EÖTVÖS LORÁND UNIVERSITY
FACULTY OF INFORMATICS
DEPARTMENT OF ARTIFICIAL INTELLIGENCE

Facial Behavior Analysis for Children with Autism Spectrum Disorder using Socially Assistive Robots

BRUNO CARLOS DOS SANTOS MELÍCIO
Computer Science Msc,
Artificial Intelligence specialization,
ELTE
Neptun: A1W636
brunomelicio.ai@gmail.com

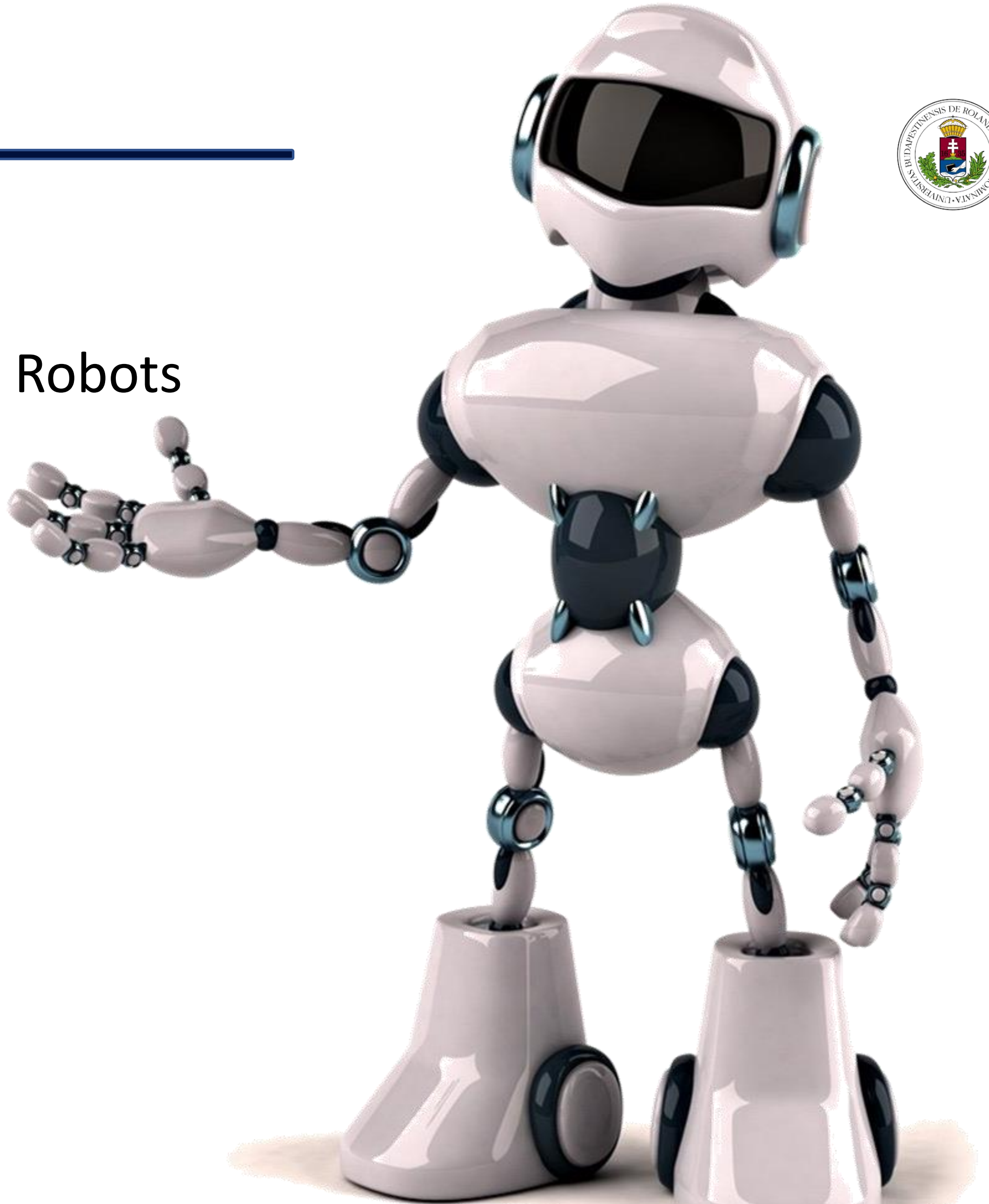
Budapest,
11 January, 2021

Affective Computing Project

CONTENT

1. Introduction
   i. ASD diagnosis with Deep Learning and Robots
2. Facial Behavior Analysis
   i. OpenFace
3. Reviewed papers
   i. Methods and Experimental Setup
   ii. Results
4. Conclusion

References



1. INTRODUCTION

1. INTRODUCTION

Autism Spectrum Disorder (ASD)

- ASD is a complex developmental condition that involves persistent challenges in social interaction, speech and nonverbal communication, and restricted/repetitive behaviors.
- The effects of ASD and the severity of symptoms are different in each person.

Source: https://www.cdc.gov/ncbddd/autism/data.html

1. INTRODUCTION

Challenges

Medical specialists address behavioral assessments of children’s development state.

<u>Screening Tools</u> - Ages and Stages Questionnaires (ASQ); Modified Checklist for Autism in Toddlers (MCHAT); Screening Tool for Autism in Toddlers and Young Children (STAT)

There is a time gap between parents’ first concern about the child’s development impairments, their first medical evaluation, and the child’s age of confirmed diagnosis.

Treatment effective under the age of 3 -> Neuroplasticity

ASD diagnosis with Deep Learning and Robots

- Machine Learning has been used to evaluate data from questionnaires, however such data can be biased and subject to errors due to the extensive length of the questionnaires.
- Deep Learning algorithms have been used on videos of CwASD to analyze the child's behavior and attention. Unfortunately, children are usually anxious or not interested during the sessions.

1. Introduction

ASD diagnosis with Deep Learning and Robots

- Robots as a mediator between the child and the therapist.
- Robot-based screening can help in tasks such as:
  - **improving eye contact and self-initiated interactions;**
  - **turn-taking activities;**
  - **imitation;**
  - **emotion recognition;**
  - **And more.**

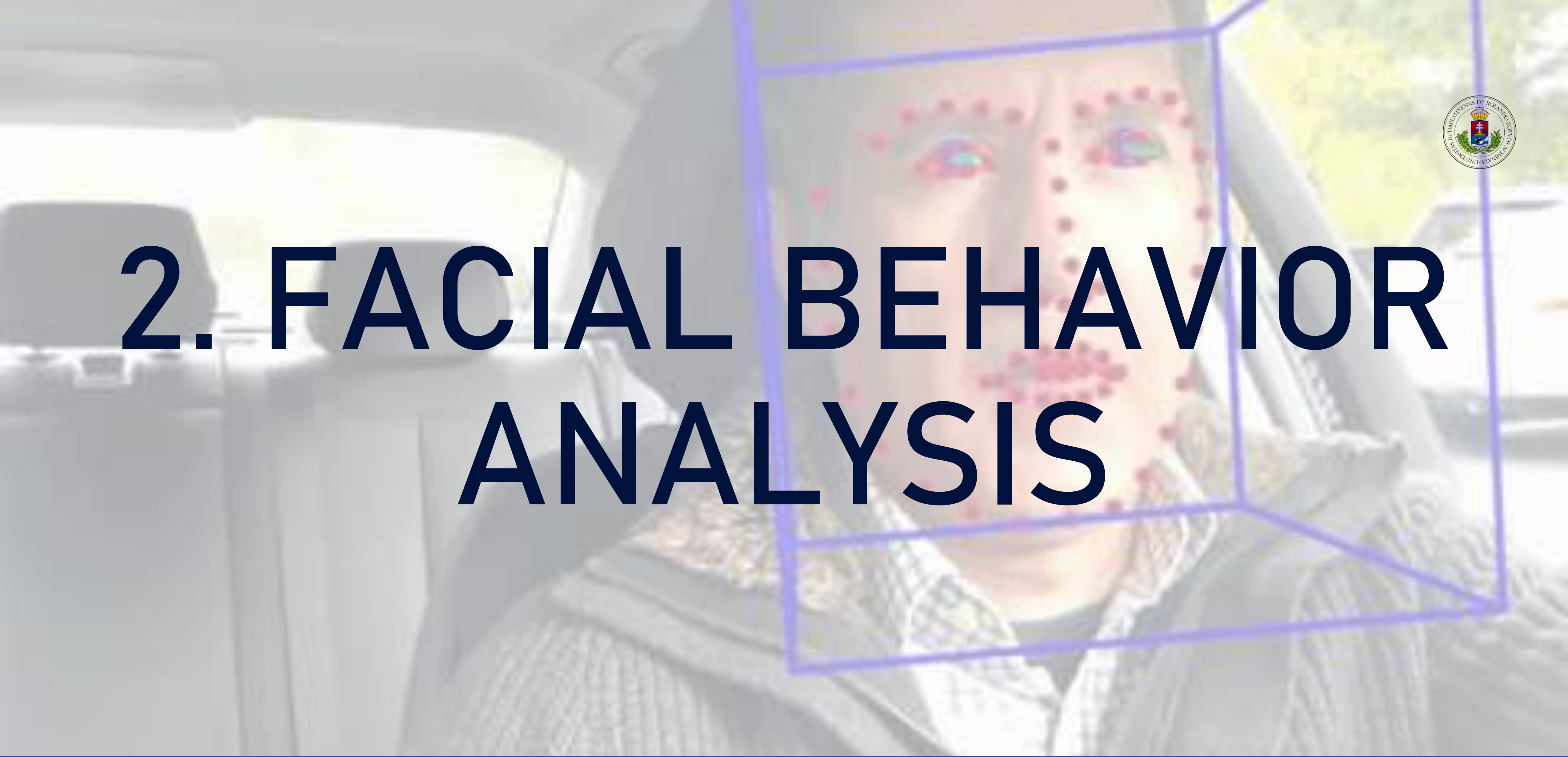
1. INTRODUCTION

Facial Behavior Analysis for Children with Autism Spectrum Disorder using Socially Assistive Robots

- In this project, we aim to show the impact of **robots** on **ASD therapy** by making sessions more enjoyable and interactive **for children with ASD**, but most importantly, more **accurate** and **efficient**, using **Deep Learning algorithms**.

- Specifically, we present how **OpenFace** is used for quantitative data analysis through algorithms such as **face and facial landmark detection**, and **estimation of the directions of gaze and head posture** for automated attention analysis based on recorded videos from the robot's built-in camera and/or external cameras.

2. FACIAL BEHAVIOR ANALYSIS



Facial Behavior Analysis

- Automatic facial behavior analysis includes understanding and recognition of affective and cognitive mental states, and interpretation of social signals.

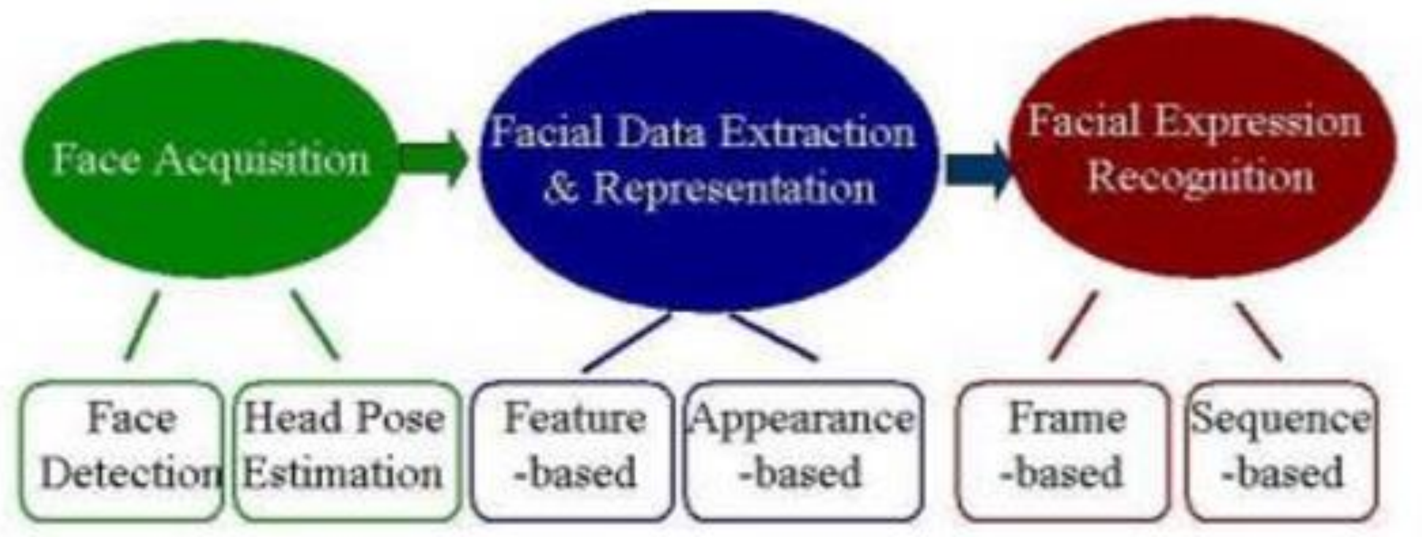
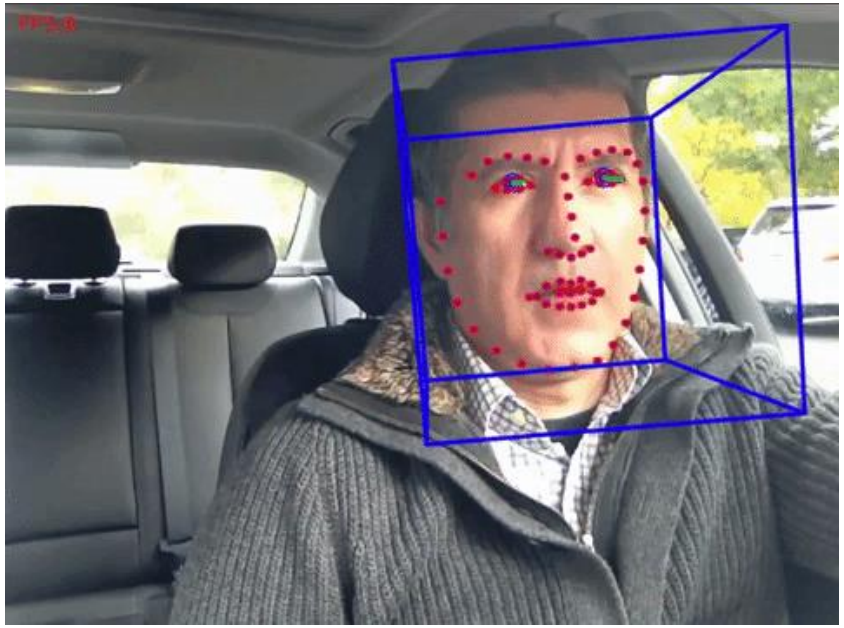


Figure 1. Automatic Facial Expression Analysis (AFEA) pipeline. Tian YL., Kanade T., Cohn J.F. (2005) [1]

2. FACIAL BEHAVIOR ANALYSIS

Facial Behavior Analysis - OpenFace

- OpenFace 2.0 [2] is a framework that implements modern Facial behavior Analysis algorithms including: facial landmark detection, head pose tracking, eye gaze and facial action unit recognition.



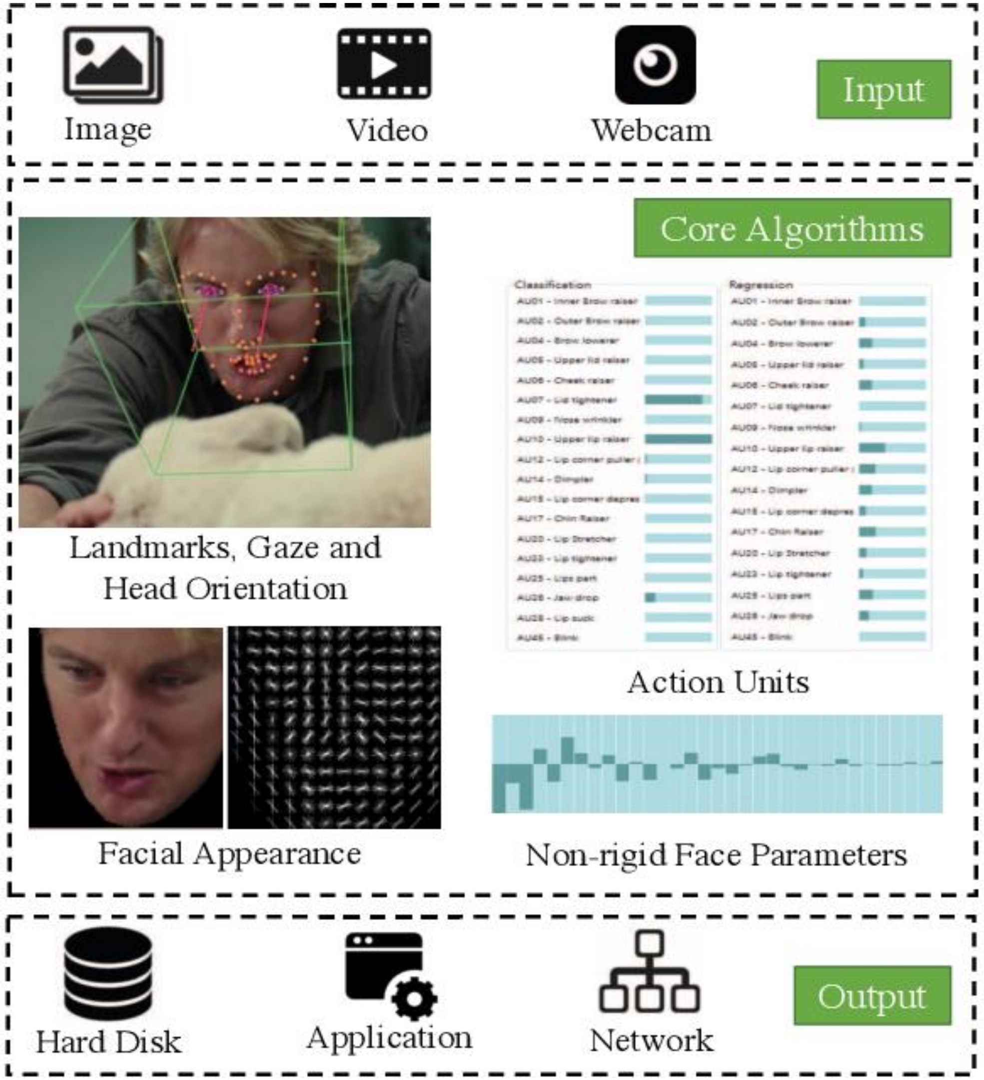


Fig. 2. OpenFace toolkit. T. Baltrusaitis, A. Zadeh, Y.C. Lim, L. Morency (2018) [2]

3. REVIEWED PAPERS

3. REVIEWED PAPERS – METHODS AND EXPERIMENTAL SETUP

Attention shifting during child–robot interaction: a preliminary clinical study for children with autism spectrum disorder.
Wan G., Deng F., Jiang Z. et al (2019) [3]

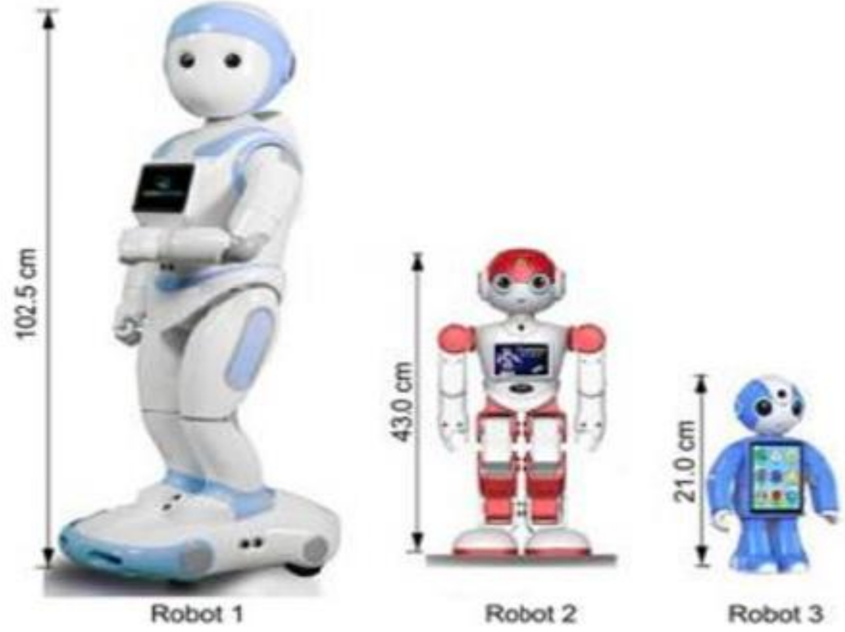


Fig. 3. Appearances of three different robots: they all had a touch screen in the chest of the body, but different in the size and the color of the body, and the dexterity of the hands. Robot 1 is Dabao, Robot 2 is XiaoE and Robot 3 is Mika. Wan G., Deng F., Jiang Z. et al. (2019) [3]

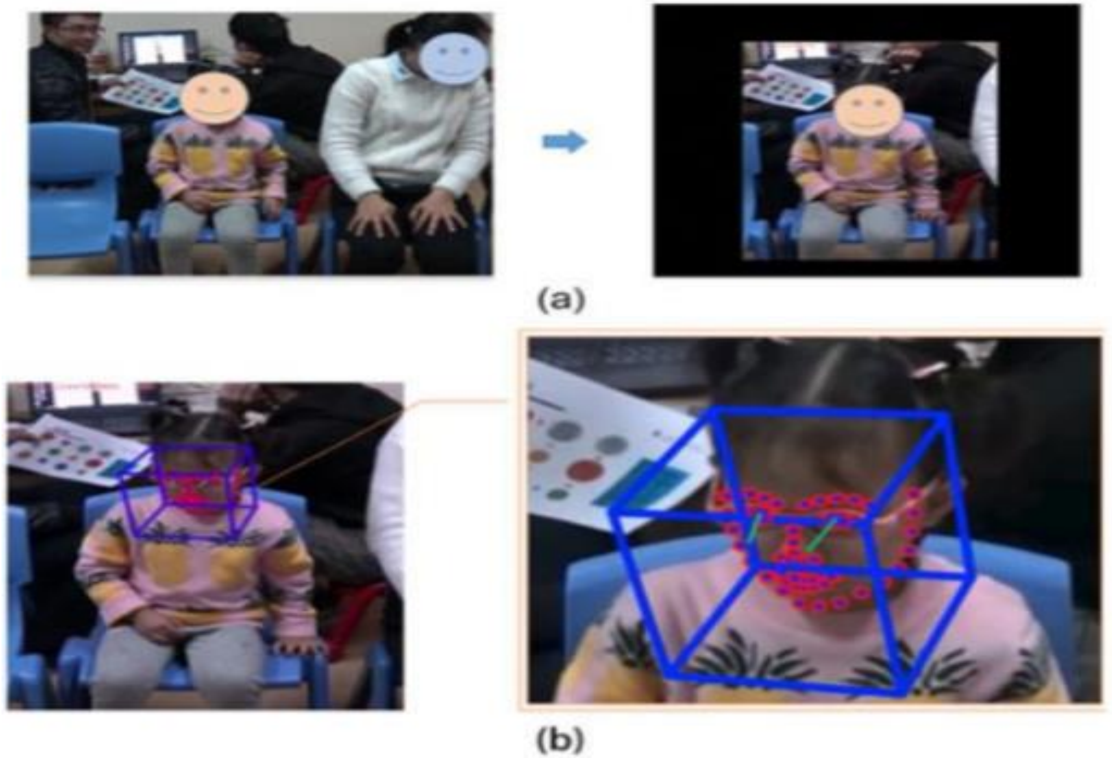


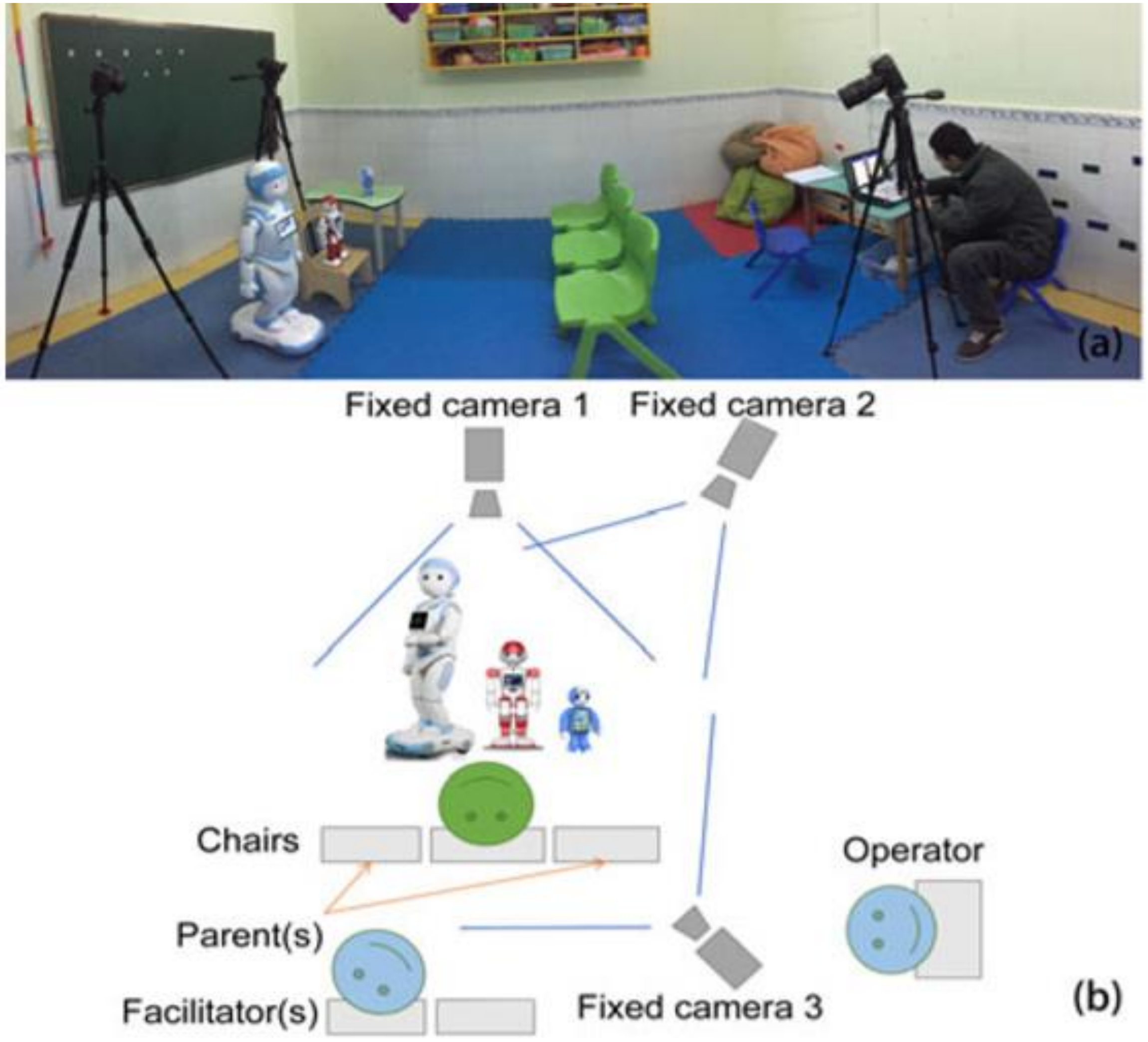
Fig. 4. (a) Non-target user filtering and (b) attention analysis of the targeted user. Wan G., Deng F., Jiang Z. et al. (2019) [3]

- The proposed attention analysis architecture can be divided into three parts: face detection and filtering, OpenFace attention analysis, and visualization of the attention data;
- The attention of the child participant can be judged by the angle of head attitude and eye sight angle;

3. REVIEWED PAPERS – METHODS AND EXPERIMENTAL SETUP

Attention shifting during child–robot interaction: a preliminary clinical study for children with autism spectrum disorder. Wan G., Deng F., Jiang Z. et al (2019) [3]

- 74 participants - 52 CwASD, 18 DD, 3 NYD and 1 TD.
- The collected data were from questionnaires filled in mostly by parents, and videos recorded by three cameras.
- Each session can be divided into two parts:
    1. each child was told to only stay sitting in chair to watch the three robots performing
    2. each child was encouraged to explore/play with the functionalities of the robots.



CwASD – Children with Autism Specturm Disorder; DD – Developmental Delay; NYD – Not Yet Diagnosed; TD – Typical Development

Fig. 5. Setup. The child sitting in the middle chair is indicated with green color with parent(s) sitting next to him/her. Wan G., Deng F., Jiang Z. et al (2019) [3]

3. REVIEWED PAPERS – METHODS AND EXPERIMENTAL SETUP

Robot-Assisted Intervention for children with special needs: A comparative assessment for autism screening. Andrés A. et al (2020) [4]

- The primary objective of this study was to identify behavior patterns associated with Joint Attention (JA) impairments and autism risk factors during a single exposed robot interactive session.

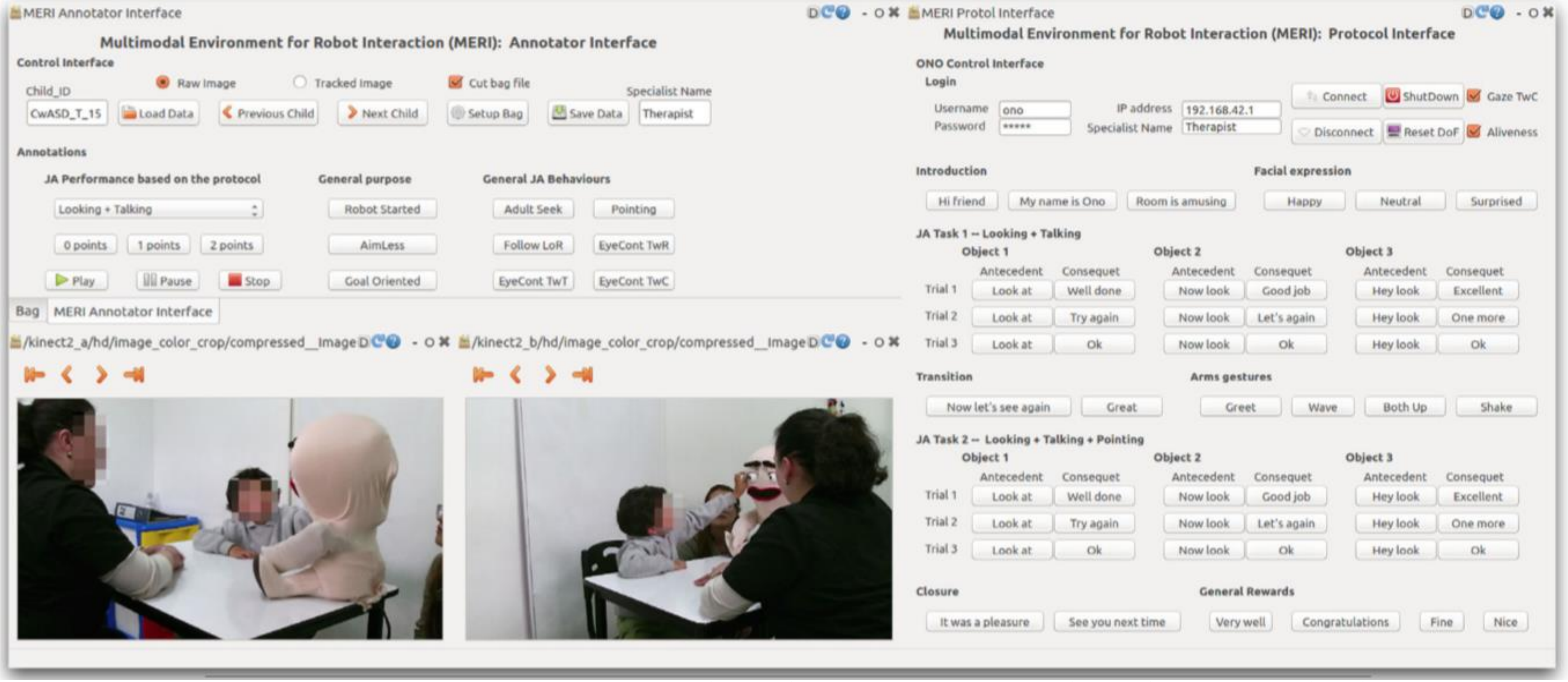


Fig. 6. MERI GUI Interface, which is composed of MERI annotator interface (MERI-AI) and MERI protocol interface (MERI-PI). Andrés A. et al (2020) [4]

3. REVIEWED PAPERS – METHODS AND EXPERIMENTAL SETUP

Robot-Assisted Intervention for children with special needs: A comparative assessment for autism screening. Andrés A. et al (2020) [4]

Fig. 7. Physical structure and appearance of the robot ONO. Andrés A. et al (2020) [4]

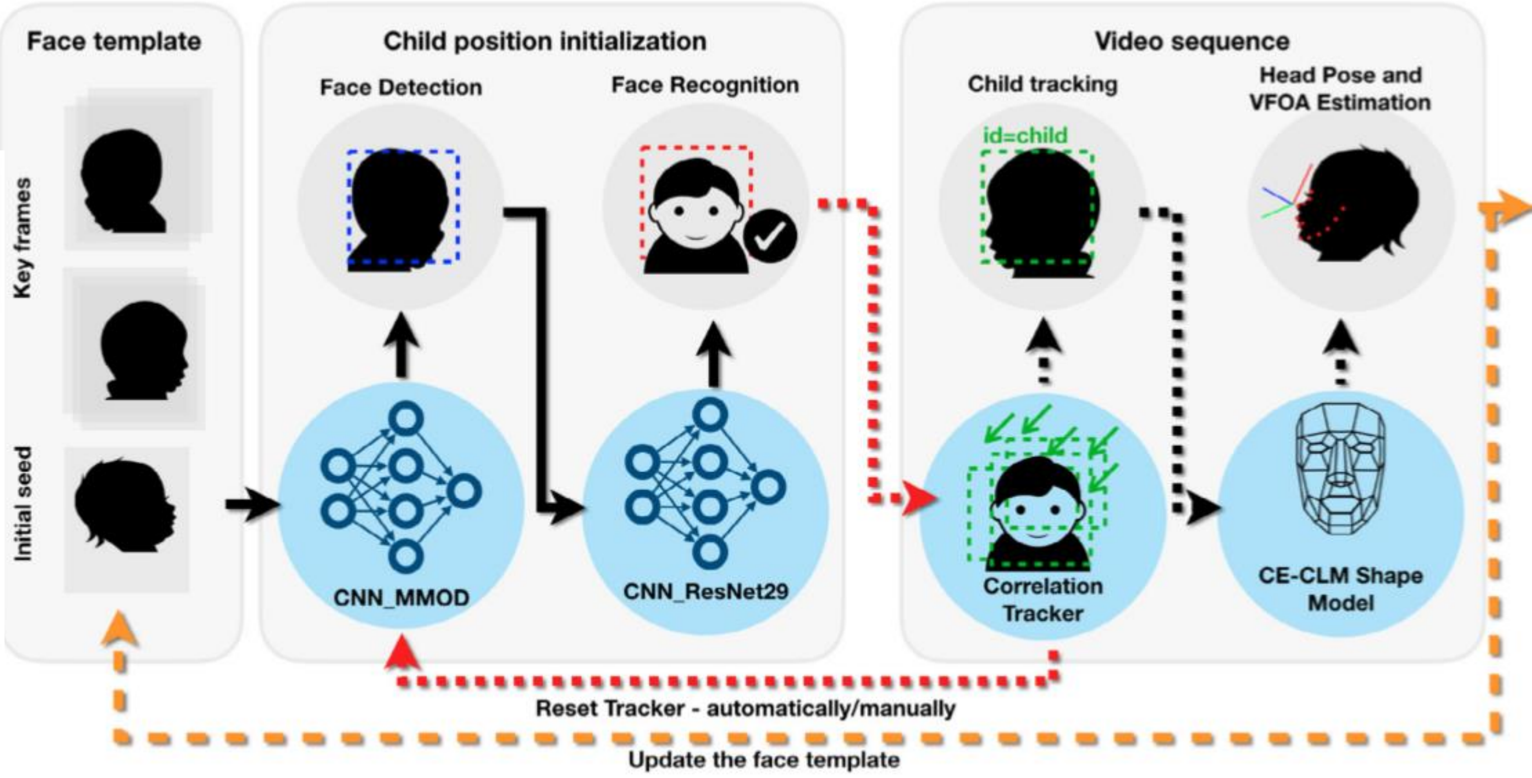


Fig. 8. Video data processing scheme of MERI system. Andrés A. et al (2020) [4]

3. REVIEWED PAPERS – METHODS AND EXPERIMENTAL SETUP

Robot-Assisted Intervention for children with special needs: A comparative assessment for autism screening. Andrés A. et al (2020) [4]

- Initially, 29 CwASD (22 boys and 7 girls; 6.62±2.38) and 16 CwDC (10 boys and 6 girls; 7.75 ± 2.70) were recruited.
- The robot-mediated intervention was designed using the Discrete Trial Teaching (DTT) protocol, which consisted of the presentation of three types of stimuli: the antecedent stimulus (Sa), acceptable response (Ra), and consequent stimulus (Sc) to achieve a specific target behavior through a positive and progressive reinforcement system.

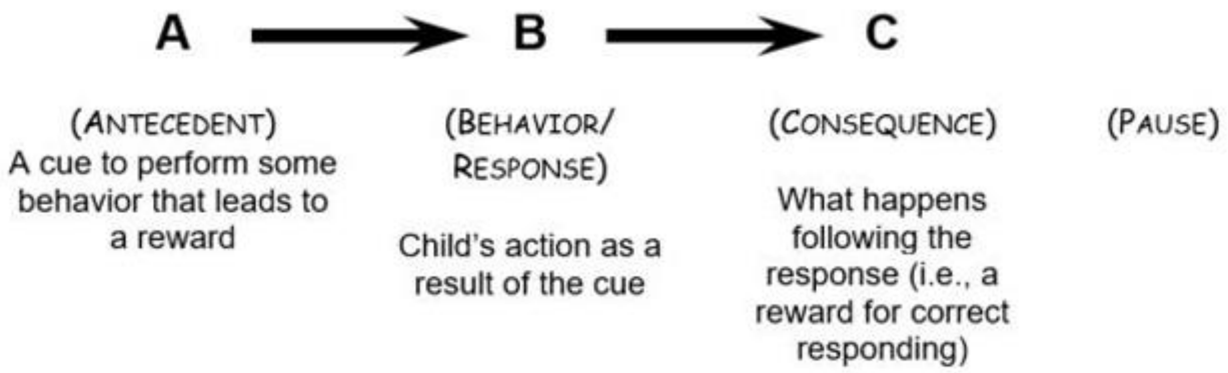


Table 1. Response scheme for assessing joint attention (JA) performance. Andrés A. et al (2020) [4]

Activity and prompt's hierarchy	JA performance score
JA task 1 - Looking + talking	2-Child turns his/her head or points after the first attempt of the robot/therapist 1-Child turns his/her head or points after the second or third attempt of the robot/therapist 0-Child does not react/does something else
JA task 2 - Looking + talking + pointing	2-Child turns his/her head and points after the first attempt of the robot/therapist 1-Child turns his/her head and points after the second or third attempt of the robot/therapist 0-Child does not react/does something else

3. REVIEWED PAPERS – METHODS AND EXPERIMENTAL SETUP

A Supervised Autonomous Approach for Robot Intervention with Children with Autism Spectrum Disorder. Silva V. et al (2019) [5]

- Use a hybrid approach with a humanoid robot and Objects based on Playware Technology (OPT) to allow the detection of the child behavior and consequently adapt the robot to the child's action. The goal of this approach is to introduce some level of automation in a supervised manner.

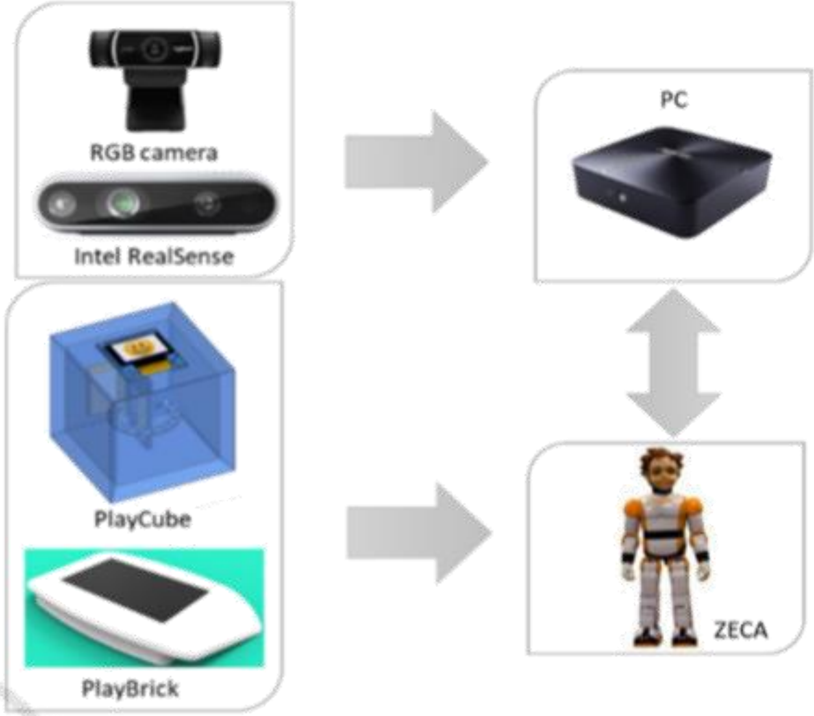


Fig. 9. The proposed system. Starting from the left bottom: PlayBrick, PlayCube, Intel RealSense D435, HP RGB camera, computer, and the humanoid robot ZECA. Silva V. et al (2019) [5]

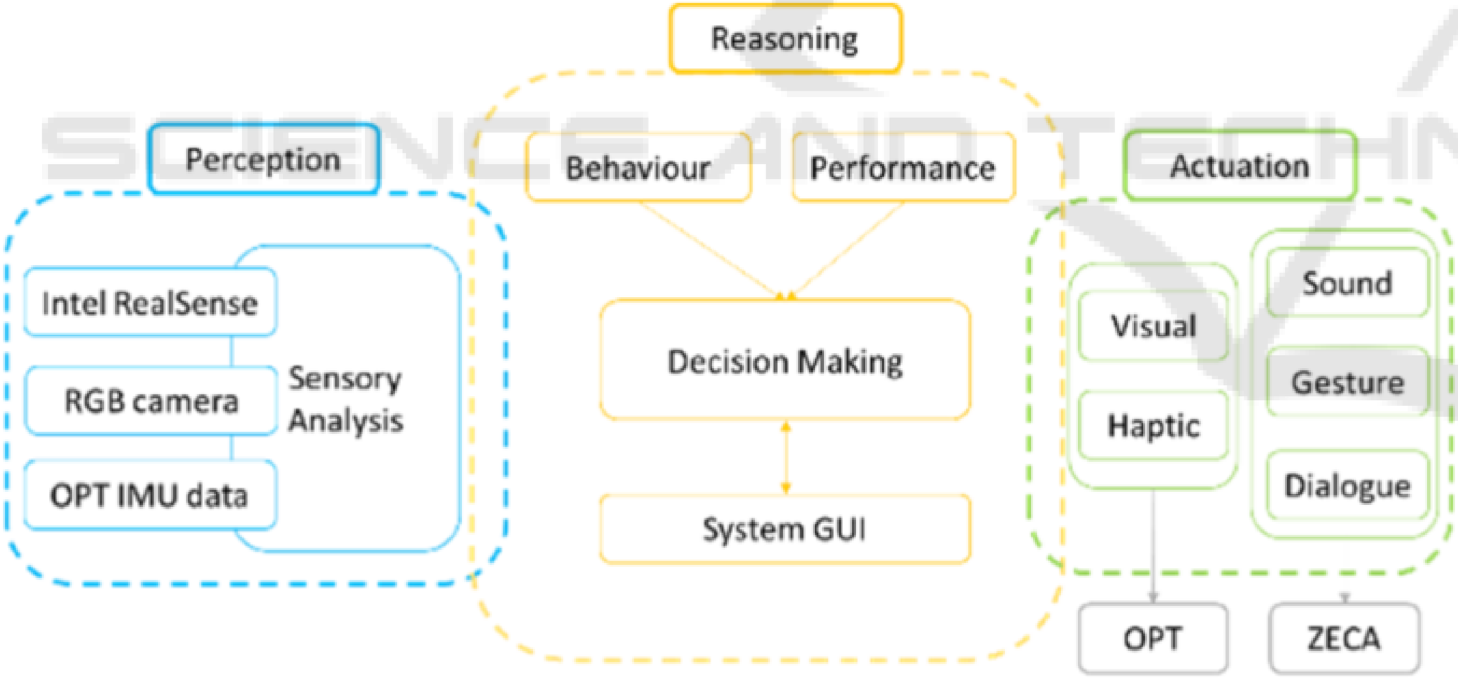


Fig. 10. The behavioural architecture is composed of three main layers – the Perception (blue), Reasoning (yellow), and Actuation (green) layers. Silva V. et al (2019) [5]

3. REVIEWED PAPERS – METHODS AND EXPERIMENTAL SETUP

A Supervised Autonomous Approach for Robot Intervention with Children with Autism Spectrum Disorder. Silva V. et al (2019) [5]

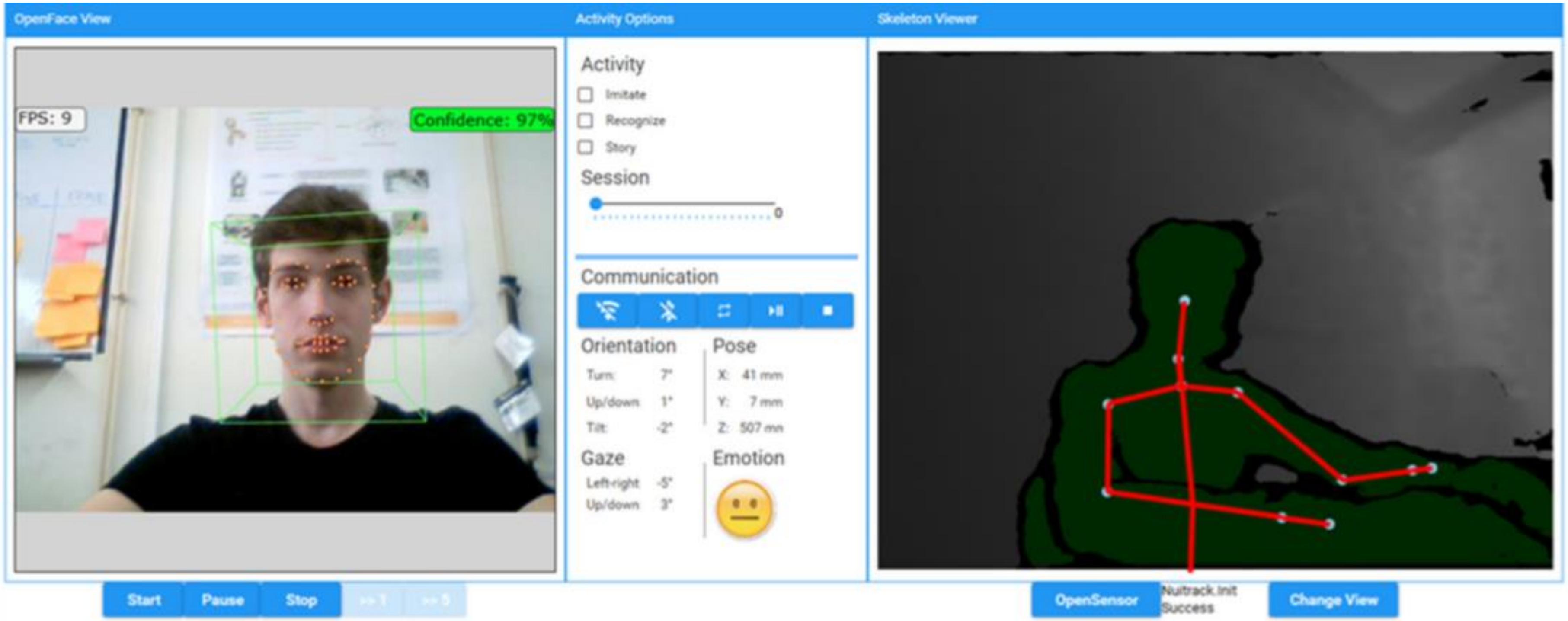


Fig. 11. The GUI. The user can easily control the overall system and receive feedback from each subsystem. It is possible to see the participant's facial data (such as gaze, head orientation, facial expression) as well as the skeleton data. Silva V. et al (2019) [5]

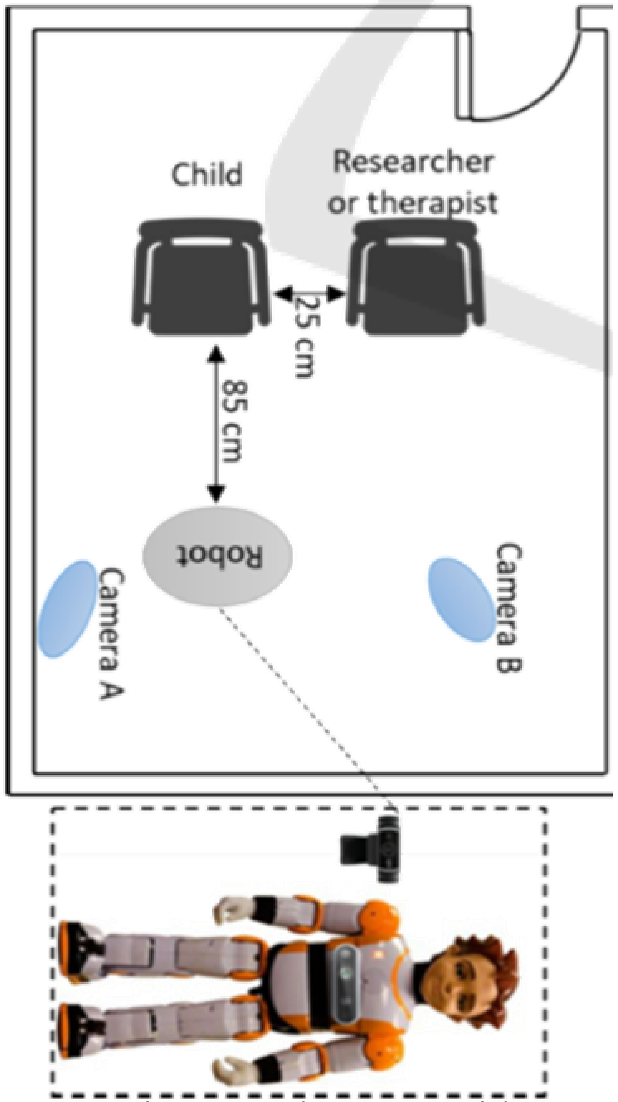


Fig. 12. The proposed experimental design with a triadic configuration. Silva V. et al (2019) [5]

- **Will be implemented in the future** with CwASD aged between 6 and 10 in a triadic setup, i.e., child-robot-researcher/therapist.
- The activities to be played are focused on emotion recognition. Two game scenarios aiming on improving the children emotion recognition skills were developed: Recognize and Storytelling.

3. REVIEWED PAPERS – METHODS AND EXPERIMENTAL SETUP

Robot-Assisted Diagnosis for Children with Autism Spectrum Disorder Based on Automated Analysis of Nonverbal Cues. Ramirez-Duque A. A., Frizera-Neto A. and Bastos T. F. (2018) [6]

- Child-Robot-Interaction (CRI) to enhance the traditional tools for ASD diagnosis is proposed, for Joint Attention (JA) assessment, using a computer vision based system.
- Implement a supervised CRI in-clinic setup for CwASD using the open source social robotic platform ROS with ONO robot.
- Developed a computer vision system to perform an Automated Analysis of nonverbal cues using OpenFace for JA estimation.

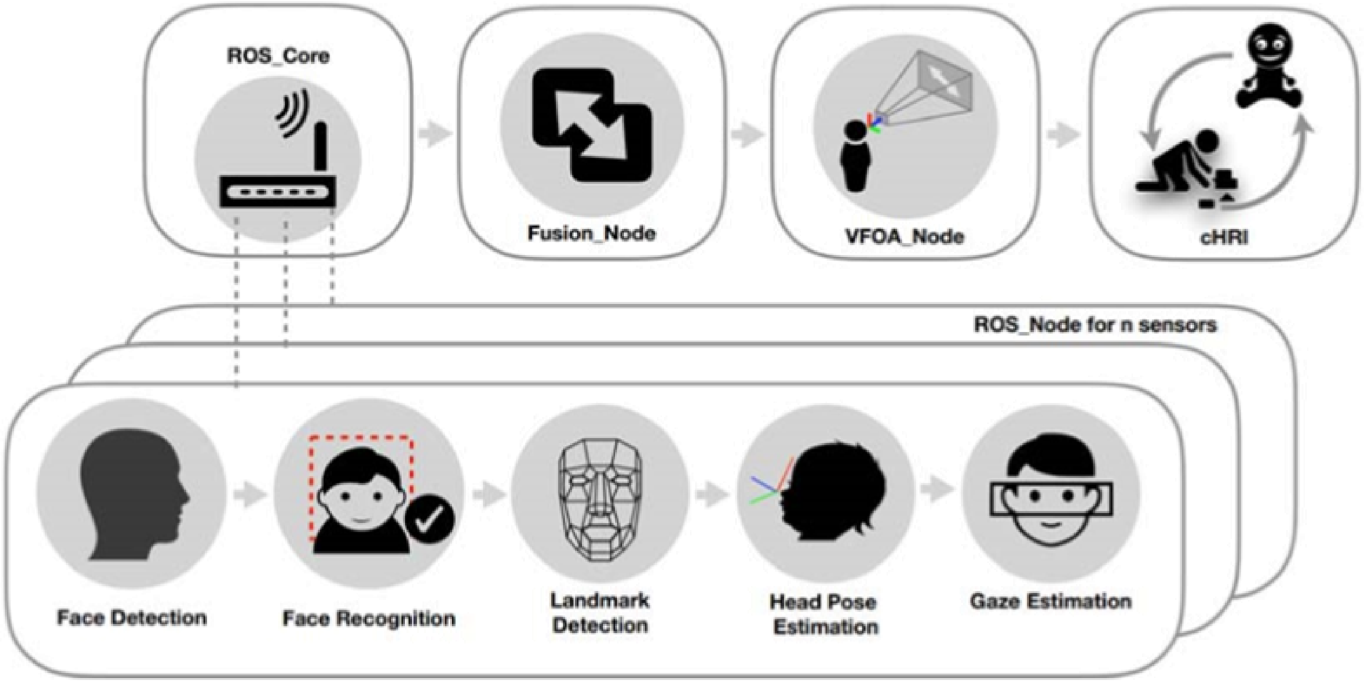


Fig. 13. System Architecture of Supervised CRI Intervention. Ramirez-Duque A. A. et al (2018) [6]

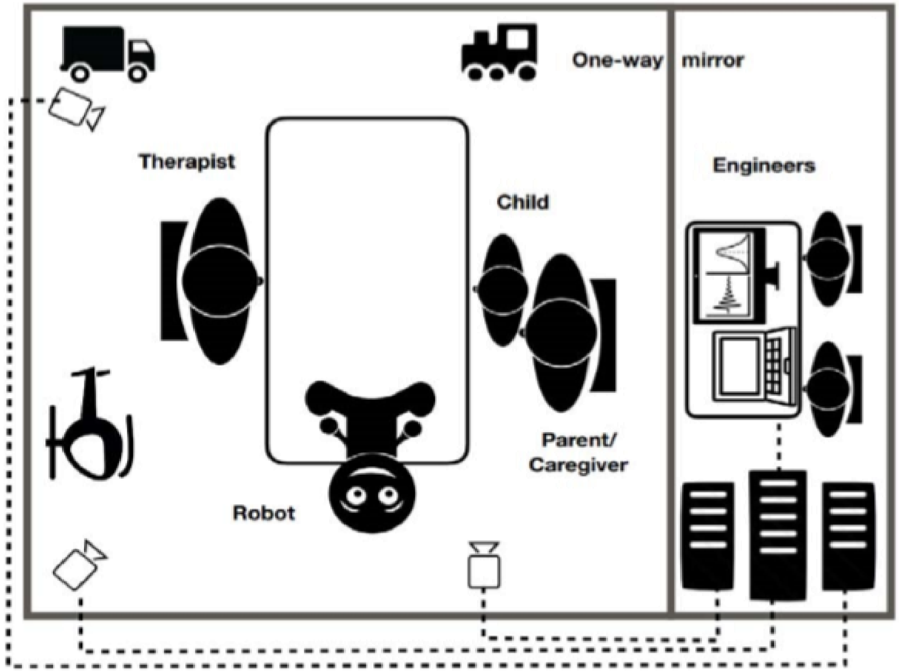


Fig. 14. Interventions room of the in-clinic setup. Ramirez-Duque A. A., Frizera-Neto A. and Bastos T. F. (2018) [6]

3. REVIEWED PAPERS – METHODS AND EXPERIMENTAL SETUP

Robot-Assisted Diagnosis for Children with Autism Spectrum Disorder Based on Automated Analysis of Nonverbal Cues. Ramirez-Duque A. A., Frizera-Neto A. and Bastos T. F. (2018) [6]

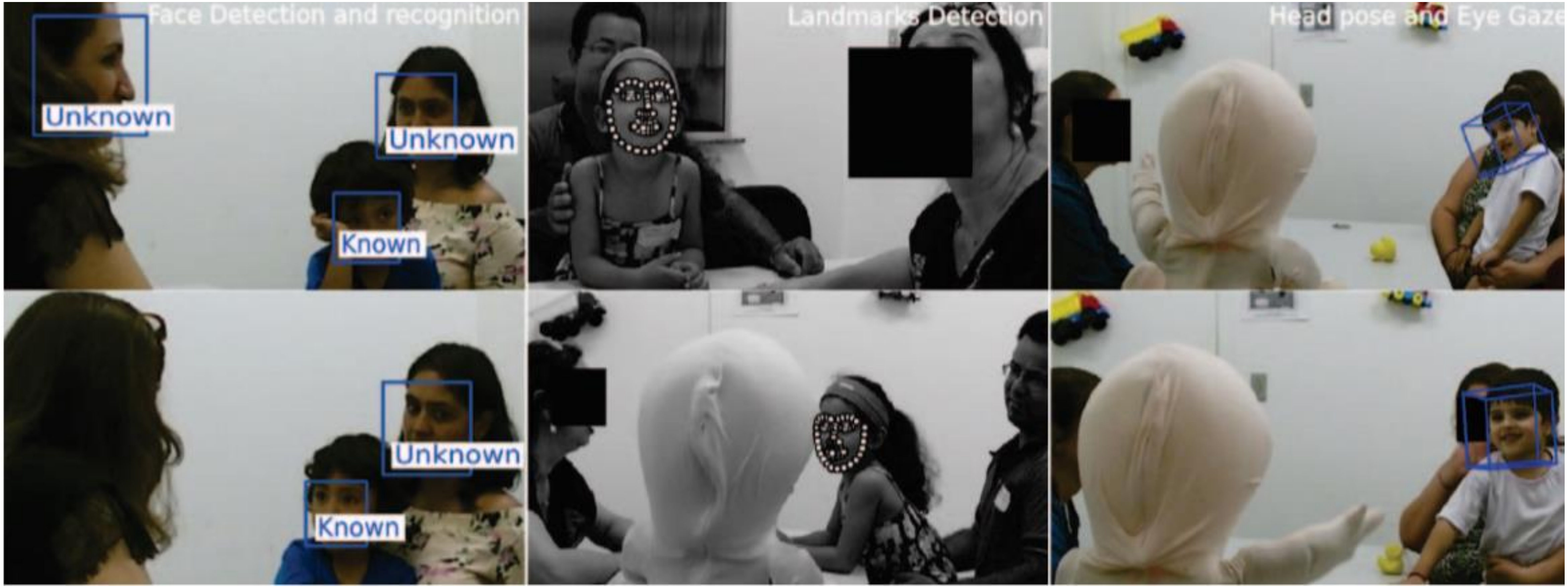


Fig. 15. Performance of the child's face analysis pipeline for the case study. Face detection and recognition, landmarks detection, head pose and eye gaze estimation were executed. Ramirez Duque A. A. et al (2018) [6]

Modeling engagement in long-term, in-home socially assistive robot interventions for children with autism spectrum disorders. Jain S. et al (2019) [7]

- This work applies supervised machine-learning algorithms to model user engagement in the context of long-term, in-home SAR interventions for CwASD. Specifically, it presents two types of engagement models for each user:

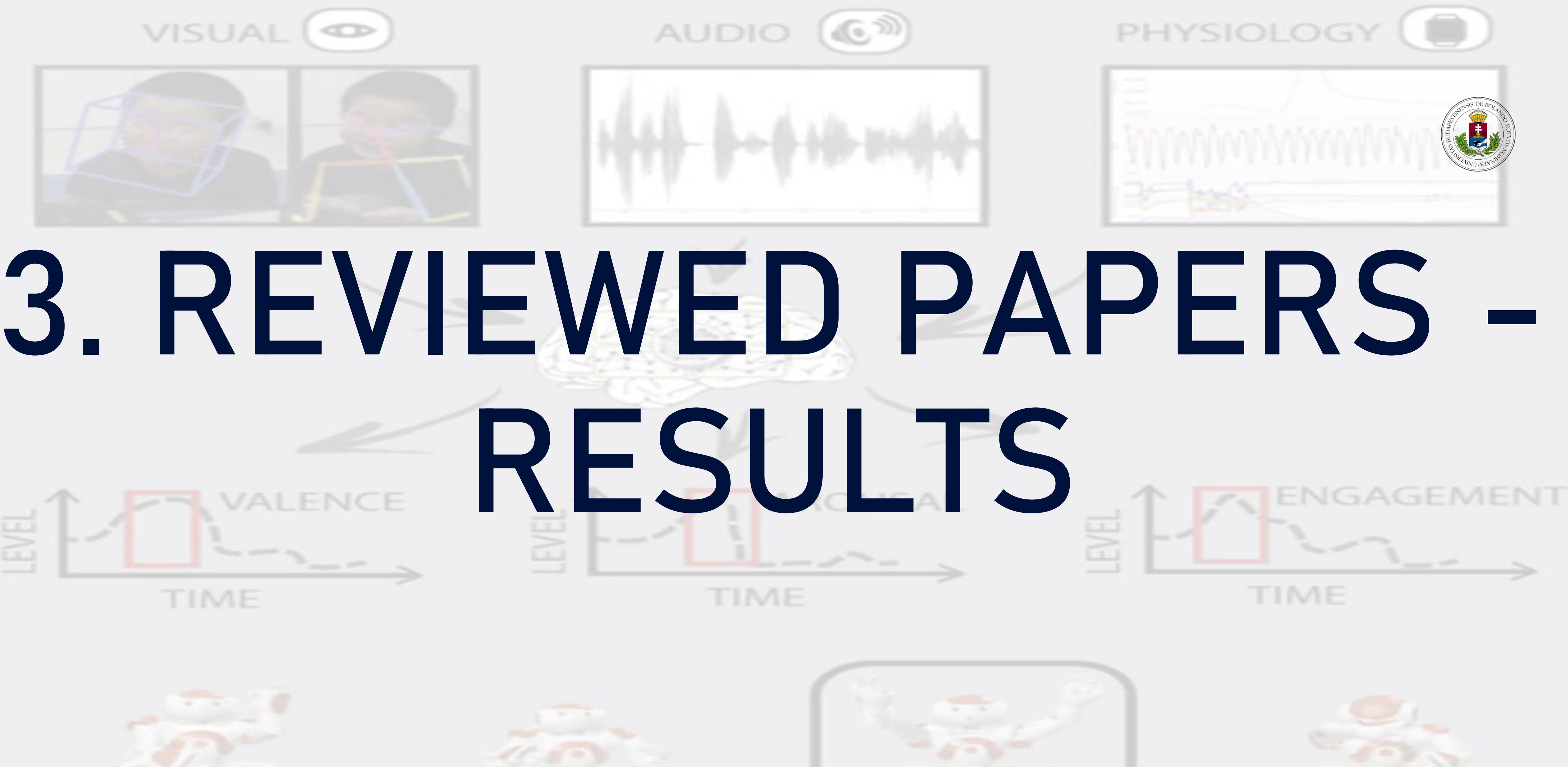
  (i) generalized models trained on data from different users

  (ii) individualized models trained on an early subset of the user's data.

- Visual and audio features were extracted from the camera data using OpenFace, OpenPose, and Praat.
- In addition, game performance features were also derived from system recordings, including the challenge level of the game being played and the count of incorrect responses to game questions.
- This work frames engagement modeling as a binary classification problem
- 7 participants

Fig. 16. Long-term, real-world SAR intervention setup. In this month-long, in-home study, child participants with ASD played math games on a tablet, while a socially assistive robot used multimodal data to provide personalized feedback and instruction (37). Jain et al (2019)[7]

3. REVIEWED PAPERS - RESULTS



3. REVIEWED PAPERS – RESULTS

Attention shifting during child–robot interaction: a preliminary clinical study for children with autism spectrum disorder. Wan G., Deng F., Jiang Z. et al (2019) [3]

Insights from 44 questionnaires:

1) Aspect: 47.73% of the parents expect the robot's gender image to be male. 63.63% of the parents expect the robots to be enthusiastic, smart, and cute, and do not want the robot to be naughty and cool. They are satisfied most with Dabao.
2) Functionalities: 88.64% of the parents hope that robots can accompany their children to play, and 71.21% of the parents expect the robot to give guidance in training under certain conditions and have a certain therapeutic effect on ASD.

Regarding, video analysis of the watching part, the final effective samples for attention analysis and visualization were reduced to 40 ASD children. From those samples, children with ASD or DD had focused on robot 2 (XiaoE) for most of the time. This might be due to the fact that robot 2 was placed in the middle of the settings.

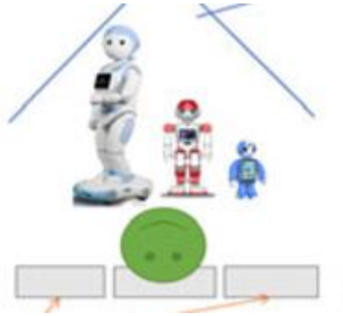


Table 2. Functionalities of the robots children played with most. Wan G., Deng F., Jiang Z. et al. (2019) [3]

Functionality	Frequency/ person-time
Touching sensing with a feedback	39
Operating (e.g., finding games to play or videos to watch)	31
Singing and dancing	13
Speech interacting	5
Imitating	4
Hugging	3

For video analysis of the exploring part, among all these three robots, robot 1 (Dabao) is the most attractive. A touching sensing functionality and a larger size of touch screen made robot 1 a more popular robot to interact with.

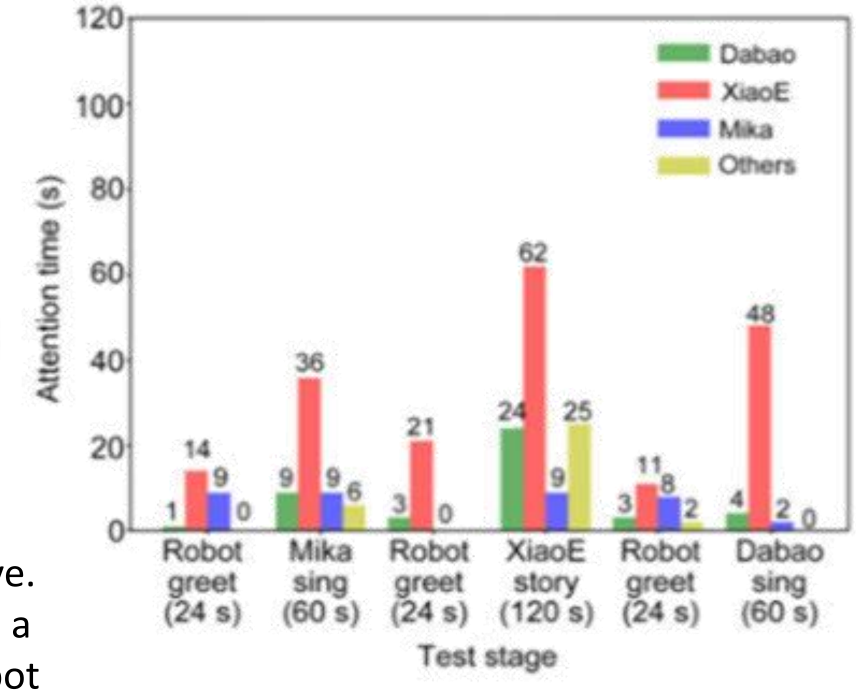


Fig. 17. Attention analysis of sample No. 1 of Shenzhen Maternal & Child Healthcare Hospital. Wan G., Deng F., Jiang Z. et al. (2019) [3]

3. REVIEWED PAPERS – RESULTS

Robot-Assisted Intervention for children with special needs: A comparative assessment for autism screening. Andrés A. et al (2020) [4]

- The statistical analysis regarding the direct child's performance metrics showed that:
  - JA score in the **therapist mediated intervention scenario, CwASD rating was lower than CwDC** (ASD mean rank = 17.98, DC mean rank = 21.83), however, the difference was not statistically significant (U = 137.500;p = 0.275).
  - JA score in the **robot mediated intervention was significantly lower for CwASD** than CwDC (ASD mean rank = 15.63, DC mean rank = 25.43; U = 83.500; p = 0.005). This means that **CwASD had greater difficulty in interpreting the robot's actions**. In fact, CwASD performed significantly worse in robot intervention compared with in therapist intervention (Z = −3.629;p = 0.000). In contrast, CwDC rated better in robot than in therapist mediated intervention (Z = −1.823;p = 0.078).
  - **Regarding the visual contact towards the robot, CwASD exhibited slight more preferences to look toward the robot mediator** compared with the results of CwDC (ASD mean rank = 21.22, DC mean rank = 16.87;U = 133.000;p = 0.240). In contrast, CwASD showed significantly less visual contact toward the therapist than CwDC (ASD mean rank = 13.48, DC mean rank = 28.73;U = 34.000;p = 0.000). Thus, CwASD spent more time looking toward the robot than toward the therapist (EcTwR > EcTwT).

Table 3. Comparisons of the outcome variables throughout both interventions according to groups. Andrés A. et al (2020) [4]

	Condition	N	Mean	Std. Dev.	Mean rank	∑ Ranks	M-W U	Sig. (2-tailed)
Eye contact TwT (%)	CwASD	23	16,03	9,84	13,48	310,00	34,000	0,000
	CwDC	15	34,75	11,01	28,73	431,00		
Eye contact TwR (%)	CwASD	23	30,98	13,78	21,22	488,00	133,000	0,244
	CwDC	15	27,17	6,87	16,87	253,00		
Adult seeking events	CwASD	23	0,65	0,57	12,35	284,00	8.000	0,000
	CwDC	15	3,27	0,88	30,47	457,00		

Through statistical data analysis, it was possible to identify 17 out of 23 children of the CwASD group that showed a different behavior pattern, which suggests that this pattern can be used to identify autism risk factors through Robot-based interventions.

3. REVIEWED PAPERS – RESULTS

A Supervised Autonomous Approach for Robot Intervention with Children with Autism Spectrum Disorder. Silva V. et al (2019) [5]

- The present paper concerns the development of a supervised autonomous system to promote social interactions with CwASD.
- The proposed framework with ZECA and OPT **will be evaluated later.** Therefore, no results were provided.
- They plan to include eight individual sessions in the children´ school:
  - Pre-test – to measure the children's skills
  - Six Practice sessions - to implement the activities for emotion recognition (Recognize and Storytelling)
  - Post-test - to evaluate if the competence was acquired

3. REVIEWED PAPERS – RESULTS

Robot-Assisted Diagnosis for Children with Autism Spectrum Disorder Based on Automated Analysis of Nonverbal Cues. Ramirez-Duque A. A., Frizera-Neto A. and Bastos T. F. (2018) [6]

- The evolution over time of the child's head pose is reported in Figure 18. The child's neck right/left rotation movement was predominant (Yaw axis), while the neck flexion/extension (Pitch axis) and neck R/L lateral flexion movements (Roll axis) remained approximately constant.

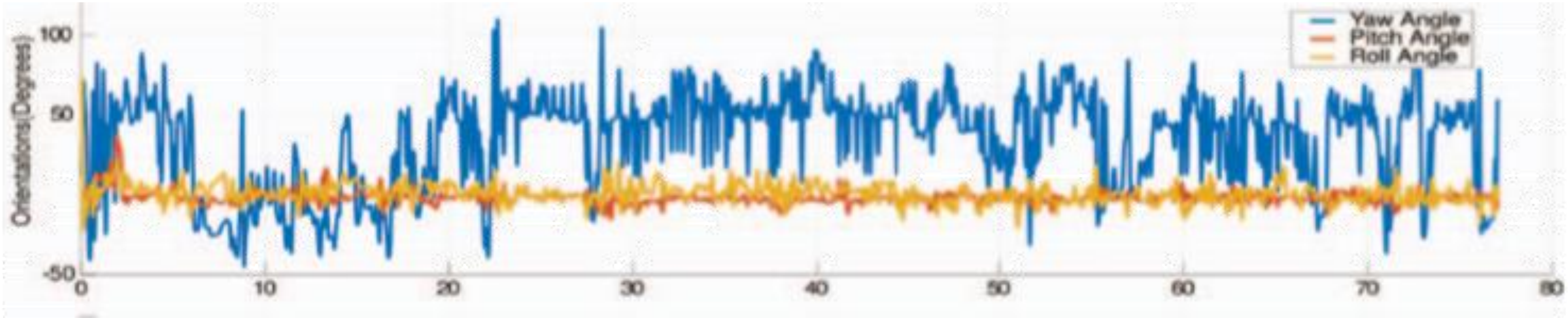


Fig. 18. The evolution over time of the child's head pose (Position and Orientation) for volunteer. A. Ramirez-Duque A. A., Frizera-Neto A. and Bastos T. F. (2018) [6]

3. REVIEWED PAPERS – RESULTS

Robot-Assisted Diagnosis for Children with Autism Spectrum Disorder Based on Automated Analysis of Nonverbal Cues. Ramirez-Duque A. A., Frizera-Neto A. and Bastos T. F. (2018) [6]

In figure 19, the temporal evolution of child's head rotation under the yaw axis of volunteer B is shown. The authors present the results of the automated VFOA estimation and JA behaviors interpretation. The plot (A) shows the overall intervention session; the plot (B) and plot (C) are a zoom of the period with therapist and robot mediator, respectively. The vertical light blue stripe indicates the intervention period with therapist-mediator, and the vertical light green stripe represents the period with robot-mediator.

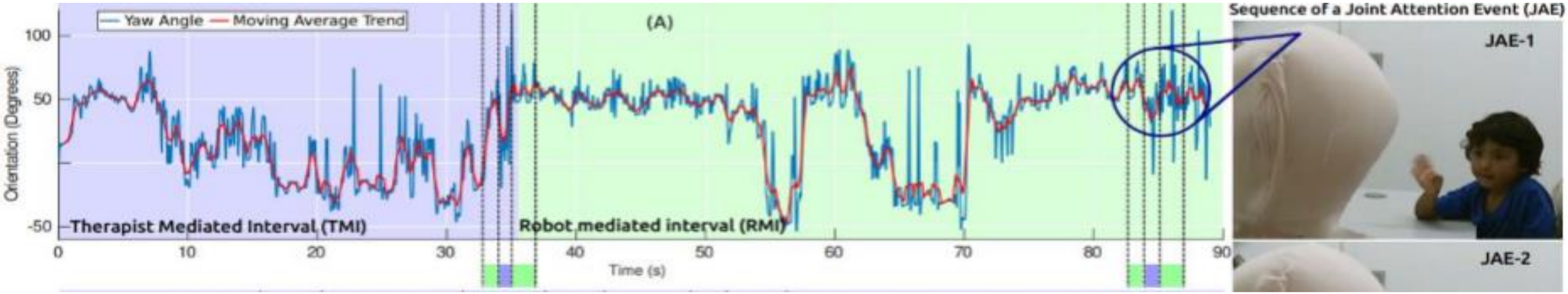


Fig. 19. Evolution over time of the child's head/neck yaw rotation for volunteer B and the JA event when the robot said good bye (JAE-1 to JAE-4) . A. Ramirez-Duque A. A., Frizera-Neto A. and Bastos T. F. (2018) [6]

3. REVIEWED PAPERS – RESULTS

Modeling engagement in long-term, in-home socially assistive robot interventions for children with autism spectrum disorders. Jain S. et al (2019) [7]

- This work presents two types of supervised ML models of user engagement, (i) generalized models trained on data from different users and (ii) individualized models trained on data from early subsets of the users' interventions. On average, these models achieved AUROC values of about 90%. Models trained on random samples of all user data were also implemented and yielded significantly higher recall for disengagement.

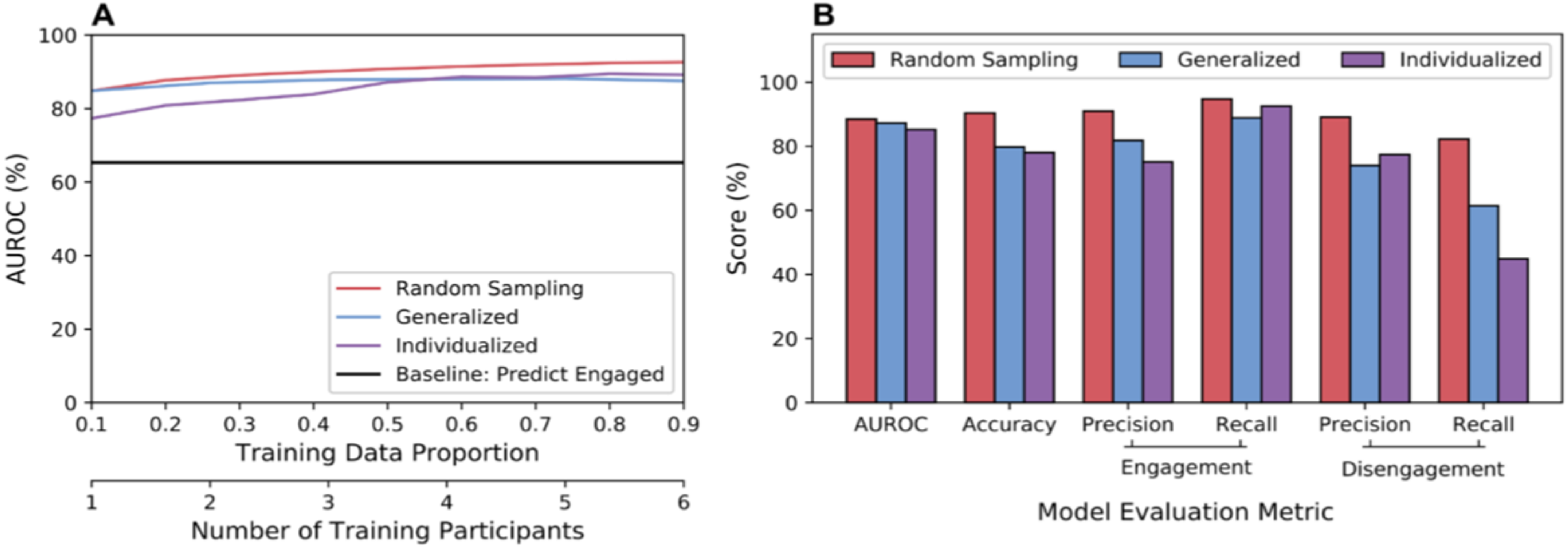


Fig. 20. Model results. Generalized models trained on different users and individualized models trained on early subsets of the intervention achieved comparable AUROC values with those of models trained on random samples of all users' data (A) but had much lower recall for disengagement (B). Jain S. et al (2019) [7]

3. REVIEWED PAPERS – RESULTS

Modeling engagement in long-term, in-home socially assistive robot interventions for children with autism spectrum disorders. Jain S. et al (2019) [7]

- Over the course of the month-long, in-home intervention, **participants were engaged an average of 65% of the time** during the CRI. However, engagement varied considerably across participants and for each participant.

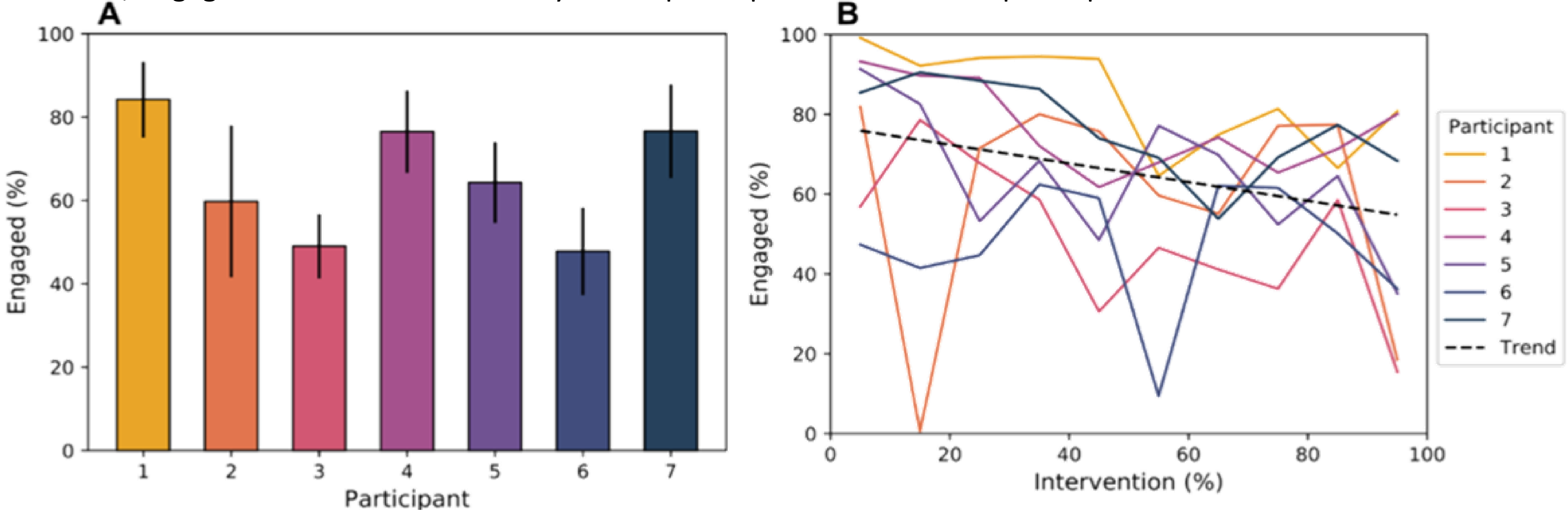


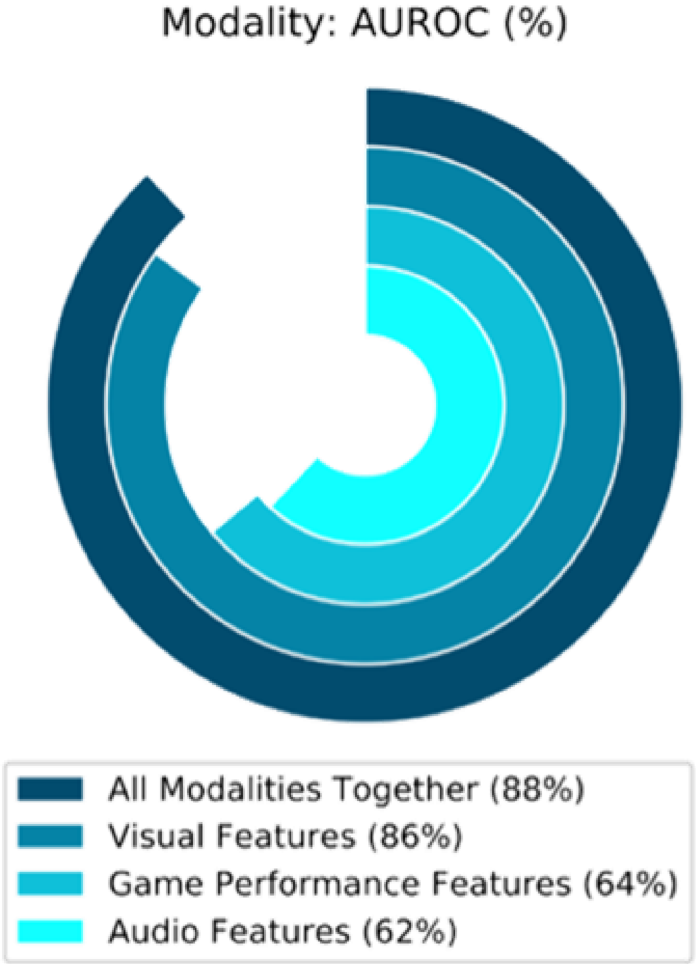
Fig. 21. Engagement by participant. This study observed a significant variance in engagement across participants (error bars, SD) (A) and for each participant (B). A decreasing trend ($P < 0.01$) in engagement was also observed over the month-long intervention (B), indicating the need for online engagement recognition and response. Jain S. et al (2019) [8]

- Also, **higher engagement for all participants was observed shortly after the robot had spoken**. Specifically, participants were engaged about 70% of the time when the robot had spoken in the previous minute but less than 50% of the time when the robot had not spoken for over a minute.

3. REVIEWED PAPERS – RESULTS

Modeling engagement in long-term, in-home socially assistive robot interventions for children with autism spectrum disorders. Jain S. et al (2019) [7]

- All modalities together outperformed each individual modality. However, models created using only visual features outperformed those created using audio or game performance features.
- In addition, this work explored several supervised ML model types but found tree-based models to be the most successful.



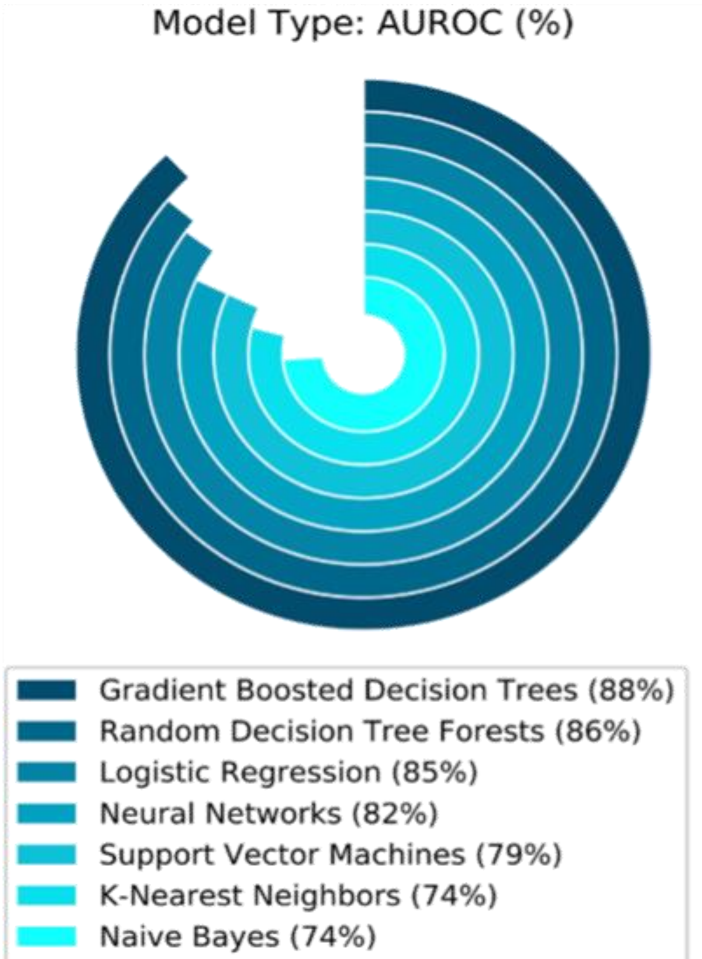
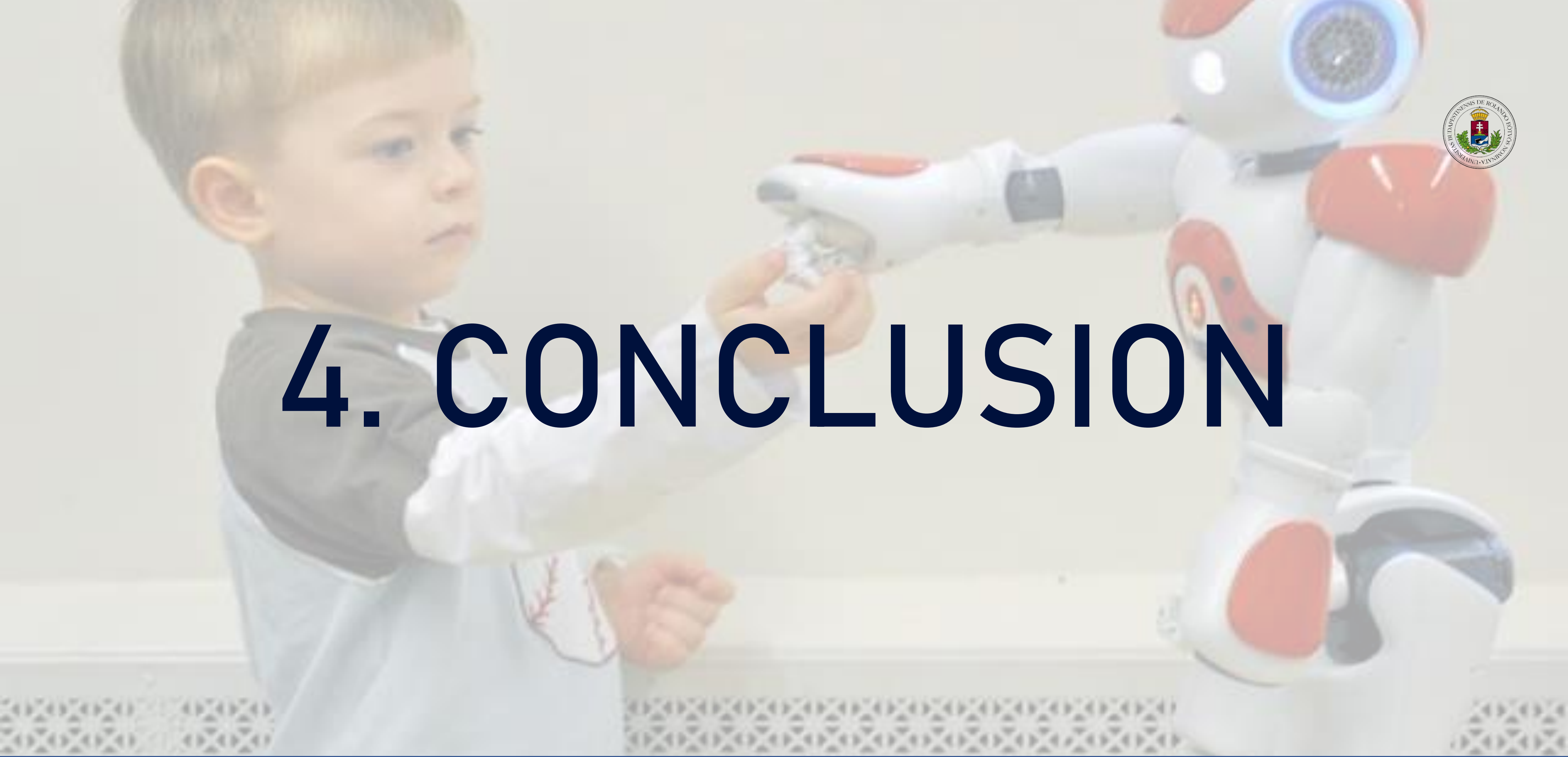


Fig. 22. Results across different modalities and model types. All modalities together outperformed each modality separately, but visual features were the most significant (A). Tree-based models were the most successful among conventional supervised ML model types (B). Jain S. et al (2019) [7]



4. CONCLUSION

4. CONCLUSION

- Autism diagnosis is a difficult and long process. Automating specific parts of such a long process can be beneficial for the development of CwASD.

- This work addresses the **integration of Robots and Deep Learning algorithms, in the therapy of CwASD**.
- We aimed to show the **impact of Robots and Facial Behavior Analysis** on ASD therapy by providing a detailed analysis of five papers that deal with the topic.

Main findings:

- CwASD exhibited **more visual contact towards the robot mediator** than towards the therapist, as well as; they show **higher energy and displacement** in the robot mediated intervention.
- CwASD's **JA score in the robot intervention was the worst**. However, this does not mean that robots are not suitable for ASD therapy. On the contrary, from the perspective of diagnosis, the use of the robot was relevant, given that it led to more clearly demonstrate behavioral differences between the two groups of children.
- Functionalities such as "**touching sensing**" with feedback, operating (e.g., finding games to play or videos to watch), and singing and dancing were the most attractive functionalities that CwASD would like to interact with.
- **Higher engagement of all participants was observed shortly after the robot had spoken**. Specifically, participants were engaged about 70% of the time when the robot had spoken in the previous minute, but less than 50% of the time when the robot had not spoken for over a minute.

4. CONCLUSION

- All the aforementioned results were possible due to the feature extraction from OpenFace, that successfully extracted:
  - facial landmarks;
  - head pose information;
  - eye gaze;
  - facial action units.
- that allow to **qualitatively analyze** and **quantitatively measure** the **prosocial behaviors and actions** performed by the participants during the interactions, but also to make sessions **more interactive and interesting** for CwASD.

- There is still further research to be done, but there is definitely some progress and a brilliant road ahead, full of methods yet to be discovered that will embrace the ASD community and help them participate even more in our social lives. **Like everyone else, they have a role to play in this world!**

REFERENCES

1. Tian YL., Kanade T., Cohn J.F. “Facial Expression Analysis. In: Handbook of Face Recognition.” (2005) Springer, New York, NY. https://doi.org/10.1007/0-38727257-7_12
2. T. Baltrusaitis, A. Zadeh, Y. C. Lim and L. Morency, "OpenFace 2.0: Facial Behavior Analysis Toolkit," (2018), 13th IEEE International Conference on Automatic Face & Gesture Recognition (FG 2018), Xi'an, 2018, pp. 59-66, doi: 10.1109/FG.2018.00019.
3. Wan, G., Deng, F., Jiang, Z. et al. “Attention shifting during child—robot interaction: a preliminary clinical study for children with autism spectrum disorder.” Frontiers Inf Technol Electronic Eng 20, 374–387 (2019). https://doi.org/10.1631/FITEE.1800555
4. Andrés A. Ramírez-Duque, Teodiano Bastos, Marcela Munera, Carlos A. Cifuentes, Anselmo Frizera-Neto. “RobotAssisted Intervention for children with special needs: A comparative assessment for autism screening” Robotics and Autonomous Systems, Volume 127, (2020), 103484, ISSN 0921-8890, https://doi.org/10.1016/j.robot.2020.103484
5. Silva, Vinícius & Queirós, Sandra & Soares, Filomena & Esteves, João & Matos, Demétrio. “A Supervised Autonomous Approach for Robot Intervention with Children with Autism Spectrum Disorder.” (2019). 497-503. 10.5220/0007958004970503.
6. A. A. Ramirez-Duque, A. Frizera-Neto and T. F. Bastos, "Robot-Assisted Diagnosis for Children with Autism Spectrum Disorder Based on Automated Analysis of Nonverbal Cues," (2018) 7th IEEE International Conference on Biomedical Robotics and Biomechatronics (Biorob), Enschede, 2018, pp. 456-461, doi: 10.1109/BIOROB.2018.8487909.
7. Jain, Shomik and Thiagarajan, Balasubramanian and Shi, Zhonghao and Clabaugh, Caitlyn and Matari. “Modeling engagement in long-term, in-home socially assistive robot interventions for children with autism spectrum disorders.” (2020) Science Robotics. doi: 10.1126/scirobotics.aaz3791

THANK YOU!