EasyDraw: a motion rehabilitation tool for children with autism

Roberta Simeoli[a,b], Cristiana D'Amore[a] ,Davide Marocco[a]

[a] University of Naples Federico II, Department of Humanistic Studies, Naples, 80138, Italy
[b] Neapolisanit S.R.L. Rehabilitation Center, Ottaviano NA 80044, Italy

Abstract

In line with the recent findings on motor abnormalities in autism spectrum disorder, this study presents a tool designed on a new concept of rehabilitation based on a "sensorimotor re-education". We propose the use of visual-spatial and auditory stimuli to "augment" the physical reality of the child and strengthen the kinesthetic and sensory information, with the aim of rehabilitating action planning processes using tasks based on implicit procedural learning.
The work presents the software "EasyDraw", a co-adaptive child-computer interface that controls the sensorimotor feedback through "forced" cause-effect relationships.
Our preliminary findings demonstrate that individuals with autism have spontaneous sensory-motor adaptive abilities and that this can play a pivotal role in rehabilitation processes.

Keywords

Autism, Motor rehabilitation, Human-computer interaction

1. Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by some specific impairments related to social interaction, communication and restricted behaviors, interests, and activities, which are repetitive and stereotyped. In addition, abnormalities in ASD include motor dysfunctions [1][2][3][4]. Autistic individuals may have delayed development of the fundamental movement skills, which results in difficulties in organization and planification and coordination of movements. Normally, at 3 months of age typically developing (TD) children learn to coordinate their limbs using their physical movements to self-discovery, through coordination models that lead them to achieve systematically a goal that has not been instructed or commanded [5].

Several studies focused on delayed motor development in autism and tried to understand these abnormalities. They focused on how the body perceives and acts for individuals with autism. Masterton and Biederman (1983) [6] tried to understand how motor control systems work in individuals with ASD, specifically, they questioned on goal directed movements. They suggested that their motor style is focused on proprioceptive information, rather than on visual information [7]. This result was later confirmed by other [8][9]. These studies indicated that individuals with ASD fail more when asked to program a movement towards a target positioned afar, in that case, in fact, proprioceptive information must be integrated with sensory information (e.g. visual stimuli) to complete the action [10].

Some authors, on the other hand, have reconsidered movement as the result of re-afferent feedback from the environment, whose information is shaped from the periphery to the central nervous system (CNS). At this level, movement plays a fundamental role in the intentional control of action. Torres E. B. in the 2011 [11] describes micro-movements as the result of these re-afferent feedback which lead to precise patterns of movement, which contribute to the regulation, coordination and control of the action. These motor actions are on a gradient of movement variability, from involuntary to goal-directed movements. Spontaneous or reflex movements can be considered as innate and embedded in natural and rhythmic socially influenced sequences from the very first months of life [12].

Proccedings of the Third Symposium on Psychology-Based Technologies (PSYCHOBIT2021), October 4–5, 2021, Naples, Italy
EMAIL: roberta.simeoli@unina.it (A. 1); cris.damore@studenti.unina.it (A. 2); davide.marocco@unina.it (A. 3)
ORCID: 0000-0001-7564-6816 (A. 1); 0000-0001-5185-1313 (A. 3)

In autism, the development of this type of movement is damaged, as results we observe abnormalities during the execution of motor actions (e.g., clumsiness, tiptoe walking, poor limb coordination, impaired eye-hand coordination).

These perspectives fit with Embodied Cognition theory [13], as far as, cognition is the result of experience and experience itself is the result of body-world interaction. “The body, through its sensorimotor abilities, draws biological, psychological and cultural information from the environment” [14]. According to this principle, human behavior can be defined as the result of human actions, environmental changes and their consequences on future behavior itself. This exchange is more than merely adaptive. The body is the first and main means through which human beings interface with the world. The development process relies on the integration of the information from the body (proprioceptive stimuli) and the surrounding world (sensorial stimuli). According to this statement, it may be useful to treat autism also through a sensorimotor re-education

In the last twenty years, some authors identified these motor abnormalities as typical motion patterns for autism [15][16][17][18][19][20]. These studies also play an important role for diagnostic process, given the limitations related to the diagnostic process for autism [21]. On the other hand, another important issue is to identify a valid therapeutic and rehabilitative approach to repair this damage.

Recently, some authors have wondered if it was possible to exploit the adaptive capacities of autistic individuals to work on the self-regulation of their goal-directed movements. The aim was to reshape the connection between intention and action, reinforcing the causal relationship through the use of visual and / or auditory feedback. Motor index detection was used to measure and test the quality of their movements [22].

In line with previous results and the recent studies that demonstrated the effectiveness of hi-tech tools for rehabilitation [23][24], this study presents “EasyDraw”, a software designed to work on re-organize movement planning schemes. Some preliminary descriptive findings have been reported in results session. The target of the task is stimulating the integration of sensory feedbacks, through "forcing" cause-effect relationship between their own action and the world’s “reaction”. This study fits within the research field of embodied cognition, and aim to enhance autism rehabilitation processes, towards a "sensorimotor re-education".

2. Methodology

2.1. Participants

The present study is a pilot study and involved 5 children diagnosed with ASD recruited at the Neapolisanit s.r.l. rehabilitation center. The participants were all males between the ages of 6 and 9. At the time of the study, three of the participants, were following a training with a hi-tech augmentative alternative communication tool (AAC) LI-AR [24], so they were familiar with the use of tablets.

For privacy reason we named participants with alphabetic code: A.A., E.E., G.F., G.G., P.P..

2.2. Materials

EasyDraw software was developed in Unity, using C#. A tablet with touch-sensitive screens was used to record movement coordinates of dragging movement on the screen during the task. The App consists of 2 different scenes that alternate each other. The first one (Figure 1) is a totally white screen where the user can move his finger drawing a multicolor line. This line is designed to disappear within few seconds from the touch, with the same speed and style of the movement performed. The second scene plays a short video.

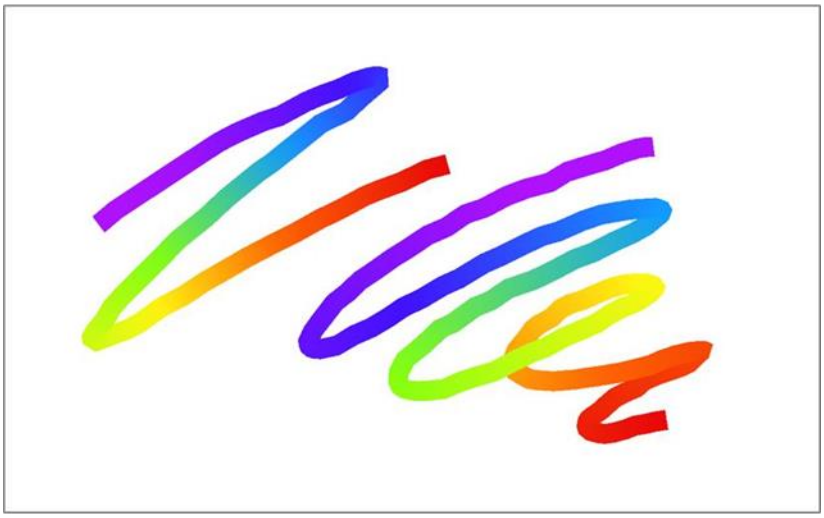

Figure 1: The image shows the first scene, the white screen and the multicolor line derived from the user's dragging movement.

Switching between the two scenes occurred when the user performed some precise movements. In particular, the software was designed to randomly choose a "target area" on the screen. The target area is always invisible to the user and, each time the user touches the area, a 13 second video starts. The video plays consecutive parts of music video and / or episodes of cartoons selected among children's favorites, according to their parents or therapist report. The target area can be placed anywhere on the screen, and its position can change each time, according to the experimenter's settings. For the study, the position was set to change after 3 times the user reached the area itself within 40 seconds from the start of the probe.

The goal was to evoke voluntary but not goal-directed movements on the screen of a tablet. The trajectories resulting from this movement were recorded runtime as spatial coordinates (x; y). The software records: (a) the number of finite trajectories (Trt), as the set of coordinates resulting from the moment the user places his finger on the screen until he lifts it off the screen; (b) the set of Trt necessary to reach the area (GenTent); (c) the (Probe) as the number of attempts necessary for the area to change; (d) the position of the target area (PosA); (e) x, y coordinates of movement. (Figure 2)

F. D. - Blocco note di Windows

File Modifica Formato Visualizza ?

Trt; 1, Prob; 0, Gen Tent; 1, V0, 13/12/2020, 09:35:05:2664, PosA; 0.18, 6.77, PosTrt 1; -8.694292, -8.097622
Trt; 1, Prob; 0, Gen Tent; 1, V0, 13/12/2020, 09:35:05:3118, PosA; 0.18, 6.77, PosTrt 1; -8.451403, -8.048603
Trt; 1, Prob; 0, Gen Tent; 1, V0, 13/12/2020, 09:35:05:3280, PosA; 0.18, 6.77, PosTrt 1; -7.54239, -7.646422
Trt; 1, Prob; 0, Gen Tent; 1, V0, 13/12/2020, 09:35:05:3419, PosA; 0.18, 6.77, PosTrt 1; -7.038915, -7.411525
Trt; 1, Prob; 0, Gen Tent; 1, V0, 13/12/2020, 09:35:05:3629, PosA; 0.18, 6.77, PosTrt 1; -6.728407, -7.175975
Trt; 1, Prob; 0, Gen Tent; 1, V0, 13/12/2020, 09:35:05:3802, PosA; 0.18, 6.77, PosTrt 1; -6.222568, -6.832433
Trt; 1, Prob; 0, Gen Tent; 1, V0, 18/12/2020, 09:35:05:3960, PosA; 0.18, 6.77, PosTrt 1; -5.726104, -6.46728
Trt; 1, Prob; 0, Gen Tent; 1, V0, 18/12/2020, 09:35:05:4109, PosA; 0.18, 6.77, PosTrt 1; -4.566822, -5.393381
Trt; 1, Prob; 0, Gen Tent; 1, V0, 18/12/2020, 09:35:05:4263, PosA; 0.18, 6.77, PosTrt 1; -4.566822, -5.393381
Trt; 1, Prob; 0, Gen Tent; 1, V0, 18/12/2020, 09:35:05:4431, PosA; 0.18, 6.77, PosTrt 1; -3.841119, -4.704683
Trt; 1, Prob; 0, Gen Tent; 1, V0, 18/12/2020, 09:35:05:4565, PosA; 0.18, 6.77, PosTrt 1; -3.346625, -4.11691
Trt; 1, Prob; 0, Gen Tent; 1, V0, 18/12/2020, 09:35:05:4728, PosA; 0.18, 6.77, PosTrt 1; -2.907817, -3.521633
Trt; 2, Prob; 0, Gen Tent; 1, V0, 18/12/2020, 09:35:05:4903, PosA; 0.18, 6.77, PosTrt 1; -2.541117, -2.986789
Trt; 2, Prob; 0, Gen Tent; 1, V0, 18/12/2020, 09:35:05:5057, PosA; 0.18, 6.77, PosTrt 1; -2.324028, -2.540061
Trt; 2, Prob; 0, Gen Tent; 1, V0, 18/12/2020, 09:35:05:5235, PosA; 0.18, 6.77, PosTrt 1; -2.058805, -2.033225
Trt; 2, Prob; 0, Gen Tent; 1, V0, 18/12/2020, 09:35:05:5380, PosA; 0.18, 6.77, PosTrt 1; -1.827675, -1.529582

Figure 2: The figure shows a portion of the datasheet resulting from the task.

2.3. Procedure

During the test, the participants sat on small children's tables facing the therapist. For the pilot study experimenter set default settings for all the participants. The target area was 1.1 x 0.8 mm. The acquisition criteria for changing area was set to 3 probe in 40 sec. Participants received the tablet set on the white scene and no instructions were provided. If participants do not interact whit the tablet for 10 sec, therapist may suggest verbally or with some physical prompt to start exploring the screen. The goal was to obtain an interaction with the screen as autonomous as possible. Each participant could learn how to perform the task, without any external suggestion, so that the experience of their own actions would suggest the goal of their movement itself. The task was completed when the last video was played, regardless of the performance.

2.4. Measurement

The coordinate of movement were analyzed as: (a) MeanSpeed, the average speed values per Trial; (b) MeanAcceleration, the average acceleration values per trial; (c) Straightness index, the ratio between the distance of the starting and ending points of a trajectory and its length; (d) Directional change, the change in direction over time; (e) MeanLenght, the average amount of finite trajectories conducted during each task; (f) Trt, the average number of finite trajectories needed to reach the acquisition criterion for each Trial. In addition we observed the change in time spent to reach the target area as: (g) DTxT, the decreasing trend per trial obtained by the difference of time between first and last probe for each trial; (h) DT the general decreasing trend of time spent to reach the target area from the beginning to the end of the whole task.

3. Results

Participants engaged with task for an average duration of 7 min and 66 sec, with a minimum of 4 min and 11 sec and a maximum of 10 min and 45 sec. Each participants reached the target area for at least 2 times, conducting the number of probe necessary to complete the video. Their main speed was of 5.127298 mm/ms^2, while their average acceleration was 19.50328 mm/ms^2. The average STH value was 0.429447, for 2 of the participants this value showed an increasing trend within the trials. For all the participants, except for one of them, the DC value showed a decreasing trend.

All the participants showed a general sharp decrease in time spent to reach the target area (DT). An average decrease in time was recorded also for each trial. A.A. showed a 95% of DT and DTxT, G.F. had a 97% of DT and 91% of DTxT, G.G reached a 94% of DT and a 71% of DTxT, P.P. showed a weaker decrease with a 52% of DT and a 74,64% of DTxT. E.E. was the only one to show a non-consistent decreasing trend, in fact we observed an increasing trend (IT) of time during 2 trial amounted to 41% and a DT for the other two of 30%.

The differences emerged for E.E. triggered to a more detailed analysis of his movement performance. Furthermore we compared it with G.F. performance as his results were consistent to the group. Following a more detailed description of motion data for two of the participants. G.F. (Figure 3) and E.E. (Figure 4) showed the best performances reaching the greatest number of target area, but they also showed the most divergent features of movement. These 2 participants needed the fewest number of attempts to reach the acquisition criteria and thus change the target position. G.F. took 10 min and 54 sec to complete the task, and he reached the target area 18 times with an average of 3,75 probe per trial (3 was the minimum of probe necessary to the target area to change position). E.E. took 6 minute and 42 seconds to complete the task and he reached the target area 16 times with an average of 4 probe per trial.

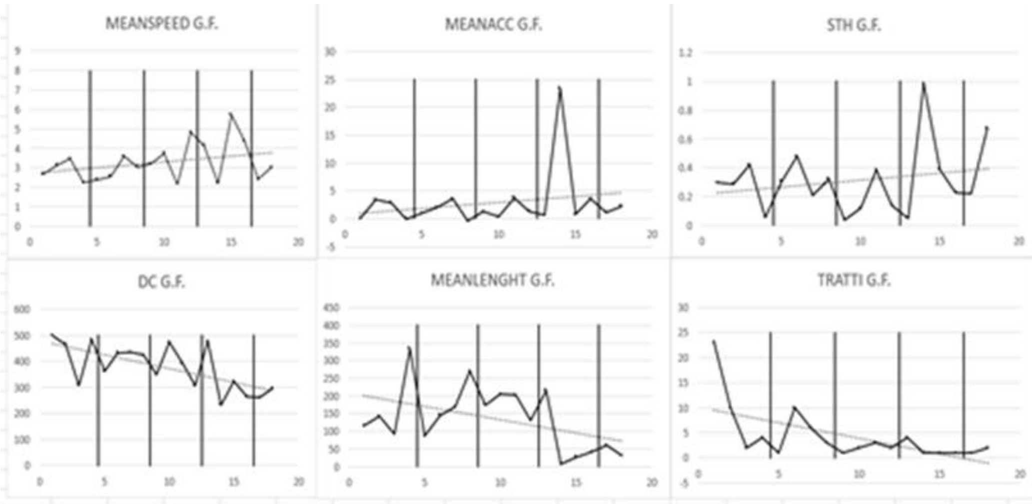

Figure 3: The graphs show the trend of some motion features during the G.F.'s performance. Respectively related to speed, acceleration, straightness, directional change, trajectory length and number of traits drawn during the performance, divided per trials.

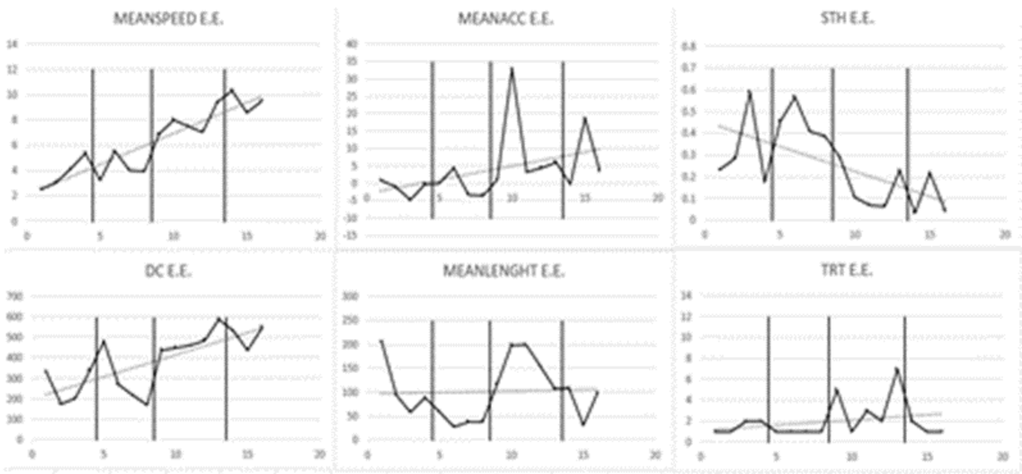

Figure 4: The graphs show the trend of some motion features during the E.E.'s performance. Respectively related to speed, acceleration, straightness, directional change, trajectory length and number of traits drawn during the performance, divided per trials.

4. Discussion

This study, overall, presents a new way of thinking about rehabilitation for children with autism. We focused on how autistic individuals perceive the world and integrate these information with their own body perception. In an embodied perspective we propose a rehabilitation process that, without any instruction, physical prompt or imitation aid, could stimulate the child to discover the world and the cause-effect relation between his action and the world reaction. The aim was to design a task that would provide an experiential acquisition rather than an habit, using an implicit learning process. At this point in the work, we still have limited results to confirm the statement but we obtained preliminary finding on motion learning trend.

In general, we observed that, despite some motor pattern differences, each participant was able to meet the acquisition criteria and complete the trial at least two times and at most 5 times, employing on average 7 min. Most of the participants showed an increasing trend in acceleration and speed values, a decreasing value for the DC measure, a decreasing number of finite trajectories (Trt) and mean length of these trajectory. Quite all participants showed a general decreasing trend in time spent reaching the area showing an adaptive behavior to the task. For some of the participants we observed divergent trend, regardless of the performance, as shown in Figure 3 and Figure 4.

Although G.F. and E.E. showed similar performance, their pattern of movement showed some interesting differences. E.E. showed the most atypical results, with a decreasing of STH and an increasing DC value, he drawn trajectories the most irregular. Furthermore, is evident an increase of trajectories' length as well as an increasing of number of finite trajectories drawn to complete the task. These movement pattern may suggest a gradual worsening of the performance, but this did not actually occur. These data reflect what has been observed during the experimentation. In fact, the observation of the experimental session and the therapist report, highlighted the presence of stereotyped behavior. Thus, these results could be probably due to the E.E.'s tendency to visually self-stimulate with the multicolor line produced during movement. So, during the task, whenever the white screen was presented, the child started to draw his multicolor line until he was satisfied and only after his self-stimulation was concluded he get the target area.

This result highlights that such a tool has the potential to provide new behavioral measures. A limitation of usability is also highlighted, in fact, it probably requires a greater customization level. For example, for children like E.E., the tool could be programmed to produce no visual effect during movement, but only the final consequence. Furthermore, this work, as mentioned, is inspired by the works of Torres, Yanovich, Metaxas from 2013 [22], in their study, the authors programmed the software to play the video as long as the participant stay in a certain position. Extensions of the present work could follow this direction, in order to strengthen the cause-effect dynamics. Further longitudinal studies and, a larger sample, are certainly necessary to observe both evolution over time and differences between individuals with ASD and other populations.

This study demonstrates that specific rehabilitation conditions, with little or no instruction, allow the children to independently discover the implicit goals of a task and independently learn how to plan their future actions in order to maximize the reward. Furthermore, analyzing this type of data, we may be able to quantify in real time the levels of predictability and reliability of the movement, from random to exploratory and goal-directed movements. The idea is that for ASD individuals the capacity of learning retention could be better and more effective if the interventions were based on spontaneous discovery rather than exclusively on explicit commands.

Through these activities could be possible to involve people with autism in spontaneous exploration, modulate their motor outputs according to external stimuli and make external reinforcements self-determined, leading to a more ecological learning process.

5. References

[1] Damasio, A. R., Maurer, R. G. (1978). A neurological model for childhood autism. Archives of Neurology, 35(12), 777-786.

[2] Donnellan, A. M., Hill, D., Leary, M. R. (1995). Movement Differences and Diversity in Autism/Mental Retardation: Appreciating and Acommodating People with Communication and Behavior Challenges. Madison, WI: DRI Press..

[3] Donnellan, A. M., Hill, D. A., Leary, M. R. (2013). Rethinking autism: implications of sensory and movement differences for understanding and support. Frontiers in Integrative Neuroscience, 6, 124. doi: 10.3389/ fnint.2012.00124.

[4] Esposito, M., Autism, I. J., Ijard-, R. D., Esposito, M., Sloan, J., Nappo, R., Fadda, R., Fotia, F., Napoli, E., Mazzone, L., Vicari, E. S. (2019). Sensory Processing, Gastrointestinal Symptoms and Parental Feeding Practices in The Explanation of Food Selectivity: Clustering Children with and Without Autism. International Journal of Autism & Related Disabilities, 2(1), 1–12. https://doi.org/10.29011/2642-3227.000020.

[5] Thelen, E., Fisher, D. M. (1983). From spontaneous to instrumental behavior: kinematic analysis of movement changes during very early learning. Child Dev. 54, 129–140. doi: 10.2307/1129869.

[6] Masterton B. A., Biederman G. B., (1983), "Proprioceptive versus visual control in autistic children", Journal of Autism and Developmental Disorders, vol 13, pp 141–152.

[7] Glazebrook, C., Gonzalez, D., Hansen, S., Elliott, D. (2009). The role of vision for online control of manual aiming movements in persons with autism spectrum disorders. Autism: the international journal of research and practice, 13(4), 411–433. https://doi.org/10.1177/1362361309105659.

[8] Mottron, L., Burack, J. A. (2001). Enhanced perceptual functioning in the development of autism. In J. A. Burack, T. Charman, N. Yirmiya, & P. R. Zelazo (Eds.), The development of autism: Perspectives from theory and research (p. 131–148). Lawrence Erlbaum Associates Publishers.

[9] Plaisted, K., O'Riordan, M., Baron-Cohen, S. (1998). Enhanced discrimination of novel, highly similar stimuli by adults with autism during a perceptual learning task. Journal of child psychology and psychiatry, and allied disciplines, 39(5), 765–775.

[10] Barakova, E. I., Chonnaparamutt, W. (2009). Timing sensory integration: Robot simulation of autistic behavior. IEEE Robotics and Automation Magazine, 16(3), 51–58. https://doi.org/10.1109/MRA.2009.933626.

[11] Torres, E. B. (2011). Two classes of movements in motor control. Experimental Brain Research, 215(3-4), 269-283.

[12] Condon, W., Sander, L. (1974). Synchrony Demonstrated between Movements of the Neonate and Adult Speech. Child Development, 45(2), 456-462. doi:10.2307/1127968.

[13] De Jaegher, H. (2013). Embodiment and sense-making in autism. Frontiers in Integrative Neuroscience, 7(3), 1–19. https://doi.org/10.3389/fnint.2013.00015I.

[14] Valera F. J., Thompson E., Rosch E., (1991) “The Embodied Mind: Cognitive Science and Human Experience”, MIT Press, pp 172-173.

[15] Goodwin, M. S., Intille, S. S., Albinali, F., Velicer, W. F. (2011). Automated detection of stereotypical motor movements. J. Autism Dev. Disord. 41, 770– 782.

[16] Goodwin, M. S., Haghighi, M., Tang, Q., Akcakaya, M., Erdogmus, D., Intille, S. (2014). “Moving towards a real-time system for automatically recognizing stereotypical motor movements in individuals on the autism spectrum using wireless accelerometry. UbiComp 2014,” in Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing, (New York, NY: ACM), 861–872. doi: 10.1145/2632048.2632096.

[17] Simeoli, R., Arnucci, M., Rega, A., Marocco, D. (2020). Movement detection software to enhance autism assessment processes. ACM International Conference Proceeding Series. https://doi.org/10.1145/3401956.3404246.

[18] Simeoli, R., Milano, N., Rega, A., Marocco, D. (2021). Using Technology to Identify Children With Autism Through Motor Abnormalities. 12(May), 1–11. https://doi.org/10.3389/fpsyg.2021.635696.

[19] Simeoli, R., Rega, A., Marocco, D. (2019). Micro-movement as an objective measure to assess autism spectrum disorder. Qwerty, 14(2), 49–65. https://doi.org/10.30557/QW000017.

[20] Anzulewicz, A., Sobota, K., Delafield-Butt, J. T. (2016). Toward the Autism Motor Signature: Gesture patterns during smart tablet gameplay identify children with autism. Scientific Reports, 6(8), 1–13. https://doi.org/10.1038/srep31107.

[21] Ferrara, R., Nappo, R., Ansermet, F., Ricci, P., Massoni, F., Carbone, G., Sparaci, A., Nonnis, E., Ricci, L., Ricci, S. (2021). The impact of dsm-5 on the diagnosis of autism spectrum disorder. Psychiatric Annals, 51(1), 38–46. https://doi.org/10.3928/00485713-20201205-01

[22] Torres, E. B., Brincker, M., Isenhower, R. W., Yanovich, P., Stigler, K. A., Nurnberger, J. I., Metaxas, D. N., José, J. V. (2013). Autism: The micro-movement perspective. Frontiers in Integrative Neuroscience, 7, Article 32. https://doi.org/10.3389/fnint.2013.00032.

[23] Nappo, R., Iorio, M., Somma, F. (2020). ASTRAS: A software for the assessment and training of executive functions in children. CEUR Workshop Proceedings, 2730, 1–10.

[24] Simeoli, R., Iovino, L., Rega, A., Marocco, D. (2020). LI-AR: An integration of technology and ABA methodology to improve communicative behavior in autism. CEUR Workshop Proceedings, 2730, 1–6.