Visual metrics for educational videogames linked to socially assistive robots in an inclusive education framework

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Abstract. In gamification, the development of "visual metrics for educational video games linked to social assistance robots in the framework of inclusive education" seeks to provide support, not only to regular children but also to children with specific psychosocial disabilities, such as those diagnosed with autism spectrum disorder (ASD). However, personalizing each child's experiences represents a limitation, especially for those with atypical behaviors. 'LOLY,' a social assistance robot, works together with mobile applications associated with the family of educational video game series called 'MIDI-AM,' forming a social robotic platform. This platform offers the user curricular digital content to reinforce the teaching-learning processes and motivate regular children and those with ASD. In the present study, technical, programmatic experiments and focus groups were carried out, using open-source facial recognition algorithms to monitor and evaluate the degree of user attention throughout the interaction. The objective is to evaluate the management of a social robot linked to educational video games through established metrics, which allow monitoring the user's facial expressions during its use and define a scenario that ensures consistency in the results for its applicability in therapies and reinforcement in the teaching process, mainly adaptable for inclusive early childhood education.

Keywords: Autism, Gamification, Teaching-Learning, Human-Robot-Game, ASD, Educational Digital Games, Usability.

1 Introduction

Today, video games are becoming increasingly popular within people's entertainment activities and are attracting the interest of researchers about their opportunities for studies in players [1]. The new generations access electronic devices at an increasingly young age. This widespread access is in addition to making them dexterous when using them, opens up a window of opportunities for researchers in which the use of new technologies as a learning tool is studied [2]. The positioning of smartphones and tablets as indispensable artifacts of contemporary life makes it possible to implement educational video games on these devices as part of the gamification strategies applied to regular and inclusive education.

Videogames, known as educational digital games (EDG) or serious games, contribute a fun way to teach content. This contribution creates a good impression about gamification, increasing acceptance levels among users, capturing children's attention and reinforcing their learning [3], and improving their well-being and mental health [4]. In the realization of serious games, especially for special and inclusive education, patients diagnosed with particular health or psychosocial conditions must participate from the first stage of developing the application or the game [5].

On the other hand, social assistance robots (SAR) used together with EDGs contribute to the learning process by encouraging user interaction and active listening [6]. The platform created as part of this research called MIDI-LOLY is a Human-Robot-Game (HRG) platform in which a social robot, 'LOLY,' is linked with different digital educational games [7]. These EDGs are made up of animated stories about primary education curricular content and level games called MIDI-AM (an acronym for Children's Interactive Educational Multimedia), developed as mobile applications [8]. Together, it seeks to improve the learning experience of children, who are studying the first years of primary education, and especially to capture and motivate the attention of children with autism spectrum disorder (ASD), thus promoting inclusive education [7].

ASD is a neurological and developmental condition commonly diagnosed during childhood. It remains for life and influences interpersonal communication and the learning process, presenting restricted and repetitive behaviors, interests, and activities [9]. Several studies have used social robots for educational purposes in children with ASD, hoping to assess their contribution to the learning process. Similarly, studies involving human-computer interaction indicate that educational video games help reduce apathy and distraction, characteristic of their behavior [10, 11]. Similar attention patterns have been found in video games tested by users with ASD and with regular or known neurotypical users, using a gaze locator [12].

The social assistance robots used in gamification are a relatively new technology that focuses on developing intelligent robots capable of assisting in social interactions. Some authors have already highlighted the importance of their use in establishing interactive software-robotics-videogames environments as learning tools to teach and achieve rehabilitation of children with ASD [13]. Social assistance robots can offer personalized and affordable therapeutic assistance to children with ASD [14]. The biggest challenge is that children with ASD have apparent differences in language proficiency and variations in cognitive ability [15], social behavior, and understanding [16]. Due to this variation, the learning styles across the spectrum are not uniform, so there are different methods currently used to work with these groups [17]. For this reason, the study of gaming or gamification techniques is also essential since some methodological adjustment may be required to achieve the desired objectives [18].

In some cases, when interacting with robots and with EDG, children with ASD show social behaviors, such as imitation, robot eye gaze, and joint attention, which may be helpful in possible treatments [19, 20]. It is argued that these social behaviors, rare in children with ASD, can be caused by the robot and spontaneously on other occasions [21]. Therefore, variations such as linking the robot to an EDG for increasing children's potential, in terms of the degree of attention, are proposed [7]. Therefore, the need arises to carry out some monitored follow-up of the Human-Robot-Game interaction to evaluate results of use and behavior.

In this sense, there are alternatives for open-source facial recognition algorithms with which different visual characteristics of the user can be monitored and evaluated throughout the interaction. One of them is the OpenFace application, which allows performing a facial analysis of the user during the interaction with the LOLY social robot and the games of the MIDI-AM family. In addition, with visual monitoring, an observational operator can be dispensed with to provide an interpretation when the Game-Robot-Child interaction session is finished.

Therapies for children with ASD using social robots in conjunction with EDGs is a new field that aspires to develop novel treatments to improve the quality of learning and behaviors of children and their families. For this purpose, it is essential to develop tools that evaluate the Child-Robot and Child-Game interactivity utilizing parameters such as the degree of attention and the times of activity and concentration.

2 Materials and methods

For the present explanatory study, field tests were developed in educational support centers working with regular or neurotypical children and with ASD. Focus groups and technical measurement of the results were carried out for the observation processes of the Robot-Game use activity and the evaluation of programmatic results.

2.1 Sample

The selected technique is cluster sampling, dividing the children into two groups. The first group comprises neurotypical children with ASD, play together with LOLY, and an EDG from the MIDI-AM series. The second group works with children who play with the same EDG selected for the first group, but only using the Tablet. The total focal sample was 11 children with ages between four and eight years. Of this sample, five are neurotypical children, and six are children with grade one and two ASD (high and medium achievement). Each child played between 10 and 12 minutes on average, time estimated to be enough to complete each of the five chapters of the monitored EDG of the MIDI-AM series called 'Anibopi.' The game used for the tests focuses on the teaching of living and non-living beings. The interaction of each child with the MIDI-LOLY platform was individual, and only the presence of the child, her representative, and a trained observer or technician were allowed to assist if required. All sessions were recorded on audio and video, with the written authorization of each representative.

2.2 Data collection

The data collection for the analysis and evaluation of the recorded interactions is carried out in two different processes. On the one hand, there are the games of the MIDI-AM family, which are capable of running on an Android tablet or phone, linked or not to the LOLY robot. These applications collect data throughout the interaction and store it in an interchange format log file called JSON (JavaScript Object Notation). This file contains valuable variables for the analysis of performance in the interaction, such as the number of game stories viewed, correct and incorrect answers, number of withdrawals, the average time to complete a level, among other variables necessary to evaluate the usability and playability of MIDI-AM applications. In addition, the social assistance robot providing support and encouraging participation in children allows the complete interaction to be recorded on audio and video. Likewise, the LOLY robot can work with various applications of the MIDI-AM series (as shown in Fig. 1). However, the 'Anibopi' application is used exclusively for the experiments in this study.

The video that is produced during the game is stored in the cloud and later processed with OpenFace. This analysis finally produces a file in CSV (comma-separated values) format with variables of interest such as confidence level, emotions, head position, and eye gaze. The MIDI dashboard is an online platform where all the data interactions corresponding to any of the applications that make up the MIDI-AM family are stored. Therefore, each JSON generated by the mobile application plus the video data processed by OpenFace are stored in this medium. The dashboard serves as a storage space and environment in which the present analysis of the data available for each interaction can be accessed.

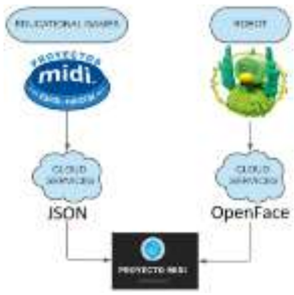

Fig. 1. The general architecture of the MIDI-LOLY platform

2.3 Visual Control Tool

OpenFace is open-source software that allows facial recognition using neural networks, and in this case, it is used to monitor emotions and degrees of attention through the position of the head and the gaze of the eye [22]. The data is obtained from a video coming from a camera located on LOLY's forehead. In this way, the software is used through a program in Node.js in which the user sends an image or a video for subsequent facial recognition analysis; later, it returns a CSV file with the results of the analysis [23].

Face detection. - A restricted local neural fields (CLFN) model is used for the detection of facial points. This model can identify 68 facial points and is continuously improved by training the distribution of the points in different groups (eyes, lips, and eyebrows) [22]. From the coordinates of each facial point, identifiable emotions are determined, such as neutrality, anger, surprise, happiness, sadness, and disinterest.

Head position. - the position of the head is estimated from the 68 facial points previously identified. This identification is possible because the software uses a three-dimensional representation for facial points and displays them in the image using an orthogonal projection of the camera. Although the program needs to have calibration parameters for the camera (focal length and main point), it can work without them using an estimate based on the size of the image [22]. Binary variables were created from the raw outputs of the program. Two possible scenarios are considered, one in which the head is perpendicular and the other in which the head is tilted downward.

Eye Gaze. - Work was done in conjunction with the modules concerning the analysis of face detection. Once the position of the pupil and the eye have been detected, the CLFN model will use this information to generate variables that allow estimating the gaze of the eye [24]. Four possible scenarios are considered in which the user can direct his attention: 1) to the robotic face, 2) to the robotic bust, 3) to the Tablet, or 4) he is simply not paying attention to the interaction. The facial points, head movements in three axes, and gaze estimation are shown in Fig. 2.

Fig. 2. Facial Points / Head Movement / Eye Gaze - OpenFace

2.4 Required settings

Once the output variables are described, the experiments help determine that the position of the head and the eye's gaze variables depending considerably on the setting in which the tests are carried out because they work with angles. Meanwhile, the emotions work correctly, regardless of the scene-river in which the interaction takes place.

Head position uses the variables Pose_Rx, Pose_Ry, and Pose_Rz to determine whether the user's head is perpendicular to the camera or tilted downward. These variables are in radians, so they are transformed to sexagesimal degrees.

On the other hand, the eye's gaze uses the variables gaze_angle_x, gaze_angle_y, and uses the binary variables c_perpendicular and c_inc_down to control the child attending the interaction. The gaze_angle_x and gaze_angle_y variables are in radians, so they are also transformed to sexagesimal degrees.

Finally, the emotions are identified with the facial points located by the program. Regardless of the scenario in which the interaction occurs, correct detection of the face allows determining the emotion during observation. Several test videos were made with the focus groups and tests in a computer laboratory to analyze results.

2.5 Stage

The interaction took place in a therapy room especially suitable for the care of children with ASD of the Asperger Ecuador Foundation. A table, chair with standard dimensions used in therapies with children focused the child's height from the robot's camera in everyday attention situations. For the Tablet with the game installed, a support device was used to keep it vertical in order to be able to visualize the front of the child's gaze more appropriately. The LOLY robot was about 60cm from the child's face, while the Tablet was about 30cm (as shown in Fig. 3). However, the main problem is the amplitude of the video captured from the forehead of the LOLY robot when using a fisheye lens. With this lens, the environment is widely captured and less of the child subject of study. This matter implies that the area occupied in the painting by the child's face is smaller than the external space captured, and as a result, the facial points are more concentrated. Furthermore, the camera's height (see Fig. 3.c) is much higher than the level of the child's head. All of this makes it difficult in the first instance to make correct estimates with face recognition software (as shown in Fig. 3.b).

Fig. 3. Interaction scenario: a) General scheme; b) Frame captured by LOLY's camera; and c) Camera location in LOLY

3 Results

3.1 OpenFace Results

Although the focus group tests were carried out with 11 children, they needed to wear a mask, given the current pandemic situation, making it difficult to analyze their recordings using OpenFace. Only one representative agreed to allow the child to carry out the interaction without a mask, always with her consent and considering all biosecurity measures. The results found for one of the children, recorded without a mask, are described below. This child, whom we will call RsbO, is seven years old and currently receives regular virtual classes of primary education, but with a basic knowledge of curricular content in the Natural Environment area, about living and non-living beings, that is the topic covered by the game used for the evaluation.

Fig. 4 shows that the child paid attention to the LOLY robot for 71% (Fig. 4.b) of the interaction time, while to the Tablet only 27% (Fig. 4.a). Overall, the records indicated that the child was 98% attentive to all interaction (Fig. 4.c). These results, together with those of the dashboard, show excellent participation of the child during the five stories with content about 'The Beings' that the game presents, guided by instructions given by the LOLY robot. No dropouts or incorrect answers occurred during the game activities, adding up to a total of 10/10 correct answers.

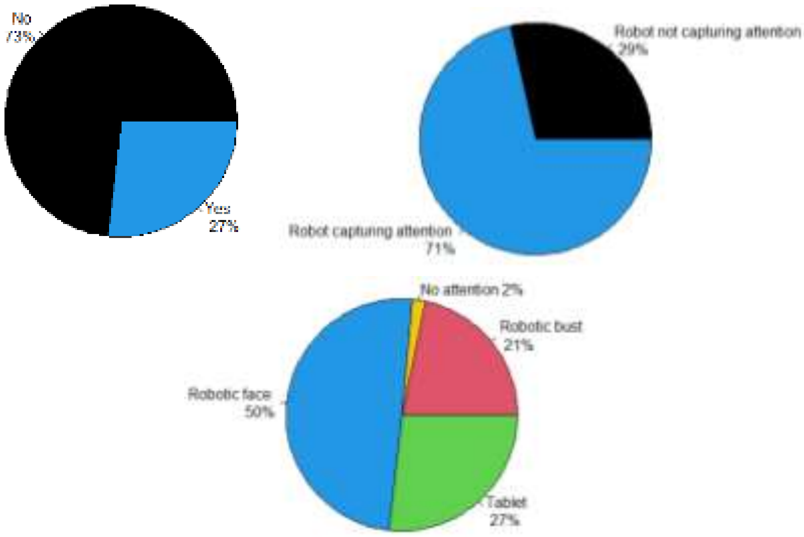

Fig. 4. Attention results obtained with OpenFace

Furthermore, Fig. 5 shows that, in the case of the RsbO child, he remained 71% of the time with his head in a perpendicular position, which, as previously mentioned, was the condition to determine that the child was looking at the robot. In addition, he spent 27% of the time observing the Tablet and only 2% neglecting the interaction. Therefore, taking into account 12 minutes of intervention, 98% of attention is a high and promising percentage.

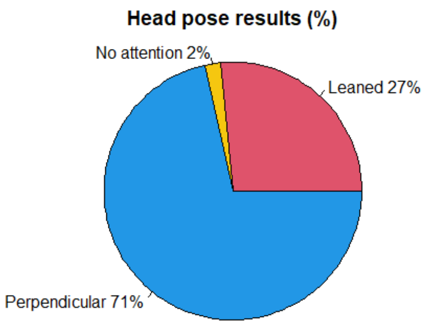

Fig. 5. Attention results (head position) obtained with OpenFace

Following those mentioned above, it is suggested that LOLY is not a distraction for children during the learning process, since despite the high degree of attention they pay to the robot, their performance in the game is not affected. On the contrary, it is observed that it stimulates the child's attention when giving instructions or indicating whether he corrects the answers or movements that the robot must perform in the game.

Regarding the evaluation of feelings or moods, as shown in Fig. 6, it is positive that 67% and 12% of the total time, the child has reflected happiness and surprise on her face, respectively. Additionally, as a result of evaluating emotional situations, it is detected that it is not relevant that 2% of the time, the child has shown disinterest. Mainly, when comparing this data with the results that the MIDI dashboard metrics show, it was identified that this child did not make any mistakes in all the interactions.

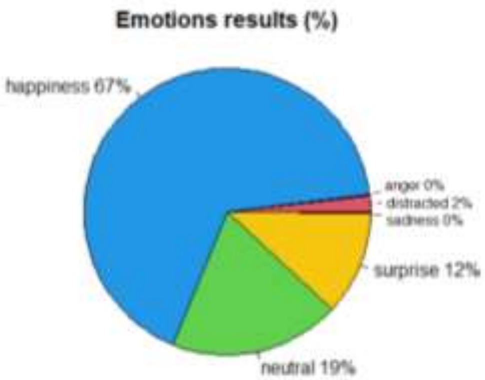

Fig. 6. Empathy results obtained with OpenFace

The mood at different specific moments of the game still needs to be analyzed as a whole to determine in which specific parts of the game the child shows a particular type of emotion. However, within this stage of the study, it was not possible to analyze the combination of these results.

3.2 Dashboard results

The results from the MIDI-AM dashboard for the focal test carried out with children who played for the first time with the Robot LOLY, and Anibopi can be seen in Fig. 7. This figure shows that they all had the same number of hits, in this case, 12 and that three of them had at least one mistake. Only two children showed a higher number of mistakes. These cases are assumed to be related to the child's age, who is barely four years old, the youngest in the sample, and with a low level of literacy justifiable at his age. Furthermore, he had no knowledge of the Natural Environment; Unlike the other three children, who have already received regular classes and are currently receiving virtual classes. Child 4 is also highlighted (with whom the test was carried out with the full face), who did not have any mistakes and had a previous knowledge base on the content of Natural Environment. It should be noted that the number of attempts presents a significant variance. Nevertheless, this variance is also determined by the times they played the games, since in most cases, they repeated the same, noting that they wanted to continue playing with LOLY and the Tablet.

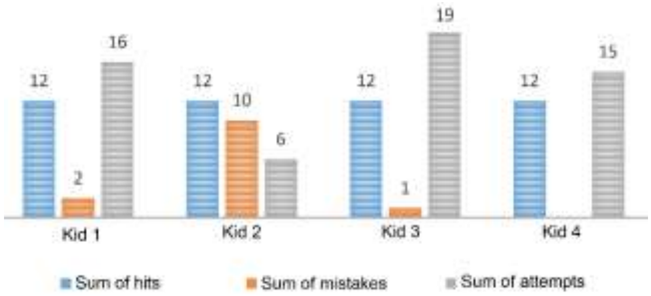

Fig. 7. Empathy results obtained with OpenFace

Additionally, Fig. 8 shows the first round of games performed without LOLY on the focal tests, while Fig. 9 shows the second round of games with LOLY. Both graphs highlight tests 3 and 8 ("pr3", "pr8", identification codes of neurotypical children), which obtained the same number of correct answers in both the first and second tests. However, the number of mistakes and attempts with the pr3 child slightly increased while playing with LOLY. Something similar happens with test 6 ("pr6" child ASD), but there was no mistake when playing on stage with the robot in this test. Besides, in the pr6 child, there are many attempts and fewer hits than the test without LOLY. This child's results suggest, in the first instance, that LOLY may be a partial distractor for children with ASD and neurotypical when it comes to performing a game action. However, this did not represent a negative point by showing that the number of attempts increases with LOLY. On the contrary, this indicates the children's desire to continue playing with the intervention of the robot, seeking to achieve more outstanding successes than mistakes with the help of LOLY, especially in the case of children with ASD.

Fig. 8. Empathy results obtained with OpenFace without 'LOLY.'

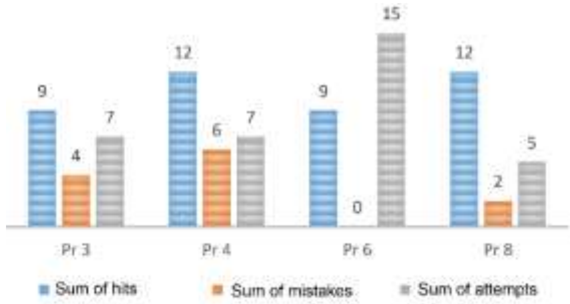

Fig. 9. Empathy results obtained with OpenFace with 'LOLY.'

Except for the above, test 4 ("pr4") reflected a more significant number of hits and missed with LOLY, unlike the scenario without the robot, but maintaining the same number of attempts in both cases. Thus, the observed result of this scenario was mainly due to the learning curve of the pr4 child, mainly due to their initial learning conditions. However, obtaining higher hits without increasing the number of attempts allows us to deduce LOLY's contribution to the interaction. It is generally identified that children stay in the game longer when they are motivated by LOLY's intervention.

It should be noted that the focal tests were carried out periodically in three different sessions with similar results. However, it is highlighted that the hypotheses raised about moods or emotions have not yet been fully verified. This matter happens due to the videos of all the children could not being processed with the parameters established in the program due to the use of a mask during the sessions.

4 Discussion and conclusion

A study of the Human-Robot-Game (HRG) platform was carried out to analyze the work of a social assistance robot interacting with educational digital games (EDG) used by a child in a therapeutic session like a game. In addition, this platform providing support seeks to encourage the active participation of children with ASD and neuro-typicals in their educational learning activities. The current work is a baseline for developing improvements between the social robot LOLY and the MIDI-AM series video games such as Anibopi. This research is considered innovative and relevant, as it does not identify studies that have documented similar tests of the functioning of EDG with Robotics in children through the evolution of use metrics and facial recognition. The degrees of emotion and attention captured through videos during the game's action are verified within these metrics.

Focus groups were carried out with several children, but in particular with one child identified as RsbO. The scenario in which the interaction with RsbO was carried out, although it was not ideal, made it possible to confirm the viability of the OpenFace facial recognition program as a tool for analyzing the degree of attention; Likewise, it allowed to identify possible improvements required in the EDGs and particularly in the robot. It was evidenced that the place where the camera is located in the face of the

LOLY robot is not the most appropriate. This matter occurs due to the degrees of movement in the head that the robot has. In other words, when LOLY moves her head, she is also moving the camera. For this reason, specific observations reached atypical degrees, making it difficult to estimate the position of the head and the gaze of the eye. Therefore, the location of the robot's camera is suggested, preferably on the chest, which would considerably improve the degree of vision and precision of movement during the recording of the child's evaluation.

Hypotheses raised as follows: LOLY improves the learning experience of neurotypical children or children with ASD; LOLY is not a distraction for children during the learning process; o LOLY is a stimulus to capture the child's attention and keep playing. One of the most relevant hypotheses in the educational field is to evaluate if a social robot like LOLY is more effective in children who do not know the area to which the content of the game that is guided by the robot is dedicated, such as the analyzed case of the Anibopi game, on the Natural Environment.

In the study carried out, it has not been possible to answer all the questions, given the limitations caused by the COVID-19 pandemic, which caused, for example, the impossibility of being able to do specific tests in focus groups without the use of masks. However, the scenario under which it is possible to carry out the tests in the best conditions is determined, that is an appropriate position of the LOLY camera, efficient distance from the child to the robot, the need for not mandatory use of a mask, and a sample uniform of evaluated that allows creating more representative subsamples.

We suggest for further investigation adds in the MIDI-AM dashboard the playtimes of the child for the different activities of the game. This playtime recorded will help contrast the information provided by the OpenFace facial recognition software to determine or rule out which parts of the application the joint use of the robot-game generates negative or primarily positive emotions in ASD neurotypical children to improve its therapeutic or educational use.

References

[1] Villani, D., Carissoli, C., Triberti, S., Marchetti, A., Gilli, G., and Riva, G. 2018.: Videogames for Emotion Regulation: A Systematic Review. Games Health Journal., 7:85-99. doi: 10.1089/g4h.2017.0108

[2] Bartoli, L., Corradi, C., Garzotto, F., and Valoriani, M. 2013. Exploring motion-based touchless games for autistic children's learning.

[3] Proceedings of the 12th International Conference on Interaction Design and Children. doi: 10.1145/2485760.2485774.

[4] Gros, B. 2007.Digital games in education: Me design of games-based learning environments. Journal of Research on Technology in Education, 40: 23-38. doi: 10.1080/15391523.2007.10782494.

[5] Cheng, V.W.S., Davenport, T., Johnson, D., Vella, K., and Hickie, I.B. 2019. Gamification in apps and technologies for improving mental health and well-being: systematic review. JMIR mental health, 6: e13717.

[6] Sardi, L., Idri, A., and Fernández-Alemán, J.L. 2017. A systematic review of gamification in e-Health. Journal of Biomedical Informatics, 71: 31-48. doi:10.1016/j.jbi.2017.05.011.

[7] Feil-Seifer, D., and Matarić, M.J. 2005. Defining socially assistive robotics. Proceedings of the 2005 IEEE 9th International Conference on Rehabilitation Robotics. doi: 10.1109/ICORR.2005.1501143.

[8] Paillacho, D.F., Solorzano, N.I., and Paillacho, J.S. 2021. LOLY 1.0: A Proposed Human-Robot-Game Platform Architecture for the Engagement of Children with Autism in the Learning Process. Proceeding of the 1st International Conference on Systems and Information Science. doi: 10.1007/978-3-030-59194-6_19.

[9] Solórzano, N.I., Elizalde, E.S., Carrera, D.A., Park, D.H., and Sornoza, L.I. 2020. MIDI-AM Model to Identify a Methodology for the Creation of Innovative Educational Digital Games: A Proposed Serious Game Methodology Based on University Research Experiences. In P. Ariana Daniela Del & R. Nuria Lloret (Eds.), Improving University Reputation Through Academic Digital Branding, pp. 133-167. IGI Global, Hershey, PA, USA. doi: 10.4018/978-1-7998-4930-8.ch009

[10] Buescher, A.V., Cidav, Z., Knapp, M., and Mandell, D.S. 2014. Costs of autism spectrum disorders in the United Kingdom and the United States. JAMA pediatrics, 168: 721-728. doi:https://doi.org/10.1001/jamapediatrics.2014.210

[11] Contreras, R.S., Serra, A., and Terrón, J.L. 2019. Games and ADHD-ADD: A Systematic Mapping Study. Acta Ludologica, 2: 4-26.

[12] Kozima, H., Nakagawa, C., and Yasuda, Y.2005. Interactive robots for communication-care: A case-study in autism therapy. Proceedings of the 14th IEEE Workshop on Robot and Human Interactive Communication. doi: 10.1109/ROMAN.2005.1513802.

[13] Finke, E.H., Wilkinson, K.M., and Hickerson, B.D. 2017. Social Referencing Gaze Behavior During a Videogame Task: Eye Tracking Evidence from Children With and Without ASD. Journal of Autism and Developmental Disorders, 47: 415-423. doi:10.1007/s10803-016-2968-1.

[14] Dautenhahn, K.. 2000. Design issues on interactive environments for children with autism.Proceedings of the the 3rd Int Conf on Disability, Virtual Reality and Associated Technologies.

[15] Clabaugh, C., Ragusa, G., Sha, F., and Matarić, M. 2015. Designing a socially assistive robot for personalized number concepts learning in preschool children. . Proceedings of the 5th Joint International Conference on Development and Learning and Epigenetic Robotics. doi:10.1109/DEVLRN.2015.7346164.

[16] Volkmar, F.R., Paul, R., Rogers, S.J., and Pelphrey, K.A. 2014. Handbook of autism and pervasive developmental disorders, diagnosis, development, and brain mechanisms. John Wiley & Sons, New Jersey, USA.

[17] Rice, K., Moriuchi, J.M., Jones, W., and Klin, A. 2012. Parsing heterogeneity in autism spectrum disorders: Visual scanning of dynamic social scenes in school-aged children. Journal of the American Academy of Child and Adolescent Psychiatry 51:238-248. doi:10.1016/j.jaac.2011.12.017. J.

[18] Meyers, B., Goin-Kochel, R., and Mackintosh, V. 2005. Therapies for children with autism spectrum disorders: How many are children using. Proceedings of the biennial meeting of the Society for Research in Child Development.

[19] Constain M., G.E., Collazos O., C., and Moreira, F. 2019. The Gamification in the Design of Computational Applications to Support the Autism Treatments: An Advance in the State of the Art. Proceedings of the World Conference on Information Systems and Technologies. doi: 10.1007/978-3-030-16187-3_19

[20] Robins, B., Dickerson, P., Stribling, P., and Dautenhahn, K. 2004. Robot-mediated joint attention in children with autism: A case study in robot-human interaction. Interaction Studies, 5: 161-198. doi: 10.1075/is.5.2.02rob

[21] Scassellati, B. 2007. How social robots will help us to diagnose, treat, and understand autism. In: Thrun S., Brooks R., Durrant-Whyte H. (eds) Robotics Research. Springer Tracts

in Advanced Robotics, pp. 552-563. Springer, Berlin, Heidelberg. doi: 10.1007/978-3-540-48113-3_47

[22] Colton, M.B., Ricks, D.J., Goodrich, M.A., Dariush, B., Fujimura, K., and Fujiki, M. 2009. Toward therapist-in-the-loop assistive robotics for children with autism and specific language impairment. Proceedings of the 23rd Convention of the Society for the Study of Artificial Intelligence and Simulation of Behaviour.

[23] Baltrusaitis, T., Zadeh, A., Lim, Y.C., and Morency, L.P. 2018. OpenFace 2.0: Facial behavior analysis toolkit. Proceedings of the 13th IEEE International Conference on Automatic Face and Gesture Recognition. doi: 10.1109/FG.2018.00019

[24] Baltrusaitis, T. 2019. Output Format OpenFace. GitHub. https://github.com/TadasBaltrusaitis/OpenFace/wiki/Output-Format.

[25] Baltrusaitis, T., Robinson, P., and Morency, L.P. 2016. OpenFace: An open-source facial behavior analysis toolkit. Proceedings of the IEEE Winter Conference on Applications of Computer Vision. doi: 10.1109/WACV.2016.7477553.