ASTRAS, A PLATFORM FOR THE COGNITIVE TRAINING OF EXECUTIVE FUNCTIONS IN CHILDREN WITH NEURODEVELOPMENTAL DISORDERS: PRELIMINARY USABILITY AND GAME EXPERIENCE TESTING

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Abstract

Executive functions (EF) may be defined as those cognitive processes which are crucial for a goal-directed activity and allow for an individual to meet environmental demands.

A deficit of the executive functions has been reported in several neurodevelopmental disorders chiefly among them attention deficit/hyperactivity disorder (ADHD) and learning specific disorder (LSD) and it is well known the extent to which this deficit affects the clinical condition, academic achievement, socialization as well as the inhibition of maladaptive and/or aggressive behaviours.

A growing interest about alternative methods for the assessment and training of executive functions in children is emerging since the technology has been considerably advancing and gamification makes the cognitive interventions more engaging and enjoyable.

The present work aims to describe ASTRAS, a software for the assessment and training of executive functions in children, and the data about the usability and game of experience in two samples of children: with typical (N= 378) an atypical (N=37) development.

Results demonstrated satisfying positive responses during the interaction of children in both samples with the software (es. they report liking the platform, manifest enjoyment or found it entertaining). Furthermore, children found the software easy to use and a small percentage of them ask for a support from the therapist.

Bind together, our results show that ASTRAS is usable and engaging for users and it triggers positive emotional reactions among them, which makes it promising for the assessment and training of executive functions in children.

Keywords: Executive Functions, Cognitive Training, Computer-Based rehabilitation, Gamification.

1 INTRODUCTION

Executive Functions (EFs) can be defined as un umbrella term for higher-order cognitive functions, required to direct behaviour toward a goal. EFs includes attention (i.e., the concentration on some phenomenon and the exclusion of other stimuli), inhibition (i.e., the ability to inhibit dominant responses), working memory (WM, i.e., remembering task-relevant information), updating (i.e., updating and monitoring information in the WM, replacing old and no longer relevant information with more relevant input), cognitive flexibility (i.e., switching between different tasks or instructions), and planning (i.e., choosing the necessary actions to reach a goal). These processes are necessary to cope with new and challenging environmental conditions and to regulate one's own behaviour [1]–[3]. Considering their definitions, EFs clearly play an important role both in atypical and typical development.

Despite the EFs role is not precisely defined in the etiopathogenesis of several neurodevelopmental disorders [4] and it seems not enough to distinguish among different clinical profiles [5], researchers agree that EFs impairment significantly affects the neurodevelopmental disorder's symptomatology. EFs are involved in many neurodevelopment disorders [6], [7], including Attention Deficit and Hyperactivity Disorder [8], Autism Spectrum Disorder [9], [10], Learning Disabilities [11], [12], but also in genetic syndrome (i.e., Prader-Willis) [13] and Intellectual Disabilities [14], [15].

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The variation in EFs abilities can be found also in typical development [16]. For example, children's EFs are strongly associated with academic achievement [17]. As a result, scholars and practitioners reported considerable interest in school-based interventions focusing on EFs, hypothesizing that an explicit focus on developing executive functioning skills in school could yield substantial gains in typical development student achievement [18].

Thus, in line with the Research Domain Criteria (RDoC) [19], attention should be focused on EFs difficulties to provide individualized support rather than assuming that all children with or without a certain disorder have the same abilities. Considering the role of EFs deficits in children with both atypical and typical development, the assessment and treatment of EFs have received considerable attention. Several authors [20] underlined the importance of including in the assessment different tasks to highlight the complexity of EFs. Other authors paid attention to the ecological validity of EFs measures, proposing challenging tasks that reflect the actual cognitive demands of everyday life [21]. Finally, cognitive classic tasks are often viewed as boring and repetitive, which negatively impact on data quality and reduce intervention effects. Growing evidence underlined the importance to take advantage of technology for neurodevelopmental disorders [22]–[24] and specifically to propose the use of alternative, more engaging, and enjoyable ways to assess and treat EFs [25].

All these aspects are included in gamification (i.e., the evaluation of skills through gaming activities with appropriate software). Gamification uses well-established procedures including several classic tasks, but it proposes challenging activities similarly to everyday life tasks, and adds all the typical game elements (scores, challenges, achievement of goals) to promote children's interest and attention. Specifically, these tasks are defined serious games (i.e., games designed with a primary goal other than entertainment) [26] and may provide a possible solution to difficulties relate to cognitive assessment, making its funnier and easier [27].

Several technological platforms have been released, but, to our knowledge, no one has developed a computer-based tool for the assessment of EFs in children with both neurodevelopmental disorder and typical development. Moreover, the importance of remote training was previously underconsidered, but, considering the current historical time, computer-based tools should allow therapist to start the training session from remote offering the opportunity to provide a telerehabilitation.

This work focuses on ASTRAS [28], a software developed at Neapolisanit, aiming at assessing and training EFs in children with neurodevelopmental disorders. The software was developed in the scientific research activity of the M.E.T.A. (Laboratory for the study and development of methodologies and learning technologies) of the Neapolisanit Rehabilitation Center s.r.l. of Ottaviano (Na), the technological start-up Garage94 s.r.l. and the spin-off Lab.da of the University of Padua. The present study aims to describe data about the usability and the experience of children with both atypical and typical development about the usage of the software.

2 THE SOFTWARE

ASTRAS is designed as a useful tool supporting the therapists during their treatments and, at the same time, a pleasant gaming environment for children both engaging and challenging. Firstly, in ASTRAS we sought to design a software for the assessment and training of the main executive functions in children with neurodevelopmental disorders. ASTRAS includes two different sessions, namely an assessment and training and the user interface (UI) has been designed to allow the therapist to set a training program taking into account the results of patients in the assessment session.

Importantly, in order to make ASTRAS more engaging for children we used some gamification principles, that is the application of typical elements of game playing to other areas of activity [29], [30]. Assessment and training tasks share the characteristics of game elements such as:

1. design: the assets of each task (i.e., scenario and characters) are cartoon-like. Furthermore, training's tasks share common themes (e.g. the space);
2. mechanics: tasks have been designed as challenges in which children can also compete with others;
3. components: assessment and training tasks have been designed with different levels of difficulty, in order to increase the load of the specific executive domain. Bind together, these game features aim to improve children engagement, motivation as well as learning and reduce the negative aspects of the cognitive assessment and training: the frustration and anxiety. Furthermore, ASTRAS hosts a wide range of tasks/games to make the gaming experience more variable and avoid delivering the same task.

Finally, in ASTRAS we targeted five main executive functions consistently with Miyake and colleagues [31], namely selective attention, working memory, inhibition, planning and cognitive flexibility. The rationale is that deficits of executive functions is more likely to be reported in children with neurodevelopmental disorders. Importantly, deficits of executive functioning are associated with: 1) a higher severity of the disorder [32]; 2) learning impairments (e.g. in ADHD patients) [4], [33], [34]; 3) problems with academic achievement [35], [36]; 4) maladaptive and/or aggressive behaviours [37]. On the other hand, atypically developing children seem to profit from working on executive functions since they acquire new strategies of self-regulation, goal-oriented behaviour, problem solving [38]. In other words, working on executive functions fosters the gains of the therapy.

2.1 Assessment design

Assessment includes ten tasks, two for each executive domain (selective attention, working memory, inhibition, cognitive flexibility and planning). Additionally, other two tasks have been developed to assess the updating of working memory. Each task consists of trials, which progressively increase in difficulty.

Below a small description of the tasks for each cognitive domain has been provided (see figure 1 for an example of the assessment tasks).

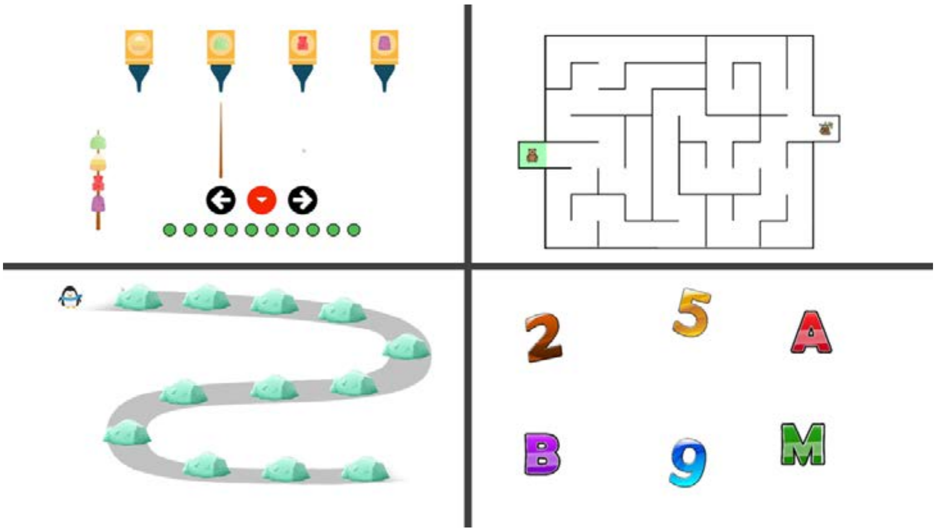

Figure 1. The figure shows the screenshots of four assessment tasks. From the top right-hand corner: Planning task, Maze task, Go-No Go task; Trail task.

Cancellation. It assesses the visual selective attention. In this task, children are shown a clutter of items, and asked to tap with their finger the target item (e.g. a star), ignoring the other stimuli.

Listening. It assesses the auditory selective attention. In this task, children are provided a sequence of animal sounds. They have to tap a paw on the centre of the screen when they hear a target sound (e.g. a frog).

Sequence of quantity. It assesses the working memory. In this task, a sequence of numbers appears on the screen. Children have to repeat the sequence either forward or backward.

Visual sequence. It assesses the visuo-spatial working memory. In this task, a sequence of flashing stars is visualized on the screen. The participant has to reproduce the sequence either forward or backward.

Auditory updating. It assesses the auditory updating of working memory. In this task, children listen to the tones in sequence. After each tone is heard children decide whether the new tone is the same from 1 (1-Back) or 2 trials (2- Back) before.

Visual updating. It assesses the visuo-spatial updating of working memory. In this task, children have to decide whether the position of a ghost is the same of 1 (1-Back) or 2 trials (2-Back) before.

Go-No Go. It assesses the motor inhibition. In this task, children have to move a penguin only when he/she listen to a GO sound.

Matching. It assesses the cognitive inhibition. In this task, children have to identify, from a subsequent set of stimuli, the one that "matches" the sample. Color-shape association: it assesses the cognitive flexibility.

In this task, children have to choose, from two stimuli displayed on the top of the screen, the one that has the same target criterion of the sample (shape or color). The target criterion is provided by the software.

Trail. It assesses the cognitive flexibility. In this task, children have to tap in ascending order a clutter of numbers and letters.

Maze. It assesses the planning. In this task, children must trace through a maze without crossing the maze lines.

Planning. It assesses planning. In this task, children have to reproduce a picture (e.g. a cake) in a given number of steps.

Importantly, the assessment is mandatory to unlock the training exercises. The rationale is that the training part needs to rely on a cognitive profile highlighting individual's strengths and weaknesses in order to be efficient.

2.2 Training design

Training includes 40 tasks/games (see figure 2 for an example).

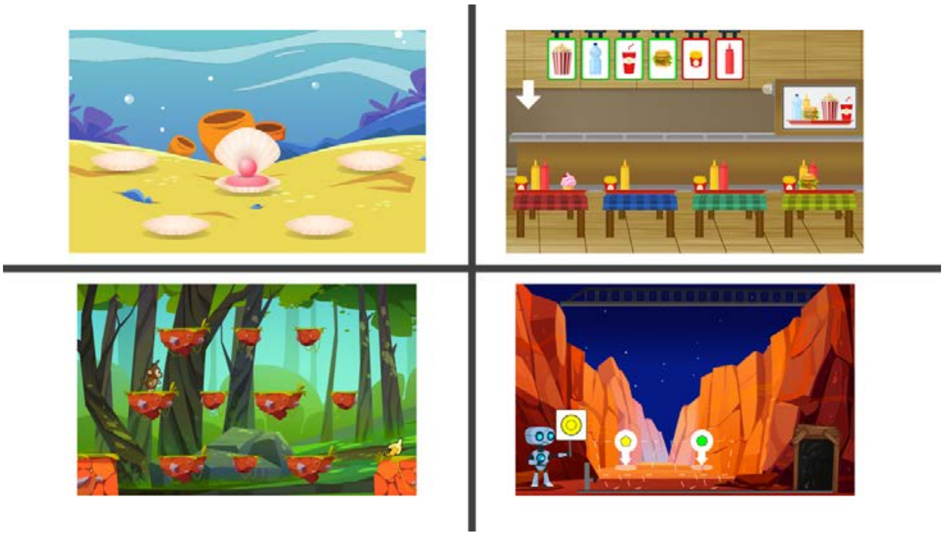

Figure 2. The figure shows the screenshots of four training tasks. From the top right-hand corner are shown tasks testing: inhibition, planning, working memory and cognitive flexibility.

Thirty-seven out of forty have been designed to address a specific executive function. Additionally, other three tasks have been designed in order to train more than one executive functions in a daily life scenario ("life skills"). For each training task the therapist chooses: 1) the executive domain to train; 2) the specific task/game for that executive domain; 3) the number of exercises; 4) the difficulty (1 to 4); 5) the prompt (i.e. the visual or auditory support to help children in accomplishing the task). Figure 4 reports the user interface of training.

3 METHODOLOGY

3.1 Participants

37 children with atypical development (CAD: mean age=9, SD=2) and 378 children with typical development (CTD: mean age=9, SD=1) were recruited for the present study. CAD were recruited from a population of patients that were treated at the Neapolisanit for different neurodevelopmental disorders (see table 1 for a description) and which showed an impairment at least one test measuring executive functions. CTD were recruited at local primary schools in north Italy (Veneto and Lombardy), in centre of Italy (Emilia-Romagna) and south Italy (Molise). Data were collected with the main goal of future standardization. For all participants, parents signed a consent form before commencement of the study. This study was approved by the local ethics committee, in agreement with the Tenets of the Declaration of Helsinki (2013).

Table 1. Frequency and percentage of each neurodevelopmental disorder in CAD sample.

Neurodevelopmental disorder	*Frequency*	*Percentage %*
Attention Deficit Hyperactivity Disorder	3	8%
High-functioning autism	7	19%
Conduct Disorder	4	11%
Specific Learning Deficits	13	35%
Verbal dyspraxia	1	3%
Anxiety Disorder	2	5%
Language Disorder	1	3%
Autism Spectrum Disorder	3	8%
Intellectual Impairments	3	8%

3.2 Methods and Procedure

ASTRAS was used for the assessment and training of the executive functions in CAD. Since CTD were recruited for a future standardization, they performed only the assessment tasks.

The users' impressions with regard to both assessment and training tasks were recorded by the therapists by means of an ad-hoc checklist. The checklist aimed to record children's spontaneous comments and reactions which were observed during the sessions. Specifically, through the checklist we sought to explore children's positive (e.g. the user shows a clear manifestation of enjoyment) and negative reactions (e.g. the user stops playing with the software) as well as those technical problems children met during the usage of the software (e.g. the user asks for help for a properly use of the software).

3.3 Analysis

Preliminarily, a set of descriptive analyses were carried out separately for CTD and CAD about reaction/comment in the assessment and training tasks. Then, data about each reaction/comment were merged resulting in three main measures, namely positive reactions, negative reactions and technical problems. These data were submitted to a chi-square analyses in order to test whether positive, negative reactions and technical problems: 1) were more frequent in CAD as compared to CTD; 2) were more frequent in the assessment tasks as compared to training task (this analysis was performed only for CAD).

4 RESULTS

Descriptive analyses are reported in table 2.

Table 2. Frequency and percentage (in brackets) of each reaction/comment in Children with Typical Development (CTD) and Children with Atypical Development (CAD) for the assessment and training tasks

Reaction/Comment	*CTD (assessment tasks)*	*CAD (assessment tasks)*	*CAD (training tasks)*
Clear manifestation of enjoyment (e.g., he/she laughs)	197 (52%)	30 (81%)	30 (81%)
Liking the software (e.g., he/she says it is entertaining)	344 (91%)	33 (89%)	35 (95%)
Do not want to stop playing	68 (18%)	9 (24%)	16 (43%)
Cannot wait for the next session	244 (65%)	19 (51%)	28 (76%)
Impressions of contempt and irritation (e.g., he/she founds the software "silly" or useless)	2 (1%)	1 (3%)	1 (3%)
Need help at some point	67 (7%)	7 (7%)	0 (0%)
Clear reaction of boredom	4 (1%)	4 (11%)	1 (0%)
Stop playing	1 (0%)	6 (16%)	2 (3%)
Clear reaction of frustration/aggression	0 (0%)	2 (5%)	7 (5%)

Results demonstrated satisfying positive responses during the interaction of children in both samples with the software. In both groups, children were more likely to say that the software was entertaining and they showed clear manifestation of enjoyment. On the other hand, “impressions of contempt and irritation” and “clear reaction of frustration” were very rare. Furthermore, children found the software easy to use and a small percentage of them ask for a support from the therapist.

A chi-square test was performed to examine the relation between children with typical and atypical development and their reactions as well as technical problems during the interaction with the software (see figure 3). The relation between these variables was significant, $X^2(1)$, $p = .006$. CTD were more likely to report positive reactions (92%) as compared to CAD (82%). Conversely, negative reactions were about to occur more frequently in CAD. CTD and CAT did not differ in terms of technical problems.

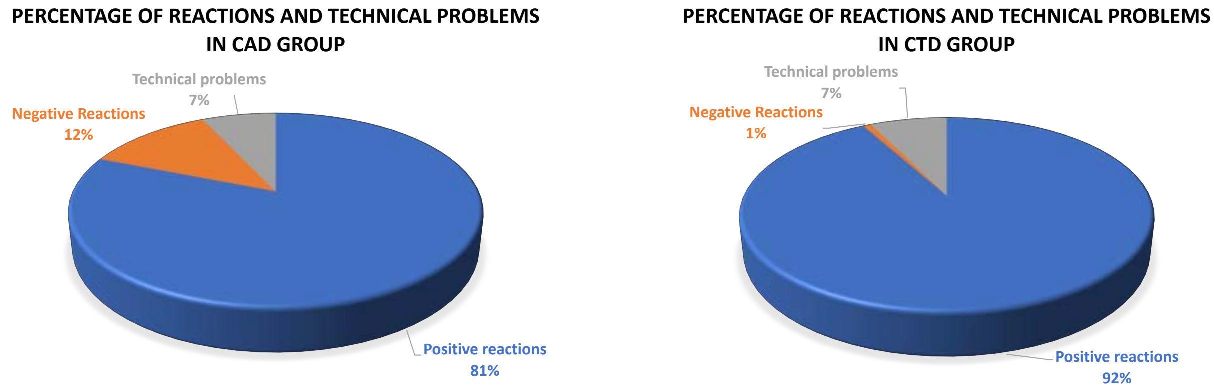

Figure 3. The figure reports the percentage of positive and negative reactions as well as the technical problems met by children with typical and atypical development in the assessment tasks.

We performed a further chi-square test to examine the frequency of positive, negative reactions as well as technical problems in the assessment and training tasks (see figure 4). This analysis was carried out only for CAD. The relation between these variables was significant, $X^2(1)$, $p = .04$. A higher percentage of positive reactions was reported in training tasks (91%). Only the 3% of CAD showed negative reactions in this kind of tasks. The percentage of CAD reporting technical problems during the assessment and training tasks was similar: 7% in the assessment tasks and 6% in the training tasks.

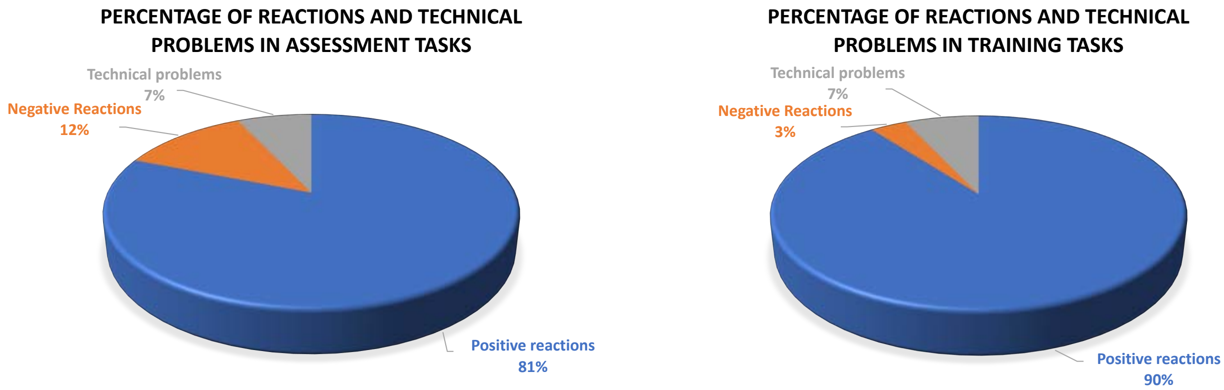

Figure 4. The figure reports the percentage of positive and negative reactions as well as the technical problems met by children with atypical development in the assessment and training tasks..

5 CONCLUSIONS

The aim of this study was twofold: 1) to offer a brief description of ASTRAS, a software for the assessment and training of executive functions in children with neurodevelopmental disorders; 2) to investigate the reactions of children with typical and atypical development during the interaction with the software.

In ASTRAS we developed an assessment session which include several tasks providing an extensive profile of executive functions and highlighting the executive domains which need to be trained.

Since cognitive tasks are also typically viewed as effortful and repetitive, which often leads to participant's disengagement and a negative impact on data quality, we used some principles of gamification in order to make the experience of therapy more positive for the children.

Interestingly, our results showed satisfying positive responses during the interaction of children in both samples with the software (es. they report liking the platform, manifest enjoyment or found it entertaining). Furthermore, children found the software easy to use and a small percentage of them ask for a support from the therapist.

In conclusion, our software can be thought as a platform hosting several tasks/games for the assessment and training of executive functions in children with neurodevelopmental disorders. ASTRAS offers the advantage to obtain an extensive assessment of executive functions and provide training tasks in-person or from remote and control patients' score ongoing. ASTRAS may be conceived as a valid ally supporting the activity of the therapist. Furthermore, through the gamification our software increase children's engagement and make the experience of the therapy more enjoyable as well as avoid drop-out.

REFERENCES

[1] D. T. Stuss and M. P. Alexander, "Executive Functions and the Frontal Lobes: a conceptual review," Psychological Research, vol. 63, pp. 289–298, 2000, doi: 10.4324/9780203837863.

[2] C. Blair and R. P. Razza, "Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten," Child Development, vol. 78, no. 2, pp. 647–663, 2007, doi: 10.1111/j.1467-8624.2007.01019.x.

[3] M. K. Rothbart, L. K. Ellis, M. R. Rueda, and M. I. Posner, "Developing Mechanisms of Temperamental Effortful Control," Journal of Personality, vol. 71, no. 6, pp. 1113–1144, 2003, doi: 10.1111/1467-6494.7106009.

[4] E. G. Willcutt, A. E. Doyle, J. T. Nigg, S. v. Faraone, and B. F. Pennington, "Validity of the executive function theory of attention-deficit/ hyperactivity disorder: A meta-analytic review," Biological Psychiatry. 2005. doi: 10.1016/j.biopsych.2005.02.006.

[5] G. Crisci, S. Caviola, R. Cardillo, and I. C. Mammarella, "Executive Functions in Neurodevelopmental Disorders: Comorbidity Overlaps Between Attention Deficit and Hyperactivity Disorder and Specific Learning Disorders," Frontiers in Human Neuroscience, vol. 15, no. February, 2021, doi: 10.3389/fnhum.2021.594234.

[6] G. M. & V. S. Marzocchi, Le funzioni esecutive in età evolutiva. Modelli neuropsicologici, strumenti diagnostici, interventi riabilitativi. Milano, 2011.

[7] Stefano Vicari & Silvia Di Vara, Funzioni esecutive e disturbi del neurosviluppo. Trento, 2017.

[8] P. D. Walshaw, B. Alloy, Lauren, and F. W. Sabb, "Executive Function in Pediatric Bipolar Disorder and Attention-Deficit Hyperactivity Disorder: In Search of Distinct Phenotypic Profiles," Neuropsychology Review, vol. 20, no. 1, pp. 103–120, 2010, doi: 10.1007/s11065-009-9126-x.

[9] B.-C. Shu, F.-W. Lung, A. Y. Tien, and B.-C. Chen, "Executive Function Deficits in Non-Retarded Autistic Children:," http://dx.doi.org/10.1177/1362361301005002006, vol. 5, no. 2, pp. 165–174, Jun. 2016, doi: 10.1177/1362361301005002006.

[10] R. Xie, X. Sun, L. Yang, and Y. Guo, "Characteristic Executive Dysfunction for High-Functioning Autism Sustained to Adulthood," Autism Research, vol. 13, no. 12, pp. 2102–2121, 2020, doi: 10.1002/aur.2304.

[11] N. Faedda et al., "Intellectual functioning and executive functions in children and adolescents with attention deficit hyperactivity disorder (ADHD) and specific learning disorder (SLD)," Scandinavian Journal of Psychology, vol. 60, no. 5, pp. 440–446, 2019, doi: 10.1111/sjop.12562.

[12] O. Moura, M. R. Simões, and M. Pereira, "Executive Functioning in Children With Developmental Dyslexia," https://doi.org/10.1080/13854046.2014.964326, vol. 28, pp. 20–41, Feb. 2014, doi: 10.1080/13854046.2014.964326.

[13] J. Perner and B. Lang, "Theory of mind and executive function: Is there a developmental relationship?," in Understanding other minds: Perspectives from developmental cognitive neuroscience, 2nd ed., New York, NY, US: Oxford University Press, 2000, pp. 150–181.

[14] H. Danielsson, L. Henry, J. Rönnberg, and L. G. Nilsson, "Executive functions in individuals with intellectual disability," Research in Developmental Disabilities, vol. 31, no. 6, pp. 1299–1304, 2010, doi: 10.1016/j.ridd.2010.07.012.

[15] B. Rosello, C. Berenguer, I. Baixauli, C. Colomer, and A. Miranda, "ADHD symptoms and learning behaviors in children with ASD without intellectual disability. A mediation analysis of executive functions," PLoS ONE, vol. 13, no. 11, pp. 1–17, 2018, doi: 10.1371/journal.pone.0207286.

[16] C. J. Vaidya, X. You, S. Mostofsky, F. Pereira, M. M. Berl, and L. Kenworthy, "Data-driven identification of subtypes of executive function across typical development, attention deficit hyperactivity disorder, and autism spectrum disorders," Journal of Child Psychology and Psychiatry, vol. 61, no. 1, pp. 51–61, Jan. 2020, doi: 10.1111/JCPP.13114.

[17] R. Jacob and J. Parkinson, "The Potential for School-Based Interventions That Target Executive Function to Improve Academic Achievement: A Review," http://dx.doi.org/10.3102/0034654314561338, vol. 85, no. 4, pp. 512–552, Dec. 2015, doi: 10.3102/0034654314561338.

[18] W. S. Barnett et al., "Educational effects of the Tools of the Mind curriculum: A randomized trial," Early Childhood Research Quarterly, vol. 23, no. 3, pp. 299–313, Sep. 2008, doi: 10.1016/J.ECRESQ.2008.03.001.

[19] N. Stockall, "Designing Homework to Mediate Executive Functioning Deficits in Students With Disabilities:," http://dx.doi.org/10.1177/1053451217692565, vol. 53, no. 1, pp. 3–11, Feb. 2017, doi: 10.1177/1053451217692565.

[20] M. Poletti and P. Montanari, "Valutazione Dell 'Attenzione E Delle Funzioni Esecutive in Età Evolutiva : Rassegna Degli Strumenti Italiani," Giornale di neuropsichiatria dell'età evolutivaiornale di neuropsichiatria dell'età evolutiva, vol. 34, no. 1, pp. 1–7, 2014.

[21] A. Wallisch, L. M. Little, E. Dean, and W. Dunn, "Executive Function Measures for Children: A Scoping Review of Ecological Validity," OTJR Occupation, Participation and Health, vol. 38, no. 1, pp. 6–14, 2018, doi: 10.1177/1539449217727118.

[22] R. Simeoli, N. Milano, A. Rega, and D. Marocco, "Using Technology to Identify Children With Autism Through Motor Abnormalities," Frontiers in Psychology, vol. 12, May 2021, doi: 10.3389/fpsyg.2021.635696.

[23] R. Simeoli, A. Rega, and D. Marocco, "Micro-movement as an objective measure to assess autism spectrum disorder," Qwerty, vol. 14, no. 2, pp. 49–65, 2019, doi: 10.30557/QW000017.

[24] S. Vita, A. Rega, L. Iovino, and A. Mennitto, "'TED': Teaching Educational Device, a digital tool to educational practice for special needs.," 2020. [Online]. Available: https://www.researchgate.net/publication/345598936

[25] M. Ponticorvo, A. Rega, and O. Miglino, "Toward tutoring systems inspired by applied behavioral analysis," 2018. doi: 10.1007/978-3-319-91464-0_16.

[26] D. Charsky, "From edutainment to serious games: A change in the use of game characteristics," Games and Culture, vol. 5, no. 2, pp. 177–198, 2010, doi: 10.1177/1555412009354727.

[27] J. Lumsden, E. A. Edwards, N. S. Lawrence, D. Coyle, and M. R. Munafò, "Gamification of cognitive assessment and cognitive training: A systematic review of applications and efficacy," JMIR Serious Games, vol. 4, no. 2, 2016, doi: 10.2196/games.5888.

[28] R. Nappo, M. Iorio, and F. Somma, "ASTRAS : a software for the assessment and training of executive functions in children," in Proceedings of the Second Symposium of Psychology-Based Technologies, 2020, pp. 1–10.

[29] K. Huotari and J. Hamari, "Defining gamification - A service marketing perspective," 2012. doi: 10.1145/2393132.2393137.

[30] K. Robson, K. Plangger, J. H. Kietzmann, I. McCarthy, and L. Pitt, "Is it all a game? Understanding the principles of gamification," Business Horizons, 2015, doi: 10.1016/j.bushor.2015.03.006.

[31] A. Miyake, N. P. Friedman, M. J. Emerson, a H. Witzki, A. Howerter, and T. D. Wager, "The unity and diversity of executive functions and their contributions to complex 'Frontal Lobe' tasks: a latent variable analysis.," Cognitive psychology, vol. 41, no. 1, pp. 49–100, 2000, doi: 10.1006/cogp.1999.0734.

[32] Y. Moriguchi, N. Chevalier, and P. D. Zelazo, Editorial: Development of Executive Function during Childhood, vol. 7, no. JAN. 2016. doi: 10.3389/fpsyg.2016.00006.

[33] R. Martinussen, J. Hayden, S. Hogg-Johnson, and R. Tannock, “A meta-analysis of working memory impairments in children with attention-deficit/hyperactivity disorder,” Journal of the American Academy of Child and Adolescent Psychiatry, 2005, doi: 10.1097/01.chi.0000153228.72591.73.

[34] J. E. Schreiber, K. L. Possin, J. M. Girard, and C. Rey-Casserly, “Executive function in children with attention deficit/hyperactivity disorder: The NIH EXAMINER battery,” Journal of the International Neuropsychological Society, 2014, doi: 10.1017/S1355617713001100.

[35] L. A. Jacobson, A. P. Williford, and R. C. Pianta, “The role of executive function in children’s competent adjustment to middle school,” Child Neuropsychology, 2011, doi: 10.1080/09297049.2010.535654.

[36] R. E. Mattison and S. D. Mayes, “Relationships between learning disability, executive function, and psychopathology in children with ADHD,” Journal of Attention Disorders, 2012, doi: 10.1177/1087054710380188.

[37] C. A. Riccio, L. L. Hewitt, and J. J. Blake, “Relation of measures of executive function to aggressive behavior in children,” Applied Neuropsychology, vol. 18, no. 1, pp. 1–10, 2011, doi: 10.1080/09084282.2010.525143.

[38] Z. K. Takacs and R. Kassai, “The efficacy of different interventions to foster children’s executive function skills: A series of meta-analyses,” Psychological Bulletin, vol. 145, no. 7, pp. 653–697, 2019, doi: 10.1037/bul0000195.