaran Robotics NAO, which is the most common (80%) humanoid platform employed in human-robot interaction studies with children with ASD [13]. The user interface application for controlling the robot's behaviour was developed using the NAO API Java library, which allows for a remote connection to the robot, provided the robot's IP and port are known. Once a connection is established, the API's Behaviour Manager can be used to access and play any of the saved behaviours on the robot.

2.3 Testing Methods

Usability testing on the other hand is carried out to evaluate how usable and intuitive real-world users find the application. This can provide useful feedback on areas missed by the developer that don't work as expected or that need to be changed to create a more intuitive design. This will be carried out by having a group of sample users from different age ranges follow an evaluation plan. This plan will outline why they are being used and provide a walkthrough of steps to be carried out on the application. When the walkthrough is finished, they will be asked to complete a SUS questionnaire [14]. The SUS questionnaire is an industry standard tool for measuring usability in applications and websites. It allows for an easily administered scale that can differentiate between a usable and unusable system even on small sample sizes.

3 Development and Implementation

3.1 Core Functionality

With the digital M-CHAT-R/F being the core part of the whole application, it was crucial that the implementation of this was well structured and easy to use. The functionality is split into the two main parts of the screening, the first stage 20 base questions and the second stage for the follow-up [15].

The first stage of the screening is very linear with a set of 20 questions that can either be answered with a Yes or No.

The second stage of the screening is classed as the follow up stage meaning it is dependent on both the answers and result from stage one. The follow up should only be carried out if the level of risk is deemed to be Medium. Using the questions that have been answered with an at-risk response in the first stage, it goes into more detail about each one using the flow charts as exemplified in Figure 1.

A video of the showing the full implementation is available on YouTube https://youtu.be/WNudXigXEVI

After each at-risk question has been followed up and the M-CHAT-R/F is completed, a final result will be provided to the user. The scoring algorithm states that if two or more of the follow up questions receive a Fail result; the child has screened positive for ASD and will need to be referred for further testing. This can be seen in Figure 2.

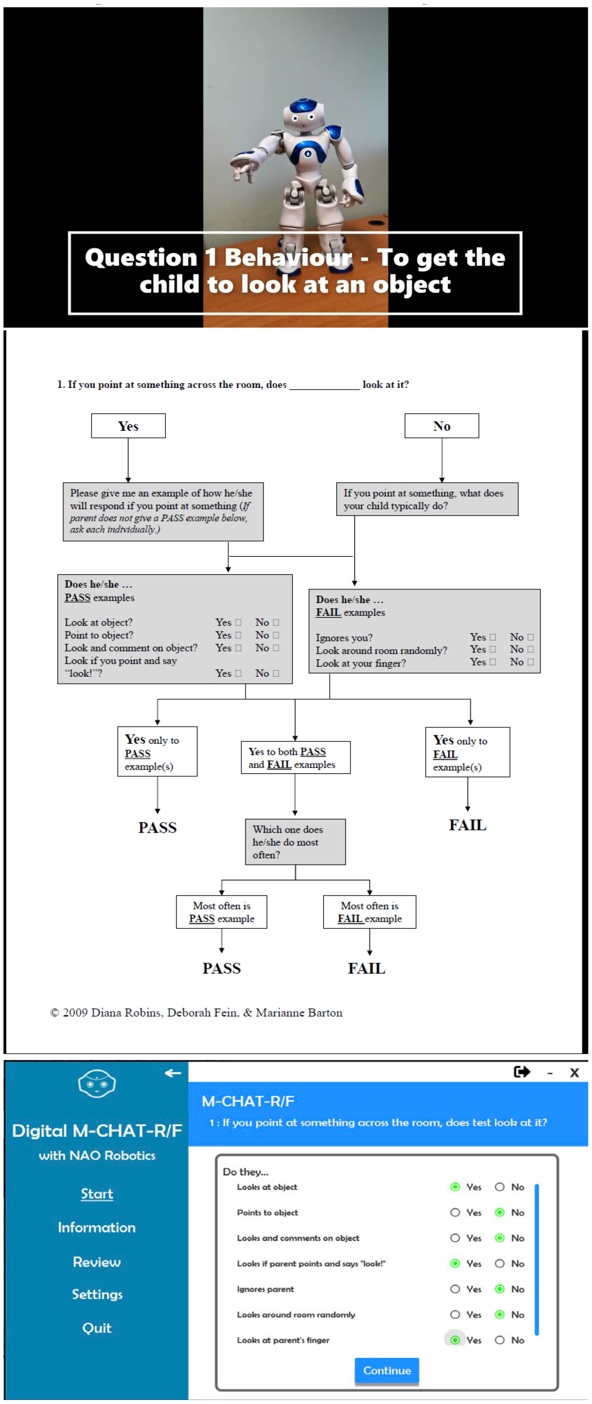

Figure 1: Example of the robot prompt (top), the M-CHAT-R/F flow (middle) and checklist implemented in GUI (bottom) for the follow up to question 1.

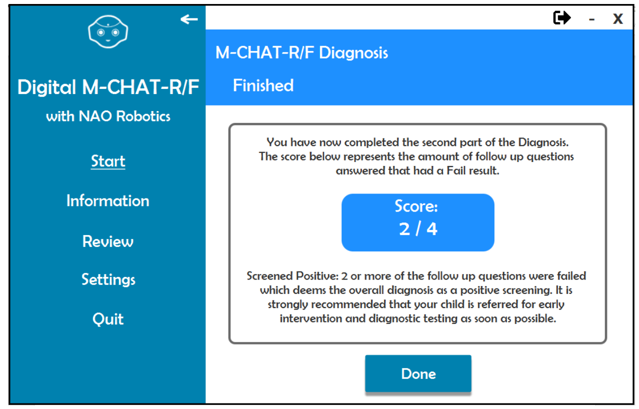

Figure 2: the score after completing both the first and second stage of the screening

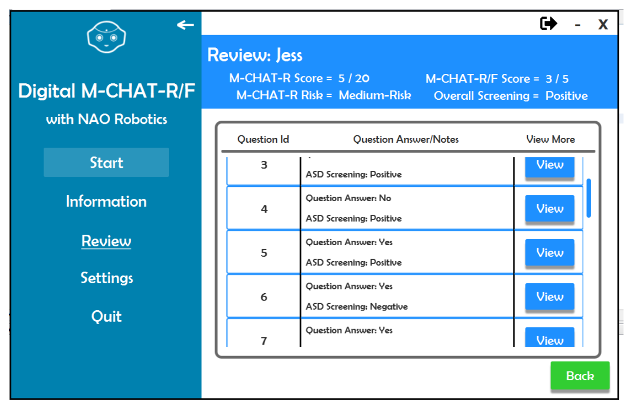

Figure 3: Example of the review functionality for clinicians

3.2 Assessment Results Review Functionality

Having the ability for users to review the results of a diagnosis after it has been finished was important to keep in line with the one of the main research aims. Each diagnosis completed by one user is saved into a results table on the database, allowing the review page to then only access diagnoses related to the currently signed in user. To keep with the intuitive GUI design requirement the control was created so reviewers could cycle through the different children they had screened to allow for easy access to results. Each icon in Figure 3 acts as a button which takes the user to another form allowing them to review all 20 questions from an individual's screening.

3.3 Usability Pilot Testing

The Usability testing carried out here followed the plan outlined in the Design section. A group of 10 users were selected among parents of children at school age and supplied with a copy of the final prototype and an evaluation plan. The SUS questionnaire implemented online allowed anonymous data to be gathered from users. A SUS score of 89.5 for 10 users shows an overwhelming success for user satisfaction with over 80.3 classed as an A grade

Table 1: Results of the SUS questionnaire

Question	AverageScore	Positive	Negative
1 I think that I would like to use this system frequently.	3.5	40%	10%
2. I found this system unnecessarily complex*	4.7	100%	0%
3. I thought this system was easy to use.	4.9	100%	0%
4. I think that I would need assistance to be able to use this system*	4.6	90%	0%
5. I found the various functions in this system were well integrated.	4.7	100%	0%
6. I thought there was too much inconsistency in this system*	4.9	100%	0%
7. I would imagine that most people would learn to use this system very quickly.	4.6	100%	0%
8. I found this system very cumbersome/awkward to use*	4.5	100%	0%
9. I felt very confident using this system.	4.5	100%	0%
10. I needed to learn a lot of things before I could get going with this system*	5	100%	0%

***Negative questions (2,4,6,8,10) are inverted: Score=(6-actual Score)**

system [16]. Moreover, most comments left at the end of the questionnaire support this score stating that the application is intuitive, well designed, and easy to use.

4 Discussion and Conclusions

The tool was completed to a high standard that was satisfactory in the pilot test with parents of children with ASD. An intuitive design was met and backed up by some very positive scores on the SUS questionnaire. Comments from the usability testing provide a few minor changes that would be included in future development to make the system usable by non-technical end users. Basic things like specifying the age range or fixing the nav bar button would all be implemented to create a full version of the application to a commercial standard.

To improve this accessibility even further, we plan to add support for different languages due to their foreign contacts who have also shown interest in this application. With an efficient database already used in the application, the further development required would be minor in comparison to the extended reach that the application would then receive.

The main area of this tool to be improved on in the future would be the planning and time management.

Further development aims come from the desktop application itself, with a key focus on creating a professional user-friendly application allowing different users to create their own accounts to store diagnosis results for later review by a more experienced party. Improvements on the GUI can make it more intuitive and to anyone with a low level of computer knowledge will be able to use it.

Overall, we conclude that this is a promising tool that could be used for mass screening of ASD. In our future work, we aim at organising larger usability studies, involving more participants to evaluate feasibility, cost, duration, and potential issues of everyday use of this diagnostic tool. Furthermore, we plan a clinical trial to refine and validate the robot-assisted digital version, then to deploy the tool to schools and kindergartens to verify its applicability in real-world environment and define the protocols for screenings. We also aim to address technical limitations and challenges posed by the cost and availability of humanoid robots like the one used for this proof-of-concept implementation and pilot test study.

Ethics statement

This work has received ethical approval from the Sheffield Hallam University Ethical committee. The M-CHAT-R/F is a copyrighted document. To reproduce the screening, permission was granted from the creators to the authors of this article.

Video availability

A video of the showing the full implementation is available on YouTube: https://youtu.be/WNudXigXEVI

Acknowledgments

The authors are grateful to all participants and Dr Diana L. Robins and her team. The work of Alessandro Di Nuovo was supported by the European Commission Horizon 2020, grant number 955778 (PERSEO).

References

[1] G. Ercolano, S. Rossi, D. Conti, and A. Di Nuovo, "Gesture recognition with a 2D low-resolution embedded camera to minimise intrusion in robot-led training of children with autism spectrum disorder," Applied Intelligence, vol. 54, no. 8, pp. 6579–6591, 2024, doi: 10.1007/s10489-024-05477-z.

[2] A. Di Nuovo, S. Varrasi, A. Lucas, D. Conti, J. McNamara, and A. Soranzo, "Assessment of Cognitive skills via Human-robot Interaction and Cloud Computing," J Bionic Eng, vol. 16, no. 3, pp. 526–539, May 2019, doi: 10.1007/s42235-019-0043-2.

[3] D. Conti, A. Cattani, S. Di Nuovo, and A. Di Nuovo, "Are Future Psychologists Willing to Accept and Use a Humanoid Robot in Their Practice? Italian and English Students' Perspective," Front Psychol, vol. 10, p. 466791, Sep. 2019, doi: 10.3389/FPSYG.2019.02138.

[4] R. Vagnetti, A. Di Nuovo, M. Mazza, and M. Valenti, "Social Robots: A Promising Tool to Support People with Autism. A Systematic Review of Recent Research and Critical Analysis from the Clinical Perspective," Rev J Autism Dev Disord, 2024, doi: 10.1007/s40489-024-00434-5.

[5] F. M. Calisto, C. Santiago, N. Nunes, and J. C. Nascimento, "Introduction of human-centric AI assistant to aid radiologists for multimodal breast image

classification," Int J Hum Comput Stud, vol. 150, p. 102607, Jun. 2021, doi: 10.1016/J.IJHCS.2021.102607.

[6] S. Rossi *et al.*, "The role of personality factors and empathy in the acceptance and performance of a social robot for psychometric evaluations," Robotics, vol. 9, no. 2, p. 39, 2020.

[7] A. P. Association, DSM 5. 2013. doi: 10.1176/appi.books.9780890425596.744053.

[8] S. Shamsuddin, H. Yussof, L. I. Ismail, S. Mohamed, F. A. Hanapiah, and N. I. Zahari, "Humanoid Robot NAO interacting with autistic children of moderately impaired intelligence to augment communication skills," Procedia Eng, vol. 41, pp. 1533–1538, 2012.

[9] A. Di Nuovo, D. Conti, G. Trubia, S. Buono, and S. Di Nuovo, "Deep Learning Systems for Estimating Visual Attention in Robot-Assisted Therapy of Children with Autism and Intellectual Disability," Robotics, vol. 7, no. 2, p. 25, 2018, doi: 10.3390/robotics7020025.

[10] D. Conti, G. Trubia, S. Buono, S. Di Nuovo, and A. Di Nuovo, "Evaluation of a Robot-Assisted Therapy for Children with Autism and Intellectual Disability," in Proceedings of Annual Conference Towards Autonomous Robotic Systems. TAROS 2018., Bristol, UK, 2018, pp. 405–415.

[11] D. L. Robins, M. Barton, and D. Fein, "Modified checklist for autism in toddlers, revised with follow-up," Pediatrics, 2009.

[12] A. Alabdulkareem, N. Alhakbani, and A. Al-Nafjan, "A Systematic Review of Research on Robot-Assisted Therapy for Children with Autism," Feb. 01, 2022, MDPI. doi: 10.3390/s22030944.

[13] N. Thomas, "How to use the system usability scale (sus) to evaluate the usability of your website," Usability Geek, vol. 4, 2015.

[14] M. Khowaja, D. L. Robins, and L. B. Adamson, "Utilizing two-tiered screening for early detection of autism spectrum disorder," Autism, vol. 22, no. 7, pp. 881–890, 2018.

[15] N. Thomas, "How to use the system usability scale (sus) to evaluate the usability of your website," Usability Geek, vol. 4, 2015.