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The Effect of Use of Social Robot NAO on Children's Motivation and Emotional States in Special Education

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Abstract— **The utilization of social robots in therapeutic and educational settings offers promising advancements, especially for children with special needs. 21 children receiving special education at Dilbade Special Education and Rehabilitation Center were evaluated under two conditions: sessions led by special education teachers and those supported by the social robot NAO. The Pediatric Motivation Scale (PMS) results demonstrate that special education sessions involving the social robot NAO increased the children's motivation compared to traditional sessions. Moreover, statistical features from the physiological signals, including Blood Volume Pulse (BVP), Electrodermal Activity (EDA), and Skin Temperature (ST) were found. Notably, all significant features from BVP, EDA, and ST have increased, which indicated that children were excited and felt positive during the sessions involving the social robot NAO. Furthermore, the subjective evaluations from children, families, and special education teachers supported the quantitative findings, with a majority expressing enthusiasm for including the social robot NAO in special education.**

Index Terms— social robot, NAO, special education, physiological signals

I. Introduction

Social robots are designed to communicate with people and possess the ability to restructure social relationships. Interacting with social robots resembles human interaction, as they can comprehend individuals, respond to situations, and exhibit social intelligence [1]. Numerous studies on social robots have focused on caring for older adults, with limited exploration of the utilization of children's health services [2]. However, these robots can present new opportunities, especially for children with special needs.

Social robots offer new possibilities, such as enhancing communication and participation in education for children diagnosed with autism spectrum disorder (ASD) [3], [4]. Incorporating social robots as support materials in the education of children diagnosed with ASD has enhanced the children's motivation and interest in the lesson [5]. A review article concluded that using social robots in education has improved learning by providing empathic feedback to the child and personalizing the experience, thereby increasing in-class motivation and participation [6]. The social robot, employing a learning paradigm and demonstrating writing skills, increased the child's motivation and involvement in the lesson [7]. Various types of social robots such as Kaspar, Lego Mindstorms, iRobiQ, Iromec, Alice, Zeno, and Pepper have previously been used for cerebral palsy and various physical and mental disabilities [8], [9], [10]–[12].

The social robot NAO is preferred in many studies due to its affordability compared to other robots with similar functionality and its wide range of capabilities [13], [14]. NAO has been used in education, therapy, emotional and behavioural support, and children's care [15]. NAO has been shown to facilitate and enhance social interaction with motivation for children with special needs [16], [17]. The social robot NAO has been selected for this study [18]–[20].

Despite the widespread use of social robots, more research is still needed to analyze the emotional states of children with special needs during human-robot interaction. This study aims to systematically investigate the effect of the social robot NAO's inclusion in special education sessions on children's motivation and emotional states. The Empatica E4 wristband has previously been used to record the physiological signals of children to recognize their emotions [10]–[12], [21]–[28]. The E4 wristband is used to record physiological signals such as blood volume pulse (BVP), electrodermal activity (EDA), and skin temperature (ST). The significant features from these physiological signals are extracted to recognize the motivation of children with special needs during NAO robot interaction. 104 features were extracted from physiological signals collected during the sessions led by special education teachers and those supported by the social robot NAO.

Statistical t-test and Mann-Whitney U Test are applied to identify statistically significant differences in the features within two groups: sessions with NAO and sessions without NAO. Several related to BVP, EDA, and ST are statistically significant among these features. It is also observed that there is an increase in all these significant features when the robot is involved. SCR has been shown to increase in response to novel stimuli [29], [30]. ST was found to increase with excitement and happiness [31]. Thus, children were found to be engaged and felt positive in the presence of the social robot NAO.

The Pediatric Motivation Scale (PMS), the first scale with demonstrated validity and reliability for evaluating children's motivation, has also been applied [32]. PMS is used first

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TABLE I
INCLUSION AND EXCLUSION CRITERIA FOR THE STUDY

Inclusion criteria	Exclusion criteria
• Children receiving special education. • Participation in a rehabilitation program due to a chronic disability. • Willingness to participate in the study. • Ability to maintain continuity throughout the intervention period. • Not participating in any other rehabilitation program during the intervention application.	• Presence of uncontrolled epileptic seizures. • Existence of visual and hearing impairments. • Lack of willingness to participate in the study.

for special education sessions and then for special education sessions involving the social robot NAO. A statistically significant difference is observed in favour of the sessions involving the robot. Furthermore, children, families, and special education teachers who participate in the study are also asked to share their opinions about the study. The subjective evaluations from children, families, and special education teachers supported the quantitative findings, with a majority expressing enthusiasm and a preference for including NAO in the special education sessions.

II. EXPERIMENTAL SETUP

This study aims to identify the significant features of physiological signals and understand if the children's motivations have been increased during their interaction with a social robot. An interaction scenario was planned with the NAO robot. The profile of children participating in the study and the interaction scenario were explained in detail in the following subsections.

A. Participants

All experiments were conducted at Dilbade Special Education and Rehabilitation Center. Children between the ages of 4 and 16 participating in a rehabilitation program due to a chronic disability and receiving special education were included. The study included children diagnosed with ASD, specific learning disability, physical disability, and mental disability. 21 special education children who met the inclusion criteria participated in the study. The inclusion and exclusion criteria for children attending the experiment are presented in Table I.

B. Ethics Statement

Approval for ethical conduct has been acquired from the Research Ethics Committee of Istanbul Medipol University (Reference number E-10840098-772.02-30). Furthermore, the parents of the children have been informed about the experimental procedure for the test and data acquisition setup.

C. Experiments

This study included a social robot NAO in children receiving special education sessions with various diagnosis groups. Special education teachers administer positive verbal feedback to enhance the learning experience in the context of specialised educational sessions for children. The literature supports verbal affective feedback as a crucial element in child-centred therapies, emphasizing its role in facilitating emotional expression, building trust, and promoting positive developmental outcomes [33]. Both verbal feedback from special education teachers and that delivered by the social robot NAO were systematically administered, and subsequent reactions of the children were recorded for analysis.

During the first 25 minutes, the social robot NAO was hidden in the session room and out of the child's sight (Figure 1). A special education session was implemented based on the child's needs. Before the special education session started, an E4 wristband was placed on the children's wrists, and the measurement was started. Points were determined according to the time interval of the data obtained at each press of the button on the device during use. When teachers gave affect to the children during special education, the button was pressed once, and verbal affect was provided. In therapeutic interventions with children, verbal feedback on affect refers to the spoken responses and comments provided by the special education teacher during a session to acknowledge, interpret, or explore the emotional expressions and experiences expressed by the child. This form of communication aims to enhance the child's awareness and understanding of their emotions, promote emotional regulation, and foster a secure therapeutic relationship. After 10 seconds, the button on E4 was pressed again, and the second point was determined from the data. The region between these two points showed us the child's reaction to the verbal emotion given by the teacher.

Fig. 1. Feedback is given by the special education teacher during the special education session

In the last 15 minutes of the session, the social robot NAO joined the session (Figure 2). Before the social robot NAO was shown, the button on the E4 wristband was pressed again and again a few seconds later to mark the time interval. This interval provided the child's reaction when he first saw the social robot NAO in the session. As the special training session continued where it left off, the time interval was marked by pressing the button on the bracelet in the same way when the affect would be given, but this time, the social robot NAO gave the affect differently. During this interval, the child's reaction to the emotion given by the social robot

NAO was recorded through the data.

Fig. 2. Feedback is given by the social robot NAO during the special education session

The children were asked to complete the Pediatric Motivation Scale, first for the traditional special education session and then for the special education session involving the NAO robot. The scale questions were read aloud to the children, and their responses were recorded.

III. METHODOLOGY

The system consists of four main parts: data collection, data processing, feature extraction, and feature selection using statistical analysis. (Figure 3).

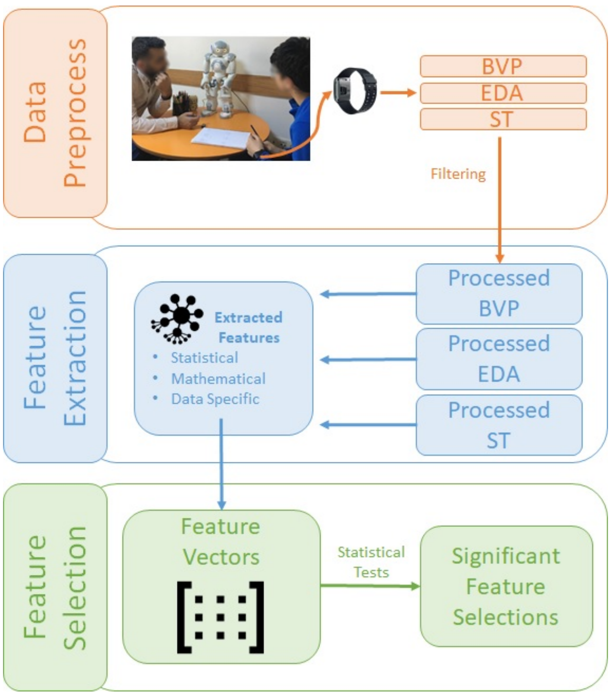

Fig. 3. System Flowchart

A. Data Collection

The EDA sensor was used to record Skin Conductivity (SC) data at a sampling rate of 4 Hz, while the photoplethysmograph (PPG) sensor was used to acquire BVP data at a sampling rate of 64 Hz. The infrared thermopile was also used to collect ST data at a sampling rate of 4 Hz. Finally, the EDA and ST sensors data was upsampled to 64 samples per second to ensure that all sensors captured equal samples.

B. Physiological Data Processing

All experimental setups were combined in a single device for data synchronization. The collection time of the physiological signals was synchronized with the device clock using the E4 Manager software. The E4 data were saved in Unix timestamp format. Synchronous timestamps with stimuli were gathered from each device during the experiment.

A sixth-order Chebyshev II filter with 18 dB stopband attenuation (Rs) and 0.1 Hz normalized stopband edge frequency (Wn) was used to preprocess the BVP signal. A fifth-order Savitzky-Golay filter with a frame length parameter equal to 11 was used to preprocess the EDA signal. No additional filtering was applied to the ST signal.

C. Feature Extraction

104 features were extracted from the physiological signals collected under two conditions: sessions with NAO and sessions without NAO. Statistical, mathematical, and time-domain Heart Rate Variability (HRV) features associated with emotional states [34] were extracted from the BVP signal (Table II). Frequency domain HRV features were excluded from this study due to the requirement of at least a two-minute observation time for their accurate computation. A total of 20 features were extracted from the BVP signal.

TABLE II
HRV AND STATISTICAL FEATURES FOR BVP

Abbreviation	Description
BVP_bpm	Beat per Minute
BVP_med	Median of the BVP
BVP_min	Minimum of the BVP
BVP_max	Maximum of the BVP
BVP_var	Variance of the BVP
BVP_kurt	Kurtosis of the BVP
BVP_skew	Skew of the BVP
BVP_peak_min	Peak minimum distance of the BVP
BVP_peak_max	Peak maximum distance of the BVP
BVP_mad	Mean absolute difference
BVP_sdnn	Standard Deviation of NN Intervals
BVP_sdsd	Standard Deviation of Successive Differences
BVP_rmssd	Root Mean Square of Successive Differences
BVP_pnn20	Percentage of successive R-R intervals that differ by more than 20 milliseconds
BVP_pnn50	percentage of successive R-R intervals that differ by more than 50 milliseconds
BVP_zero_cross	Number of zero crossings
BVP_sd1	Standard Deviation 1
BVP_sd2	Standard Deviation 2
BVP_s	Standard Deviation of the R-R Intervals
BVP_pos_peak	Positive peak of BVP

Detailed explanation for the HRV metrics can be found in [34].

The EDA signal comprises two components: Tonic EDA (SCL) and Phasic EDA (SCR). While SCRs are characterized by rapid and smooth transient events, SCL is associated with smooth variations in the EDA signal [35]. The EDA signal was decomposed into SCL and SCR components to enhance the observation of signal characteristics. 21 features were extracted from the raw EDA signal, SCL, and SCR (Table III). Consequently, 63 features were extracted for the EDA signal analysis. SCL_zcr and EDA_zcr features were excluded because they did not provide sufficient data to evaluate their significance. Furthermore, 21 statistical and mathematical features were extracted from the raw ST signal (Table III). Two ST features, ST_mad and ST_zcr, didn't provide sufficient results for evaluating their significance; thus, 19 ST features were utilized for significant feature analysis.

TABLE III
EXTRACTED FEATURES

Abbreviation	Description
Signal_mean	Mean of the signal
Signal_med	Median of the signal
Signal_std	Standard deviation of the signal
Signal_min	Minimum of the signal
Signal_max	Maximum of the signal
Signal_skew	Skewness of the signal
Signal_kurt	Kurtosis of the signal
Signal_q05	0.05 Quantile of the signal
Signal_q25	0.25 Quantile of the signal
Signal_q75	0.75 Quantile of the signal
Signal_q95	0.95 Quantile of the signal
Signal_var	Variance of the signal
Signal_ran	Range of the signal
Signal_ppv	$Signal_{max}$ / $Signal_{min}$
Signal_iqr	Inter-quartile-range of the signal
Signal_coeffvar	Coefficient of variation of signal
Signal_mad	Mean absolute deviation
Signal_rms	Root mean square
Signal_sma	Simple moving average
Signal_zcr	Zero crossing rate
Signal_ppr	$Signal_{max}$ / $Signal_{mean}$

"Signal" represents EDA, SCR of EDA, SCL of EDA, and ST

D. Statistical Tests to Find the Significant Features

Kolmogorov-Smirnov test was employed to evaluate the distribution of physiological signal features within the dataset [36], [37]. The t-test [38] was applied to the features that exhibited a normal distribution [21], [39]. The Mann-Whitney U test detected significant differences [40], [41] for physiological features that did not exhibit a normal distribution.

IV. RESULTS

A. Subjective Evaluation

12 children liked the robot interaction and wanted the social robot NAO to come to their other classes. 5 children thought it would not make any difference if they had an NAO robot in their class. 4 children did not want to express their opinion. Furthermore, families also thought children's abilities could be revealed more with robots, and this robot can also be used in other courses. Special education teachers were also asked to share their opinions. Although some special education teachers initially had negative thoughts about the effectiveness of the study in the classroom, they testified that it was very effective for some children as they recruited more children. Here is the feedback after the sessions: i) This is the first time we have had such a long attention span and enthusiastic lesson with my student with an attention deficit problem, ii) There could have been more kinds of affects, iii) The lesson was fun because the robot made it interesting to the class with its affects, iv) I was also very excited when I first saw the robot, v) The robot could be more valuable if it could communicate with students, vi) At the beginning of the study, I thought that the robot would not have any affect, but I observed that it was very effective in increasing the participation in the lesson and completing the task, especially in boys and vii) I think the social robot can be very effective, especially in children diagnosed with specific learning disabilities.

TABLE IV
THE PEDIATRIC MOTIVATION SCALE (PMS)

		PMS After Special Educators
PMS After Robot	z	-3,218
	p	0,001

B. The Pediatric Motivation Scale (PMS)

PMS was applied first for the special education session and then for the special education session involving the social robot NAO. A statistically significant difference was observed in favour of the sessions involving the robot ($p < 0.05$) (Table IV).

C. Statistical Tests

The results of the t-Test for the normally distributed BVP features and the Mann-Whitney U Test for the non-normally distributed BVP features were presented in Table V. According to the results, there is no significant difference ($p < 0.05$) between the BVP features except BVP_skew (Table V). It could be seen that BVP features did not differentiate the effect of the use of social robot NAO in special education sessions.

TABLE V
STATISTICAL TEST RESULTS FOR THE BVP FEATURES

Student's t-Test			Mann-Whitney U Test		
Feature Name	t	p	Feature Name	U	p
BVP_med	-1.69	0.09	BVP_sdsd	2126	0.49
BVP_min	0.37	0.71	BVP_pnn20	2222	0.25
BVP_skew	**2.34**	**0.02**	BVP_pnn50	1913	0.67
BVP_peak_max	-0.43	0.66	BVP_max	2257	0.18
			BVP_var	2112	0.53
			BVP_kurt	1946	0.85
			BVP_peak_min	1993	0.97
			BVP_sdnn	2112	0.53
			BVP_rmssd	2126	0.49
			BVP_bpm	2074	0.66
			BVP_mad	2046	0.76
			BVP_sd1	2126	0.49
			BVP_sd2	2111	0.54
			BVP_s	2120	0.51
			BVP_pos_peak	2257	0.18
			BVP_zero_cross	1648	0.10

All EDA, SCL, and SCR features exhibited non-normal distributions except SCL_skew. SCL_skew was significant when the t-test was applied ($p<0.05$). The results of the Mann-Whitney test were presented in Table VI. 12 features were found to be statistically significant ($p < 0.05$). It could be inferred that the features primarily associated with

TABLE VI

STATISTICAL TEST RESULTS FOR THE EDA FEATURES

Mann-Whitney U-Test					
Feature Name	U	p	Feature Name	U	p
EDA_mean	1743	0,24	SCL_q95	1724	0,20
EDA_med	1747	0,25	SCL_var	1587	0,05
EDA_min	1843	0,49	SCL_coeffvar	1618	0,07
EDA_std	**1565**	**0,04**	SCL_iqr	1630	0,08
EDA_kurt	1738	0,23	SCL_mad	1691	0,15
EDA_skew	1585	0,05	SCL_rms	1744	0,24
EDA_ran	**1568**	**0,04**	SCL_sma	1650	0,10
EDA_q25	1752	0,26	SCL_ppv	1644	0,10
EDA_q75	1745	0,24	**SCL_ppr**	**1545**	**0,03**
EDA_q05	1803	0,38	SCR_mean	1825	0,44
EDA_q95	1720	0,20	SCR_median	1952	0,87
EDA_var	**1565**	**0,04**	SCR_min	2334	0,09
EDA_coeffvar	**1550**	**0,03**	**SCR_std**	**1559**	**0,04**
EDA_iqr	1655	0,11	SCR_kurt	1684	0,14
EDA_mad	1682	0,14	SCR_skew	1808	0,39
EDA_rms	1742	0,24	**SCR_ran**	**1544**	**0,03**
EDA_sma	1650	0,10	**SCR_max**	**1499**	**0,02**
EDA_ppv	1673	0,13	SCR_q05	2331	0,09
EDA_ppr	**1416**	**0,00**	SCR_q95	1591	0,05
SCL_mean	1742	0,24	**SCR_var**	**1559**	**0,04**
SCL_med	1752	0,26	SCR_coeffvar	1750	0,25
SCL_min	1768	0,29	SCR_iqr	1743	0,24
SCL_std	1587	0,05	SCR_mad	1741	0,23
SCL_kurt	1992	0,97	**SCR_rms**	**1560**	**0,04**
SCL_ran	1619	0,07	**SCR_sma**	**1570**	**0,04**
SCL_max	1728	0,21	SCR_zcr	1819,5	0,42
SCL_q75	1745	0,24	SCR_ppv	2314	0,11
SCL_q05	1776	0,31	SCR_ppr	1755	0,26
SCL_q25	1752	0,26	SCR_q25	2247	0,20
EDA_max	1711	0,18			
SCR_q75	1741	0,23			

TABLE VII

STATISTICAL TEST RESULTS FOR THE ST FEATURES

Student's t-Test			Mann-Whitney U Test		
Feature Name	t	p	Feature Name	U	p
ST_mean	**-4,25**	< 0.01	ST_Std	1996	0,96
ST_median	**-4,24**	< 0.01	ST_kurt	1946	0,85
ST_min	**-4,20**	< 0.01	ST_ran	2031	0,82
ST_skew	0,71	0,48	ST_Var	1996	0,96
ST_max	**-4,29**	< 0.01	ST_coeffvar	2044	0,77
ST_q25	**-4,24**	< 0.01	ST_iqr	2138	0,45
ST_q75	**-4,28**	< 0.01	ST_sma	1616	0,07
ST_q05	**-4,20**	< 0.01	ST_ppv	2076	0,66
ST_q95	**-4,28**	< 0.01	ST_ppr	2061	0,71
ST_rms	**-4,25**	< 0.01			

TABLE VIII

CHANGES IN SIGNIFICANT FEATURES

Feature Name	WoR $\rightarrow$ WR	Percentage
BVP_skew	↑	59.68
EDA_std	↑	66.13
EDA_ran	↑	62.90
EDA_var	↑	66.13
EDA_coeffvar	↑	64.52
EDA_pp	↑	62.90
EDA_ppr	↑	66.13
SCL_ppr	↑	54.84
SCR_std	↑	69.35
SCR_ran	↑	68.25
SCR_max	↑	74.19
SCR_var	↑	69.35
SCR_rms	↑	69.35
SCR_sma	↑	66.67
ST_mean	↑	87.10
ST_med	↑	87.10
ST_min	↑	87.10
ST_max	↑	85.48
ST_q25	↑	87.10
ST_q75	↑	87.10
ST_q05	↑	87.10
ST_q95	↑	87.10
ST_rms	↑	87.10

WoR: Without Robot, WR: With Robot

SCR amplitude played a role in distinguishing the impact of utilizing a social robot in social education sessions. It has also been noticed that significant features related to EDA, SCL, and SCR increased when interacting with the social robot NAO (Table VIII). SCR has been shown to increase in response to novel stimuli [29], [30]. Furthermore, features generated from EDA and SCR have been used to understand positive emotional arousal as in excitement or happiness [31].

The normally distributed ST features were assessed using the t-test, and the non-normally distributed features were analyzed using the Mann-Whitney U Test (Table VII). 9 features were identified as statistically significant ($p < 0.05$). It has also been noticed that significant features related to ST increased when interacting with the social robot NAO (Table VIII). ST has been found to increase with happiness [31]. It has also previously shown that mean ST increased with attention [42].

V. CONCLUSION

This study on incorporating social robots into special education sessions for children with special needs demonstrated a notable impact on enhancing the children's excitement and motivation. According to the results of the Pediatric Motivation Scale (PMS), it was found that children exhibited higher motivation during sessions in which the social robot NAO was used. A statistical analysis from the features obtained using physiological signals, including Blood Volume Pulse (BVP), Electrodermal Activity (EDA), and Skin Temperature (ST), resulted in increased features that denoted an increase in children's excitement and positive emotions in the presence of the social robot NAO. Furthermore, the subjective evaluations from children, families, and special education teachers supported the quantitative findings by expressing their preferences for including NAO in special education sessions. These evaluations from participants and educators corroborated the quantitative findings, highlighting the potential of social robots to complement traditional educational approaches.

Note that the results should be interpreted cautiously due to the small sample size, and further research with a larger population will be performed in the future. Furthermore, the interaction between the NAO robot and children is conducted only a single time, which can be crucial since the existence of the robot, not the functionality of a robot, might trigger the excitement and motivation of the children because it was the first time for children to face the robot. Thus, as a future work, a robot-based educational session will be repeated for weeks or months to evaluate if children's excitement is still triggered.

REFERENCES

[1] E. S. Shourmasti, R. Colomo-Palacios, H. Holone, and S. Demi, "User experience in social robots," *Sensors*, vol. 21, no. 15, p. 5052, 2021.

[2] J. Dawe, C. Sutherland, A. Barco, and E. Broadbent, "Can social robots help children in healthcare contexts? a scoping review," *BMJ paediatrics open*, vol. 3, no. 1, 2019.

[3] A. Taheri, M. Alemi, A. Meghdari, H. Pouretemad, and S. Holderread, "Clinical application of humanoid robots in playing imitation games for autistic children in iran," *Procedia-Social and Behavioral Sciences*, vol. 176, pp. 898–906, 2015.

[4] C. A. Costescu, B. Vanderborght, and D. O. David, "Reversal learning task in children with autism spectrum disorder: a robot-based approach," *Journal of autism and developmental disorders*, vol. 45, pp. 3715–3725, 2015.

[5] A.-L. Popescu, N. Popescu, C. Dobre, E.-S. Apostol, and D. Popescu, "Iot and ai-based application for automatic interpretation of the affective state of children diagnosed with autism," *Sensors*, vol. 22, no. 7, p. 2528, 2022.

[6] W. Johal, "Research trends in social robots for learning," *Current Robotics Reports*, vol. 1, pp. 75–83, 2020.

[7] S. Lemaignan, A. Jacq, D. Hood, F. Garcia, A. Paiva, and P. Dillenbourg, "Learning by teaching a robot: The case of handwriting," *IEEE Robotics & Automation Magazine*, vol. 23, no. 2, pp. 56–66, 2016.

[8] G. A. Papakostas, G. K. Sidiropoulos, C. I. Papadopoulou, E. Vrochidou, V. G. Kaburlasos, M. T. Papadopoulou, V. Holeva, V.-A. Nikopoulou, and N. Dalivigkas, "Social robots in special education: A systematic review," *Electronics*, vol. 10, no. 12, p. 1398, 2021.

[9] M. Pivetti, S. Di Battista, F. Agatolio, B. Simaku, M. Moro, and E. Menegatti, "Educational robotics for children with neurodevelopmental disorders: A systematic review," *Heliyon*, vol. 6, no. 10, 2020.

[10] B. Coşkun, P. Uluer, E. Toprak, D. E. Barkana, H. Kose, T. Zorcec, B. Robins, and A. Landowska, "Stress detection of children with autism using physiological signals in kaspar robot-based intervention studies," in *2022 9th IEEE RAS/EMBS International Conference for Biomedical Robotics and Biomechatronics (BioRob)*, 2022, pp. 01–07.

[11] S. N. B. Aktaş, P. Uluer, B. Coşkun, E. Toprak, D. E. Barkana, H. Köse, T. Zorcec, B. Robins, and A. Landowska, "Stress detection of children with asd using physiological signals," in *2022 30th Signal Processing and Communications Applications Conference (SIU)*, 2022, pp. 1–4.

[12] S. Takir, H. Kose, B. Coskun, and D. E. Barkana, "Rppg detection in children with autism spectrum disorder during robot-child interaction studies," in *2022 International Conference on Digital Image Computing: Techniques and Applications (DICTA)*, 2022, pp. 1–5.

[13] A. Amirova, N. Rakhymbayeva, E. Yadollahi, A. Sandygulova, and W. Johal, "10 years of human-nao interaction research: A scoping review," *Frontiers in Robotics and AI*, vol. 8, p. 744526, 2021.

[14] O. Pino, G. Palestra, R. Trevino, and B. De Carolis, "The humanoid robot nao as trainer in a memory program for elderly people with mild cognitive impairment," *International Journal of Social Robotics*, vol. 12, pp. 21–33, 2020.

[15] V. Egido-García, D. Estévez, A. Corrales-Paredes, M.-J. Terrón-López, and P.-J. Velasco-Quintana, "Integration of a social robot in a pedagogical and logopedic intervention with children: a case study," *Sensors*, vol. 20, no. 22, p. 6483, 2020.

[16] K. Baraka, M. Couto, F. S. Melo, A. Paiva, and M. Veloso, ""sequencing matters": Investigating suitable action sequences in robot-assisted autism therapy," *Frontiers in Robotics and AI*, vol. 9, p. 784249, 2022.

[17] H. Feng, M. H. Mahoor, and F. Dino, "A music-therapy robotic platform for children with autism: A pilot study," *Frontiers in Robotics and AI*, vol. 9, p. 855819, 2022.

[18] H. N. Green, M. M. Islam, S. Ali, and T. Iqbal, "Who's laughing nao? examining perceptions of failure in a humorous robot partner," in *2022 17th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, 2022, pp. 313–322.

[19] I. A. Valagkouti, C. Troussas, A. Krouska, M. Feidakis, and C. Sgouropoulou, "Emotion recognition in human–robot interaction using the nao robot," *Computers*, vol. 11, no. 5, p. 72, 2022.

[20] J. Li, J. Zhong, and N. Wang, "A multimodal human-robot sign language interaction framework applied in social robots," *Frontiers in Neuroscience*, vol. 17, p. 1168888, 2023.

[21] E. Toprak, S. N. Bilgin Aktas, B. Coşkun, P. Uluer, H. Kose, and D. E. Barkana, "Investigation of physiological features by age groups in children with autism," in *2023 IEEE 36th International Symposium on Computer-Based Medical Systems (CBMS)*, 2023, pp. 287–292.

[22] B. Coşkun, S. Ay, D. Erol Barkana, H. Bostanci, İ. Uzun, A. B. Oktay, B. Tuncel, and D. Tarakci, "A physiological signal database of children with different special needs for stress recognition," *Scientific data*, vol. 10, no. 1, p. 382, 2023.

[23] B. Coskun, D. E. Barkana, I. Uzun, H. Bostancı, and D. Tarakcı, "Classification of stress and participation using physiological signals of children during serious game-based therapy," in *2023 Medical Technologies Congress (TIPTEKNO)*, 2023, pp. 1–4.

[24] A. Landowska, A. Karpus, T. Zawadzka, B. Robins, D. Erol Barkana, H. Kose, T. Zorcec, and N. Cummins, "Automatic emotion recognition in children with autism: A systematic literature review," *Sensors*, vol. 22, no. 4, 2022.

[25] S. Takir, E. Toprak, P. Uluer, D. Erol Barkana, and H. Kose, "Exploring the potential of multimodal emotion recognition for hearing-impaired children using physiological signals and facial expressions," in *Companion Publication of the 25th International Conference on Multimodal Interaction*, 2023, pp. 398–405.

[26] P. Uluer, H. Kose, E. Gumuslu, and D. E. Barkana, "Experience with an affective robot assistant for children with hearing disabilities," *International Journal of Social Robotics*, vol. 15, no. 4, pp. 643–660, 2023.

[27] B. Coşkun, D. E. Barkana, İ. Uzun, H. Bostancı, and D. Tarakçı, "Classification of stress and participation using physiological signals of children during serious game-based therapy," in *2023 Medical Technologies Congress (TIPTEKNO)*. IEEE, 2023, pp. 1–4.

[28] B. Coşkun, P. Uluer, E. Toprak, D. E. Barkana, H. Kose, T. Zorcec, B. Robins, and A. Landowska, "Stress detection of children with autism using physiological signals in kaspar robot-based intervention studies," in *2022 9th IEEE RAS/EMBS International Conference for Biomedical Robotics and Biomechatronics (BioRob)*. IEEE, 2022, pp. 01–07.

[29] J. T. Cacioppo, L. G. Tassinary, and G. Berntson, *Handbook of psychophysiology*. Cambridge university press, 2007.

[30] O. N. Rahma, A. P. Putra, A. Rahmatillah, Y. S. K. A. Putri, N. D. Fajriaty, K. Ain, and R. Chai, "Electrodermal activity for measuring cognitive and emotional stress level," *Journal of Medical Signals and Sensors*, vol. 12, no. 2, p. 155, 2022.

[31] S. D. Kreibig, "Autonomic nervous system activity in emotion: A review," *Biological psychology*, vol. 84, no. 3, pp. 394–421, 2010.

[32] K. Merve and T. T. ŞİMŞEK, "Pediatrik motivasyon ölçeği turkçe formunun geçerlik ve guvenirliği," *Journal of Exercise Therapy and Rehabilitation*, vol. 5, no. 2, pp. 116–124, 2018.

[33] S. A. Navaee, R. Abedanzadeh, S. Salar, and M. R. Sharif, "The effects of positive normative feedback on learning a throwing task among children with autism spectrum disorder," *Nursing and Midwifery Studies*, vol. 7, no. 2, pp. 87–89, 2018.

[34] F. Shaffer and J. P. Ginsberg, "An overview of heart rate variability metrics and norms," *Frontiers in public health*, p. 258, 2017.

[35] H. F. Posada-Quintero and K. H. Chon, "Innovations in electrodermal activity data collection and signal processing: A systematic review," *Sensors*, vol. 20, no. 2, 2020.

[36] E. Peralta, J. Lazaro, R. Bailon, V. Marozas, and E. Gil, "Optimal fiducial points for pulse rate variability analysis from forehead and finger photoplethysmographic signals," *Physiological measurement*, vol. 40, no. 2, p. 025007, 2019.

[37] H. F. Posada-Quintero, T. Dimitrov, A. Moutran, S. Park, and K. H. Chon, "Analysis of reproducibility of noninvasive measures of sympathetic autonomic control based on electrodermal activity and heart rate variability," *IEEE Access*, vol. 7, pp. 22 523–22 531, 2019.

[38] P. Mishra, U. Singh, C. M. Pandey, P. Mishra, and G. Pandey, "Application of student's t-test, analysis of variance, and covariance," *Annals of cardiac anaesthesia*, vol. 22, no. 4, p. 407, 2019.

[39] K.-S. Cheng, Y.-S. Chen, and T. Wang, "Physiological parameters assessment for emotion recognition," in *2012 IEEE-EMBS Conference on Biomedical Engineering and Sciences*, 2012, pp. 995–998.

[40] T. W. MacFarland, J. M. Yates, T. W. MacFarland, and J. M. Yates, "Mann–whitney u test," *Introduction to nonparametric statistics for the biological sciences using R*, pp. 103–132, 2016.

[41] M. K. Uçar, M. R. Bozkurt, C. Bilgin, and K. Polat, "Automatic detection of respiratory arrests in osa patients using ppg and machine learning techniques," *Neural Computing and Applications*, vol. 28, pp. 2931–2945, 2017.

[42] R. C. Vergara, C. Moënne-Loccoz, and P. E. Maldonado, "Cold-blooded attention: finger temperature predicts attentional performance," *Frontiers in human neuroscience*, vol. 11, p. 454, 2017.