BABEȘ-BOLYAI UNIVERSITY
FACULTY OF PSYCHOLOGY AND EDUCATIONAL SCIENCES
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Ph.D. THESIS SUMMARY

WORKING MEMORY MODIFIABILITY AT CHILDREN WITH ADHD UTILIZING A MULTIFUNCTIONAL DIGITALIZED INTERVENTION PROGRAM

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*Notes.*_______________________

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(2). This is to certify by Susana Farcas that:

(a) The thesis includes the original research work of Susana Farcas (author) towards the Ph.D.;

(b) Susana Farcas attended the courses on Principles of Ethics at the Doctoral School "Evidence Based Psychological Assessment and Interventions";

(c) Parts of the thesis have been already published, presented at scientific conferences, or were submitted for publication; appropriate citations for these publications and conference presentations were included in the thesis. Other co-authors have been included in the publications if they contributed to the exposition of the published text, data interpretation, etc. (their contribution was clearly explained in the footnotes of the thesis);

(d) The thesis was written according to the academic writing standards (e.g., appropriate scientific acknowledgements and citations have been made in the text by the author of the thesis). All the text of the thesis and its summary was written by Susana Farcas, who assumes all the responsibility for the academic writing; also:

- A software was used to check for the academic writing (see at http://www.plagiarism-detector.com/); the thesis has passed the critical test;
- A copy of the research datasets/databases were deposited at the Department/Graduate School.

(3). All the Tables and Figures are numbered within the corresponding chapter or subchapter of the thesis.

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KEYWORDS: ADHD, SDQ, cognitive deficits, visuospatial working memory, gamified working memory interventions, restructuring the visuospatial system

CHAPTER I. THEORETICAL BACKGROUND

1.1.Introduction and research issues

Attention Deficit Hyperactivity Disorder, abbreviated to ADHD, has become a phenomenon that is more and more common among children. According to the results of the meta-analysis of Polanczyk et al. (2007) global prevalence of ADHD was 5.29%. The prevalence of ADHD disturbance varies between 4-19%, depending on criteria and diagnostic methods used in certain countries and cultures (Stanciu, Cotrus, 2012). According to DSM-5, ADHD affects 7% of school-age children. The rate is 2:1 for male (APA, 2013). According to the medical model, ADHD is a developmental disorder with particular neurobiological determinism that impacts motor activity, impulsivity, and attention concentration, and specifically affects control capacity (APA, 2013). According to social-constructivist theoreticians (Timimi, Taylor, 2004), the described pathological forms are considered to be simply behaviors that simply do not meet prescribed social norms, so they deny the existence of this disorder (Parens, Johnston, 2009). Empirical research is essential both for understanding the mechanisms involved in the development of ADHD and for obtaining theoretical analysis on this field. The main goal of several studies is to understand how the genetic and socio-cultural factors and influences interact. More research focuses on investigating the causes and risk factors involved in ADHD. Causes remain unclear, there is not only one identified factor or marker. Studies focus on the analysis of frontal lobe functions (Arnsten et al., 2009, Barkley et al., 2006, Brennan et al., 2008, Castellanos et al., 2002, Curatolo et al., 2009, Stanciu and Cotrus, 2012), on brain chemicals, identification of neurotransmitters (Carlsson, 2000; Comings et al., 2000, and molecular genetics (Mastronardi et al., 2015), others study the subtle mechanisms of the brain involved in the genesis of ADHD. (Barkley, 2006, Biederman et al., 2011, Langley et al., 2007, Barkley, 2006, Comings et al., 2000; Wender, 2000). , 2010, Mate, 2000, Wender, 2000). The multicausality of ADHD hinders the identification process.

1.2.1. The diagnostic process

The diagnostic process is different depending on the country where the criteria are established and the procedures are evaluated. Generally, different screening tools are used, so the entire protocol is different. There are some initiatives to develop a unified approach. There is no single test to diagnose ADHD. In the European guidelines (Taylor et al., 2004) the diagnostic criteria are based on DSM-IV or ICD-10, but DSM is the most commonly used. Since 2013, DSM-5 (APA, 2013) has been used. In Europe, most often clinicians use the 10th International Classification of the World Health Organization (ICD-10). The process is similar in the UK (NCCMH - NICE, 2008), America (AAP, 2011), Canada (CADDRA, 2011) and Australia (NHMRC, 2012). All of these approaches have a complex multimodal evaluation (Brock, Clinton, 2007), which includes medical examinations, psychological assessment (firstly the global assessment of capacities with classical neuropsychological test of attention and other cognitive skills, and social-emotional assessment), pedagogical examinations. The analysis includes historical data, questionnaires, observation grids, scales and test batteries, direct observation of behavior, self-monitoring/self-evaluation of children.

1.2.2. The role of neuropsychological tests in the diagnosis of ADHD

Several criticisms have been made by researchers and practitioners, who promote a different perspective of the diagnosis, leaning toward a neuropsychological approach. In general, questionnaires, evaluation scales are often used tools, but all evaluate behavior and do not penetrate in the analysis of the cognitive, socio-emotional structure of the disorder. Therefore, neuropsychological tests and batteries are used to evaluate neurocognitive functioning of children. A new approach is underway: a dimensional one - those with ADHD cannot be classified into a simple category, rather they occupy different places on a continuum, or on a dimensional spectrum. The limits of these categories cannot be clearly defined, all children can be located behaviorally on these dimensions, or continuum (Koziol and Stevens, 2012). According to Wasserman and Wasserman (2012), the value of neuropsychological tests in the assessment of ADHD is controversial: neuropsychological tests are not sufficiently specific and sensitive; their efficacy is limited by current clinical practice, based on diagnostic criteria, based on only behavioral symptoms, and do not adequately reflect the neuropsychological and neurophysiological processes involved in ADHD. Koziol (2012) argues that neuropsychological tests are essential. Neuropsychological evaluations offer specificity in the identification and treatment of ADHD (Carmichael, 2015, Koziol, 2012, Pineda et al., 2007).

1.3.Synthesis of theoretical models

The theoretical models of ADHD disorder are fundamental to understanding the mechanisms involved in the development process. These theoretical models attempt to explain the factors involved in ADHD and their functionality.

The **Behavioral Inhibition Model** suggests that deficits in inhibitory capacity may explain the symptoms of ADHD. Inability to inhibit responses affects cognitive control and motor control of behavior; furthermore, it influences the emotional and motivational self-regulation (Barkley, 1997).

The **Dual Pathway Inhibition Model** (Sonuga-Barke, 2003) considers that there are two possible neurodevelopmental pathways that may be the cause of ADHD: 1) executive dysfunction (Sonuga-Barke, 2005); and 2) motivational deficits (Toplak et al., 2005, Luman et al.., 2005) and delay aversion (Sonuga-Barke, Wiersema, van der Meere, Roeyers, 2009). Deficits in temporal processing have been proposed as the third pathway that can influence ADHD (Sonuga-Barke, Bitsakou, Thompson, 2010, Toplak, Rucklidge et al., 2003).

The **Cognitive Energetic Model** posits that the factors involved in ADHD are: cognitive factors and energy factors (arousal, activation, and effort). The model describes 3 levels of the system: the first level is information processing, the second is composed of the energy factors and the third level consists of the control of these processes, the executive functions being responsible for the optimal functioning of these components (Sergeant, 2000, 2005).

The **Neurodevelopmental Model** according to Halperin, Schulz (2006) suggests that there are several neurological, structural and functional differences between children with and without ADHD. These neurological deficits are associated with deficits in executive functions (working memory and inhibition) and dysfunctions leading to secondary deficits. ADHD is caused by non-cortical neuronal dysfunction (in basal ganglia, in the cerebellum: but they do not involve neocortical areas).

The **Functional Working Memory Model** (Rapport et al., 2001; Rapport et al., 2008): working memory (WM) capacity, WM deficits are considered the central component of the functional WM model.

The **Working Memory Model** ADHD (Kofler et al., 2008): WM deficits are considered to be responsible for the primary and secondary characteristics associated with ADHD.

The **Neuropsychological Transactional Model** Teeter, Semrud-Clikeman, 2007): ADHD disorder is the result of several bi-directional interactions between genetic and environmental factors, cognitive, psychological, behavioral, social and family factors associated with the disorder. The model integrates behavioral, neurobiological, psycho-social and cognitive perspectives on ADHD.

1.3.1. Models of Working Memory (WM)

Baddeley - Hitch (1974) proposed a multi-component model, introduced the notion of working memory as a subsystem of short-term memory. Baddeley's WM model comprises three elements: 1) the phonological loop, 2) the visual-spatial sketchpad; 3) the central-executive system (or the central administrator) controlling the other two sub-systems that are considered subordinate systems. Baddeley defined working memory as a "*system for temporarily maintaining and manipulating information while performing a range of cognitive tasks such as comprehension, understanding, learning, thinking*" (Baddeley, 1986). According to this model, WM works in specialized subsystems for different tasks, and these subsystems operate in a relatively autonomous way with their own resources. At the same time, there are no mandatory steps, the authors suggest the parallel operation of these systems and do not exclude the possibility of common resources in the processing of information.

Baddeley's Revised WM Model: the episodic loop is the newest component added to the multi-component model (Baddeley, 2000, 2006, 2007, 20012): a temporary storage system that is capable of combining information from the phonological loop, the visual-spatial sketchpad, the long-term memory, or from perceptual input, into a coherent episode, and aims to integrate information from subsystems and ensures its unitary operation.

1.3.2. Models of Executive Functions

The concept of executive functions is very similar to the central executive system described by Baddeley (2000, 2012). According to Friedman et al. (2008), executive functions are cognitive processes that control and regulate thinking and behavior.

The **Executive Attention Model** (Engle, 2002; Kane et al., 2001) conceptualizes WM with a primary executive function assigned to attention. Compared to Baddeley's model, the central executive would have been more of an attentional system than a memory system. The functions of the executive system are focused attention, self-monitoring and attentional redirection.

The **Model of Miyake et al.** (2000) comprises three primary executive functions: A) set-shifting; B) updating, C) inhibition. Executive function deficits often occur in ADHD (Rapport et al., 2008; Willcutt, Doyle, Nigg, Faraone, Pennington, 2005; Barkley, 1997).

The Integrated Memory Model (Dehn, 2008) defines three types of WM: phonological, visual-spatial and executive WM. The integrated model (Dehn, 2008) defines WM as manipulation, management, transformation of information from short-term memory and long-term memory. Therefore, at the basis of the functioning of WM are those cognitive processes, which work with information from short and long term memory.

1.4. Methods used to measure the capacity of working memory and executive functions

A wide range of tasks are available for evaluating WM (Alloway, Gathercole, Pickering, 2006; Kane et al., 2004); generally 2 types of tasks are used: simple span and complex span tasks. Simple span tasks do not require the manipulation of information, they imply a simple revocation of information from different modalities: verbal, visual, visuo-spatial (WISC-IV, Wechsler, 2003a). Complex span tasks require manipulation of information; in these tasks it is necessary to update the information - digits or locations (visuo-spatial span, Corsi Block tapping Task- CBTT – in a reversed order, Kessels et al. 2000).

1.5. Capacity of working memory controlled by specific or general mechanisms?

It is a matter of discussion if the capacity of WM reflects a separable cognitive capacity (Baddeley, 2000, 2012, Jarvis and Gathercole, 2003, Kane et al., 2004), specific for modalities: verbal or visual-spatial, or they reflect a general domain of cognitive capacity (Alloway et al., 2006, Bayliss et al., 2003, 2005).

Working memory limits: The most important limitations of WM involved in cognitive performance at different tasks are: working memory capacity, time and energy limits or effort investment (Henry, 2012, Visu-Petra, Key, 2012).

1.6. Treatments and Interventions for Children with ADHD

The effectiveness of pharmacological treatments are limited (Connor, 2015, Connors et al., 2001, Hinshaw et al., 2000, 2007, Loe, Feldman, 2007, Olfson, Gameroff, Marcus, Jensen, 2003, Swanson et al., 2001). Critics highlight the need for more effective psychosocial treatment alternatives. There is a large base of evidence for empirically validated, evidence-based treatments: behavioral interventions, parenting interventions (Pelham et al., 2008), school-based interventions - classroom behavioral management (Fabiano et al., 2007, Pelham et al., 2005), social skills training, intensive summer treatment programs (Chronis et al., 2004), and other educational interventions. Multimodal treatments are needed to normalize the behavior of children with ADHD (Chronis et al., 2006).

The effects of cognitive interventions are contradictory and the results of the studies are inconsistent (Sonuga-Barke et al., 2013), although there is evidence for the efficacy of well-designed cognitive intervention programs (Tamm, Nakonezny, Hughes, 2014) on executive attention and WM (Beck et al., 2010, Tucha et al., 2011). Some studies have been promising, but they seem to have no long-term transfer effects (Shipstead, Hicks, Engle, 2012).

1.7. Relevance of the research topic

The high interest of the research topic addressed comes from the implications that WM and WM-based interventions might have in understanding and treating the symptoms associated with ADHD. Also, the presence of an atypical development profile has led to increased interest in the assessment of cognitive functions involved in the development of ADHD. Working memory can be considered a cognitive vulnerability factor for psychopathology. At present, we do not have a comprehensive definition of the concept of WM, which applies both in the field of cognitive psychology and in the clinical field. At the same time, systematic studies on cognitive mechanisms supporting change in children with ADHD are missing. Cognitive interventions available to increase working memory capacity are experimental and have low ecological validity, and have received many criticisms, some researchers seeing them inadequate to alleviate the symptoms of ADHD. All these arguments prove the relevance of the thesis in the field, as well as its actuality in the literature. Further research is needed to clarify some current questions and issues. As a result, the current thesis addresses some of the issues and research questions. In the next chapter the objectives of the thesis will be presented.

CHAPTER II. RESEARCH OBJECTIVES AND GENERAL METHODOLOGY

2.1. Objectives of the thesis

We propose the following objectives:
1) **Theoretical objectives**: we propose the analysis of working memory in relation to ADHD, the evaluation of the role of WM in children with ADHD and the cognitive functioning involved in the disorder.
2) **Methodological objectives**: we plan to develop a digital/ computerized program to assess the current capacity of the visual-spatial WM and an intervention program focused on the visuospatial WM.
3) **Practical objectives**: we propose to test an evaluation and intervention program to increase WM capacity of children with ADHD by an individualized intervention and to examine the value and limits of this computerized evaluation and intervention tool focused on visuospatial WM in children with ADHD symptoms. We assume that it is effective for the cognitive restoration of the visuospatial system, diminishing the cognitive deficits associated with ADHD and can be considered a complementary treatment. The goals outlined above will be tested through several studies. *Figure 1* shows the structure of the doctoral thesis.

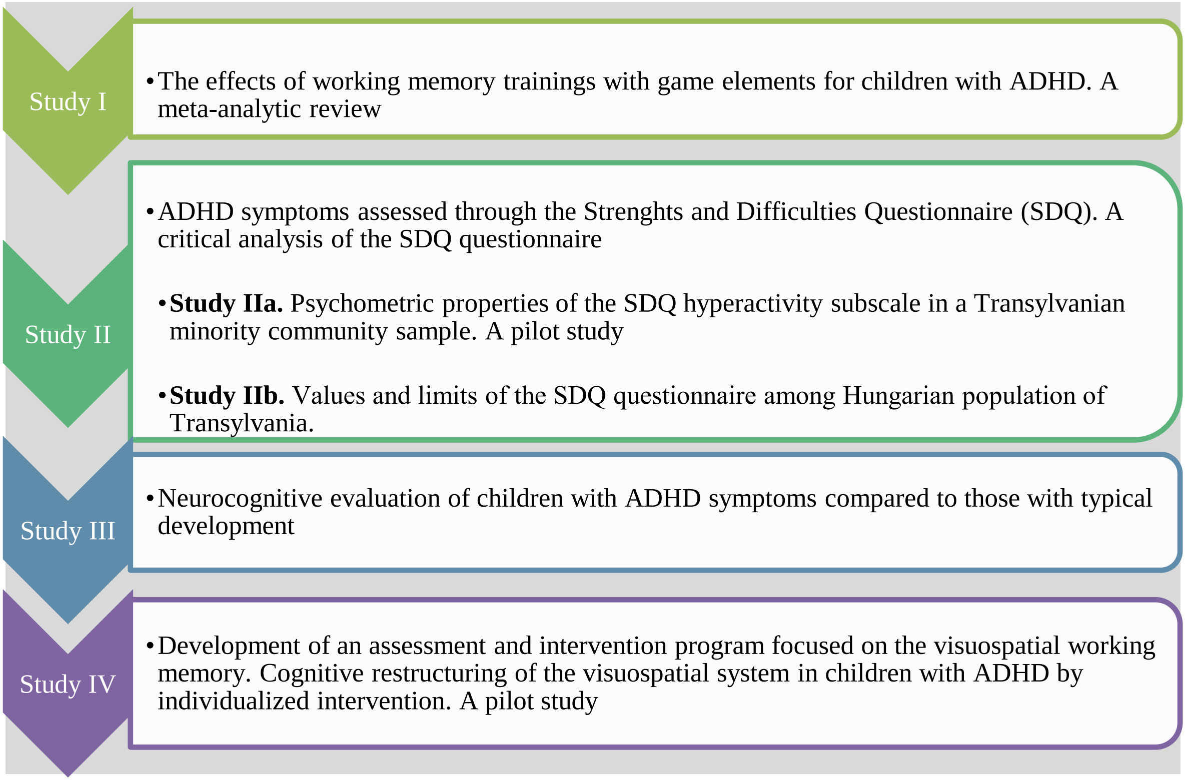


Figure 1. Structure of the doctoral thesis

CHAPTER III. ORIGINAL RESEARCH CONTRIBUTIONS

3.1. Study I. The effects of working memory trainings with game elements for children with ADHD. A meta-analytic review[1]

Introduction

There are controversies regarding the effectiveness of interventions concerning the capacity and functionality of working memory (van der Oord et al., 2014, Klingberg et al., 2005). Among previous studies, which have investigated the effectiveness of computerized intervention programs to increase the WM capacity of children with ADHD, there are few that included game elements (Prins et al., 2011, Dovis et al., 2015, Shaw et al., 2005). Therefore, this meta-analysis aims to analyze the effectiveness of interventions that focus on gamified WM trainings.

In the current meta-analysis gamified interventions focusing on basic WM have been chosen via computerized or digitalized programs. The use of game elements in interventions contributes to the activation of the dopaminergic system, which plays an essential role in cognitive functioning and contributes to the effectiveness of interventions (Bavelier et al., 2010, Howard-Jones, Demetriou, 2009, Howard-Jones et al. 2011). According to several studies (Dovis et al., 2012, 2013, 2015, Krawczyk and D'Esposito, 2013), children with ADHD have motivational problems, so they need increased rewards and feedback. Most study results are mixed, there is no consensus either in conceptualizing working memory or in using tools

[1] This study was published as follows: Fărcaş S., Szamosközi I. (2016). The effects of working memory trainings with game elements for children with ADHD. A meta-analytic review. *Transylvanian Journal of Psychology*, 17(1), 21-44.

to measure WM capacity, moreover there are concerns about the level of confidence of these tools used (Shipstead, Hicks, Engle, 2013). According to Gibson et al. (2012), the expectations of increasing the WM capacity using these interventions come from the more general hypothesis: the plasticity of the human brain. So we should not be surprised if these interventions were built to test this general hypothesis, the plasticity of WM capacity. In conclusion, taking into account the limits of existing interventions and the evidence supporting the effects of interventions on WM capacity in children with ADHD, a new meta-analysis is needed to assess the effectiveness of core WM interventions.

Objectives

The aim of this analysis was to evaluate computerized and gamified trainings and training-type specific effects of current WM trainings for children with ADHD. This meta-analysis objectives are: (1) estimation of the effect sizes based on comparison with a control group, (2) comparison of training effectiveness at different outcome levels: cognitive, behavioral, socio-emotional, academic level (3) identification of possible moderator variables of effect sizes that could explain the differences between training effectiveness.

Methods

Studies identification

Studies have been identified through a systematic computer search of articles in English in electronic databases PubMed®, PsychInfo®, ScienceDirect. The key terms entered were *ADHD* and *working memory* and *training* and *children* and *game*, and all combinations of these terms ("attention deficit disorder with hyperactivity" OR ("attention" AND "deficit" AND "disorder" AND "hyperactivity") OR "attention deficit disorder with hyperactivity" OR "adhd") AND ("memory, short-term" OR ("memory" AND "short-term") OR "short-term memory" OR ("working" AND "memory") OR "working memory") AND ("education" OR "education" OR "training" OR "education" OR "training") AND ("child" OR "child" OR "children") AND game. Other articles were also identified in the references of recently published studies, reviews, meta-analyses (at the time of the identification of the studies) related to this topic.

Selection of the studies

The inclusion criteria were: (a) studies written in English, (b) papers published in peer review journals, (c) study sample of children with ADHD diagnosis (symptoms of ADHD measured with a validated screening instrument), ages between 5-14, (d) application of gamified working memory training, (e) the inclusion of a control group, (f) studies providing sufficient data to allow calculation of effect sizes.

The initial search resulted in 551 potentially relevant articles. After 551 abstracts screened, 520 abstracts were excluded, 31 full-text articles were assessed for eligibility, 11 studies were selected based on these criteria (see *Figure 2*.) and included in the final analysis. 20 articles were excluded: did not have a WM intervention, did not have a control group, the study participants were not children with ADHD (ages between 5-14), the WM interventions were not gamified. Most interventions used were standard WM interventions (CogMed), only 4 studies used different WM trainings with game elements. *Appendix 1* presents the characteristics of the selected studies.

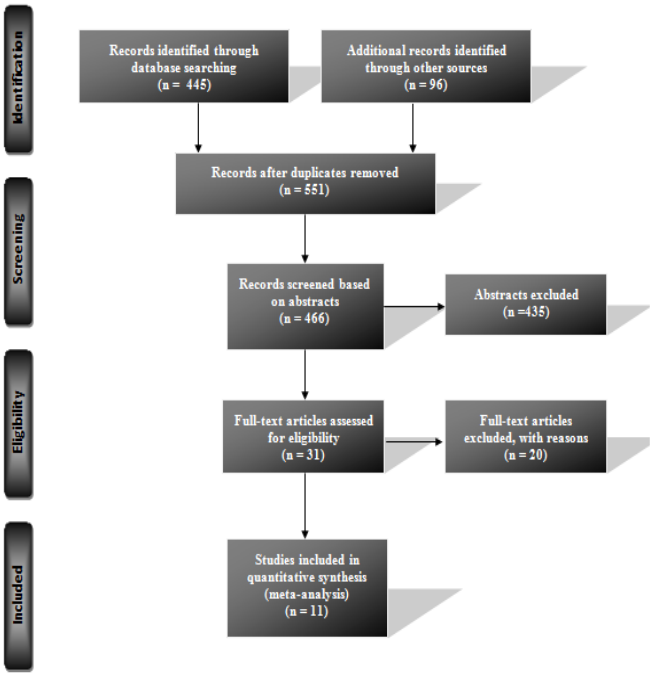


Figure 2. PRISMA Flow Diagram of studies included in the meta-analysis

Coding procedure

During the coding procedure different types of control groups (waitlist, placebo, low intensity, nonadaptative groups); types of interventions (CogMed, Braingame Brian, GWMT-other gamified trainings); length of training, training setting and types of outcome measures (three levels: behavioral, socio-emotional, cognitive and academic performance level) were used as moderator variables. To make it easier to distinguish between the gamification used, firstly, different types of game elements were defined: e.g. feedback thermometer; upgrades; competition; exploration; external feedback system. Secondly, these were used to classify the gamification parts for each study. Based on the amount of game elements 3 categories were coded: 1 for one or two elements used, 2 for two or three elements used, 3 for more than three game elements used.

The random effect model was used to analyze the data (Borenstein, Hedges, Higgins & Rothstein, 2005; Hunter, Schmidt, 2004). For the different outcomes Cohen's d coefficient (Cohen, 1988) was calculated based on the reported posttest results from control group and intervention group. Effect sizes for follow-up were also calculated.

Data analysis

Data analysis was conducted using the Comprehensive Meta-Analysis software, version 2.2 (Borenstein, Hedges, Higgins, Rothstein, 2005). Interpretation of results was based on Cohen's suggestion: an effect size of .00-.20 was regarded as trivial, .20-.50 was considered small, .50-.80 medium and greater than .80 as large effect size. For homogeneity testing Q and I^2 statistics was used (Borenstein et al., 2005). For publication bias Fail-safe N was used (Rosenthal, 1991). Based on the 11 studies included in the meta-analysis, a total number of 620 subjects were included.

Results

The overall effect size, based on comparison of posttest results between WM training and control groups was trivial, statistically nonsignificant: ES=0.078; 95% CI [-.0096, .251], p=0.381, Q(10)=1.640, p=0.998, I2=00 (See *Figure 3A-B.*). Comparison of follow-up results (based on 5 studies) between WM training and control groups revealed a small, nonsignificant effect size: ES=0.238; 95% CI [-.002, .478], p=0.052, Q(4)=1.214, p=0.876, I2=00 (See *Figure 3C-D.*).

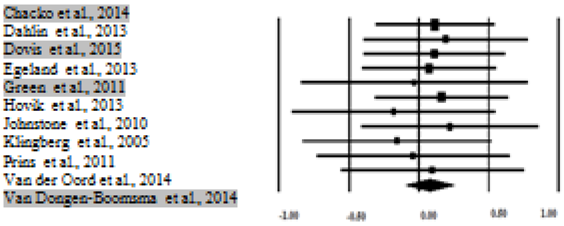
Moderator variables were also checked. The effect size on each level was computed, based on type of outcome: cognitive, behavioral, socio-emotional and academic performance.

On cognitive level (see *Figure 3E-F.*), the results showed a small effect size *ES*=0.288; 95% CI [.083, .493]; p=0.006, Q(9)=11.249, *p*=0.259, I^2=19.995. There was no evidence of heterogeneity. We tested the results for publication bias. Fail Safe N=17, smaller than $5K+10^2$ (Rosenthal, 1991), it seems that there is a possibility of publication bias (N should be greater than $5K+10^2$, where K represents the number of studies). Under the random effects model the point estimate and 95% confidence interval for the combined studies is 0.28772 (0.08268, 0.49275). Using Trim and Fill these values are unchanged. Based on follow-up results, a small effect size was obtained from 4 studies (see *Figure 3G.*): ES=0.368, 95% CI [0.104, 0.631], p= 0.006, Q(3)= 1.018, *p*=0.797, I^2 =00. Fail Safe N=5, which indicates possibilities of publication bias.

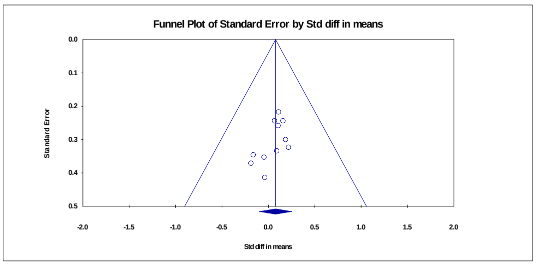
The effect of WMT on behavioral level was computed from 7 studies. The results showed a nonsignificant effect size (see *Figure 3H-I.*): *ES*= -0.194, 95% CI [-0.408, 0.021], *p*=0.076. There was no evidence of heterogeneity, Q(6)=1,812, p=0,936, I^2=00.

On socio-emotional level the ES was computed from 1 study (see *Figure 3J*). The results showed a nonsignificant effect size *ES*=0.198, 95% CI [-0.310, 0.707], p=0.445. The academic performance as a moderator variable was also tested (see *Figure 3K*). The effect size was computed from 3 studies. The results showed a nonsignificant effect *ES*=0.199, 95% CI [-0.082, 0.480], p= 0.166. There was no evidence of heterogeneity, Q(2)= 0.297, *p*=0.862. Other moderator variables were also checked.

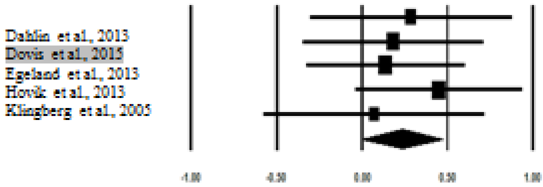
Based on different types of control groups (waitlist, placebo, low intensity, nonadaptative groups), different types of interventions and the amount of game elements, none of the results were statistically significant. For 1-2 gamification elements ES=0.149, 95% CI [-0,128, 0.425], p= 0.292, Q(3)= 0.120, *p*=0.989, I^2=0.00, for 2-3 gamification elements ES =0.052 , 95% CI [-0,236, 0.340, p= 0.723, Q(3)= 0.648, *p*=0.885, I^2=0.00, for 3 or more gamification elements: *d*=0.000, 95% CI [-0,351, 0.352, p= 0.999, Q(2)= 0.402, *p*=0.818, I^2=0.00.



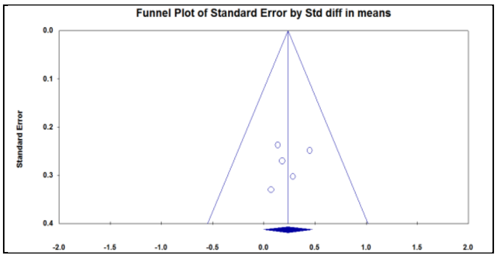
Overall ES=0.078; 95% CI [-.0096, .251], p=0.381
A. The overall effect of WMT (PT)



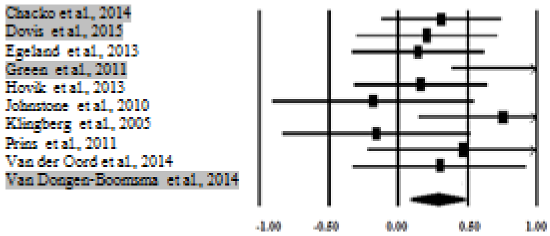
B. Funnel Plot - The overall effect of WMT

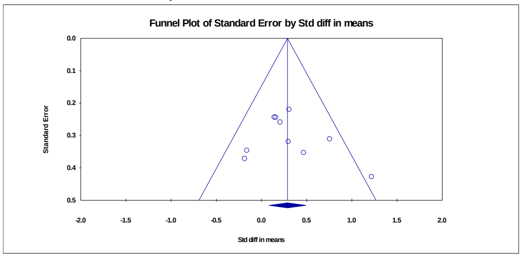


ES=0.238; 95% CI [-.002, .478], p=0.052
C. The overall effect of WMT (FU)



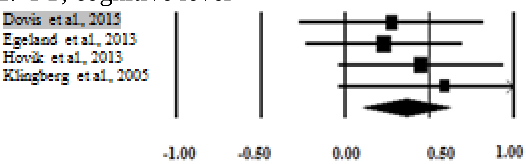
D. Funnel Plot - FU, efect overall



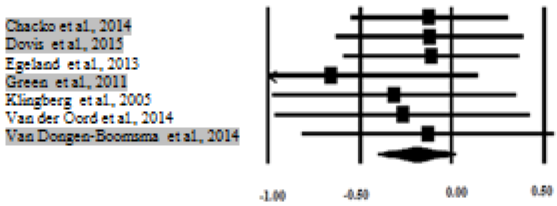


ES=0.288; 95% CI [.083, .493]; p=0.006
E. PT, cognitive level

F. Funnel Plot - PT, cognitive level

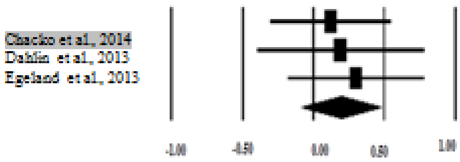


ES=0.368, 95% CI [0.104, 0.631], p= 0.006
G. FU, cognitive level



ES= -0.194, 95% CI [-0.408, 0.021], p=0.076
H. PT, behavioral level

I. F. Funnel Plot - PT, behavioral level



ES=0.198, 95% CI [-0.310, 0.707], p=0.445
J. PT, socio-emotional level

ES=0.199, 95% CI [-0.082, 0.480], p= 0.166
K. PT, academic level

Figure 3(A-K). Effect sizes based on different outcome levels.

Note. ES=effect size, WMT= working memory training, PT= posttest, FU=follow-up, gray-colored studies are placebo controlled

Discussion

The main goals of this meta-analysis were to analyze the challenges and limitations of gamified working memory trainings. The objectives of this meta-analysis were (1) the estimation of the effect sizes based on the comparison between ADHD and a control group; (2) comparison of training effectiveness at different outcome levels: cognitive, behavioral, socio-emotional, academic level; (3) and identification of possible moderator variables of effect sizes that could explain the differences between training effectiveness.

The results of the current meta-analysis showed minimal impact of WMT with game elements on ADHD. The overall effect sizes based on comparisons of posttest and also follow-up results are trivial and statistically nonsignificant. There are only a few studies that used the same WMT intervention with game elements, which makes the comparison complicated. CogMed has been one of the most widely used WMT programs, including adaptive (automatically adjusted) difficulty level. CogMed uses game elements: a reward system, daily verbal and visual feedback, does not use upgrades, exploration, nor an external feedback system; whereas Braingame Brian uses a greater amount of game elements: feedback thermometer, upgrades, competition, exploration, thereby children's ability to engage might improve.

However, these studies were probably not as homogenous as expected. Several of them used different types of control group: placebo, waitlist, treatment as usual. Therefore, moderator variables were also tested. The type of outcome had minimal effects on the results. A small, but significant effect size was found based on posttest and follow-up data, on cognitive performance as moderator variable. Therefore, analysis of the data explored the availability of game elements to enhance cognitive performance (near-transfer effects). On behavioral, socio-emotional and academic level/performance trivial effect sizes were found. None of these differences were statistically significant (no transfer effects).

These results both negate and support some of the hypotheses of previous studies. It was predicted that WMT would result in greater cognitive performance in children with ADHD. In the meta-analysis of Melby-Lervag, Hulme (2013) results showed that training VS and PHWM had short-term and also long-term effects. Previous studies (Prins et al. 2011, Dovis et al., 2015) have provided few evidence of gamification of cognitive trainings. Prins et al. (2011) have found that WM training with game elements significantly improved WM performance and motivational level of children with ADHD.

Importantly, the results of the current meta-analysis showed little clinical impact of WMT with game elements on ADHD. The generalizability of the results is problematic. A limited number of studies and samples were analyzed. A greater number of studies and samples could lead to a higher generalization of the current results. Causal factors leading to these results (nonsignificant effect sizes) remain speculative. However, the lack of far-transfer effects could be explained by the difference between WM and symptoms with clinical importance. Namely, symptoms of ADHD can be viewed as impulsive and hyperactive thoughts, or in other words, maladaptive habits which can be controlled consciously only in a limited way (Goodman, Marsh, Peterson, & Packard, 2014). Habits and routines usually follow complex sequences, and these types of behavior are more related to procedural rather than declarative processes (Cleeremans, Destrebecqz, & Boyer, 1998; Montague, Dolan, Friston, & Dayan, 2012). Moreover, procedural memory is thought to be independent from WM (Janacsek & Nemeth, 2015). Therefore, WM training alone could hardly contribute to changes in symptom manifestation.

In sum, the current study analyzing WMT with game elements has failed to provide clear benefits for ADHD children. However, the mechanisms underlying change in ADHD symptomatology through this type of interventions remain unclear. Much uncertainty still exists about the relationship between working memory trainings and ADHD. To date, there has been no clear evidence that WMT is beneficial for ADHD.

Further studies should evaluate the impact of WMT on ADHD and could also improve these interventions. Major differences in the theoretical models behind several WMT interventions are, of course, indisputable reasons for decisions regarding the methodology used by the researchers. Research to date has tended to focus on targeting global cognitive functions, executive functions rather than targeting specific cognitive functions like visuo-spatial working memory. Previously published research (Willcutt et al., 2005, Martinussen et al., 2005, Kasper et al., 2012) has found greater impairments of visuo-spatial WM in children with ADHD. Willcutt et al. (2005) found statistically significant between-group differences among children with ADHD and typically developing controls, indicated by a medium effect size (ES) of VSWM deficit (computed from 8 studies). Martinussen et al. (2005) reported large ES for VSWM. Kasper et al. (2012) reported that children with ADHD had larger VSWM deficits compared to their typically developing peers, indicated by medium ES. This evidence suggests that VSWM could be the target of future trainings therefore, further work using VSWMT is required to confirm this hypothesis.

3.2. Study II. ADHD symptoms assessed through the Strengths and Difficulties Questionnaire (SDQ). A critical analysis of the SDQ questionnaire

Introduction

The Strengths and Difficulties Questionnaire (SDQ, Goodman, 2001, Goodman et al., 2000a, Goodman et al., 2004) is widely used as an international standardized instrument measuring child behavior. It was translated in more than sixty languages, and its psychometric properties were analyzed in many countries (Marzocchi et al., 2004; Ruchkin et al., 2012).

The study conducted by Stone et al. (2010) analyzes the psychometric properties of the SDQ questionnaire. The meta-analysis aimed at a general presentation of the psychometric properties of the SDQ questionnaire for children aged 4-12. The results from 48 studies (N = 131,223) on the reliability and validity of SDQ-T (teacher version), SDQ-P (parent version) are summarized quantitatively and descriptively. Internal consistency, test-retest reliability, and inter-evaluator agreement are generally satisfactory for both. At subscale level, the SDQ-T reliability seems stronger than the SDQ-P.

Several studies have confirmed the structure of five factors of the SDQ-T, -P questionnaires (Becker et al., 2004, He et al., 2013, Sanne et al., 2009, Stone et al. ., 2010, van Leuween et al., 2006, Van Roy et al., 2008). Correlations with other tools, e. g. CBCL-SDQ, are generally higher for SDQ-T than for SDQ-P.

The SDQ's screening capability is acceptable, the AUC attests the instrument's discrimination ability, the AUC weighted values for the hyperactivity subscale are high SDQ-

P = .90 and SDQ-T = .95. Therefore, according to the meta-analysis of Stone et al. (2010), the psychometric properties of SDQ are strong, especially for SDQ-T.

The study by Stone et al. (2015) investigates the reliability, construct validity, and predictive validity of the SDQ-P and SDQ-T in children aged 4-7. In a sample of the Dutch community (N = 2,238 teachers, N = 1,513 parents, N = 1,831 children), the children were followed up for three consecutive years (T1-T3). The results demonstrate SDQ feasibility as a screening tool.

In the study of Vaz et al. (2016), parents and teachers' assessments (N = 299 students with and without problems) were analyzed. The study found that: a) ICC values (intraclass correlation coefficient) at the individual level are acceptable; b) the clinical utility of the SDQ questionnaire was fair only when there was an agreement between teacher and parent reports, using the possible 90% dichotomization system; c) three items indicated a positive probability of the scores, which indicates the clinical utility of the scores. These results suggest that SDQ is not optimized for use in the normal Australian population and that the psychometric assessment of the SDQ questionnaire is still warranted.

One study was conducted on Romanian population using the SDQ self-reported version (N = 1086), children aged 9-17, including 4 counties from Romania (Iași, Botoșani, Vaslui, Bacău). The results show low internal consistency of the subscales, confirmatory factorial analysis tends to the 5-factor structure, but none of the tested models was statistically acceptable (Sharratt et al., 2014).

Based on Hungarian population from Hungary in the Turi, Tóth and Gervai (2011) validation study all the 3 versions were used: SDQ-T, SDQ-P, SDQ-self-report (N = 286), assessing adolescents aged between 12-17 years. The internal consistency of the scales was generally acceptable, the version for teachers showed a much better internal consistency and, compared to the UK scores, there were no significant differences between the two populations.

3.2.1. Study IIa. Psychometric properties of the SDQ hyperactivity subscale in a Transylvanian minority community sample. A pilot study[2]

Objectives

Given the lack of specific tools for the population of Transylvania, the aim of the study is to verify the validity and reliability of the SDQ questionnaire in a Hungarian minority group. This study has the following specific objectives: 1) to assess the internal consistency of the hyperactivity subscale of the SDQ-P, SDQ-T in the typically developing population, in children aged 7-11 years, compared to the hyperactivity subscale from the CBCL and ADHD-RS-IV questionnaire; 2) to investigate the concurrent validity of the hyperactivity subscale from SDQ: compared to specific measurements: the hyperactivity subscale from CBCL and the ADHD-RS-IV; 3) to explore inter-evaluator agreement (between parents and teachers).

[2] This study was accepted for publication as follows: Fărcaș S., Szamosközi I., Petric E., Veres A. (2017). Psychometric properties of the SDQ hyperactivity subscale in a Transylvanian minority community sample. A pilot study. *Transylvanian Journal of Psychology*, 18 (1), 00.

Methods

Participants

In a Transylvanian community sample, a Hungarian minority group in Romania, a total of N= 42 children were assessed, the average age M(SD)=9.02 (1.33), ranged from 7 to 11 years old (47.6 % male, 52.4% female). All children attended elementary school, from preschool to fourth grade.

Instruments

Assessment of ADHD symptoms

The Hungarian version of **Strenghts and Difficulties Questionnaire - SDQ** (Goodman, 1997, Goodman, Meltzer, Bailey, 1998, Goodman, 2000a, 2005) for parents/caregivers (of 4-17 year olds) and for teachers (of 4-17 year olds); the Hyperactivity Subscale from the **Child Behavior Checklist – CBCL** (Achenbach, 2001) parent version and the **Teacher Report Form - TRF** (In: Perczel Forintos et al., 2007); and the **ADHD Rating Scale (ADHD-RS-IV-home and school version)** (DuPaul, 1998) was used, based on **DSM-IV,** the scale was completed by parents and teachers (Hungarian version in Perczel Forintos et al., 2007).

Procedure

Data were collected in the fall of 2016. Participants were recruited from different counties of Romania (Cluj, Sălaj, Harghita, Covasna, Mureș, Satu-Mare), teachers were asked to choose 2 or 3 children to be assessed, typically or atypically developing children with/without psychosocial problems. Participants were assessed at T1 (time 1): evaluation phase (test) and T2 (time 2) re-evaluation (retest), after 1 month. Parents and teachers filled out the SDQ, CBCL/TRF, ADHD-RS-IV for all the children.

Results

The SPSS (Statistical Package for Social Sciences) 20 Statistical Software was used for data analysis. Internal consistency of the subscales was calculated using Cronbach's alphas; values are high, indicating a good internal consistency of the scales (α = .75-.97).

Predicitive validity was analyzed using test-retest correlations. Results indicate good predictive validity of SDQ - hyperactivity subscale, test-retest correlations are high, r=.72 - .97. Results show good **concurrent validity** of the SDQ hyperactivity subscale: correlations with other instruments (CBCL/TRF, ADHD-RS-IV) are high: r = .85 - .95.

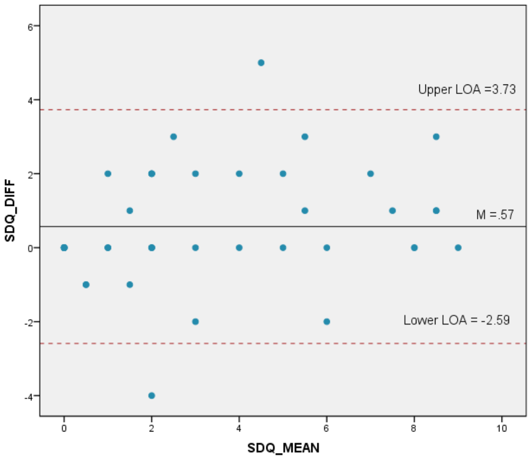
Differences between Evaluators were assessed using **Paired Samples t Test,** results show differences between teacher and parent reports using SDQ, CBCL/TRF at T1 and T2, except ADHD-RS-IV, there were no statistically significant differences between evaluations.

Bland-Altman Limits of Agreement (LOA) Plots present grafically the agreement between raters (Bland, Altman, 1986, 1999; Krouwer, 2008). As shown in *Figure 4A-E* systematic differences can be observed between parent and teacher reports. The middle solid horizontal lines show the mean bias with 95% CI, the dashed lines represent the upper and lower LOA. The degree of discrepancy between raters is indicated by the width of the LOA. *Table 1* presents the descriptive overview of the analysis.

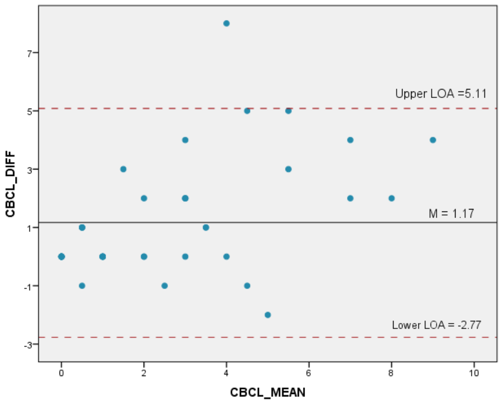
Table 1 Descriptives of Bland-Altman LOA Analysis

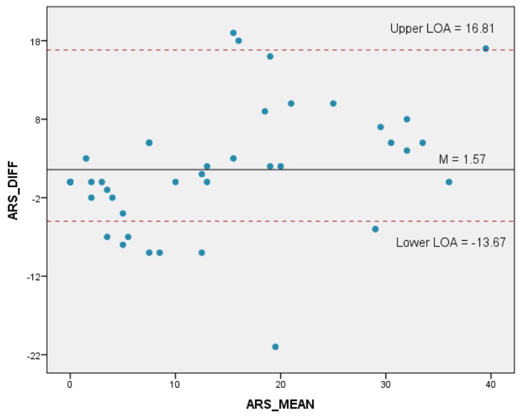
	Δ M (SD)	95 % CI Δ M	95 % lowerLOA	95 % upperLOA
SDQ - Hyperactivity Subscale	.57 (1.58)	-.03 - .30	-2.59	+3.73
CBCL/TRF- Hyperactivity Subscale	1.17 (1.97)	.20 - .64	-2.77	+5.11
ARS-total	1.57 (7.92)	.06 - .47	-13.67	+16.81
ARS-IN	.74 (4.09)	.00 - .41	-7.44	+8.92
ARS-HI	.83 (4.51)	.05 - .51	-8.19	+9.85

Note. Δ = difference between Teacher and Parent reports, LOA = limits of agreement, CI = confidence interval, SDQ=Streghts and Difficulties Questionnaire, CBCL =Child Behavior Checklist, TRF -Teacher Report Form, ARS=ADHD-RS-IV , IN= symptoms of inattention HI=simptoms of hyperactivity



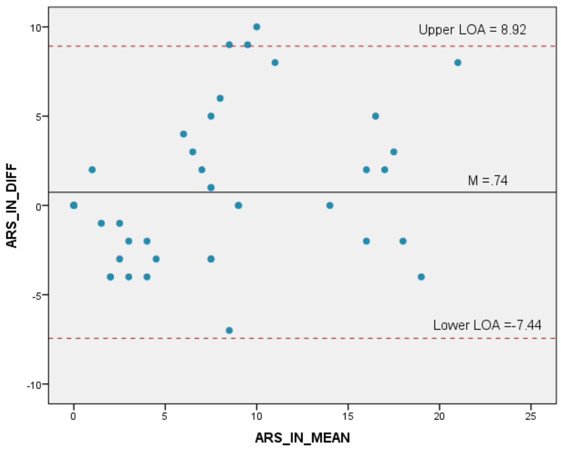
A. The Hyperactivity Subscale from SDQ



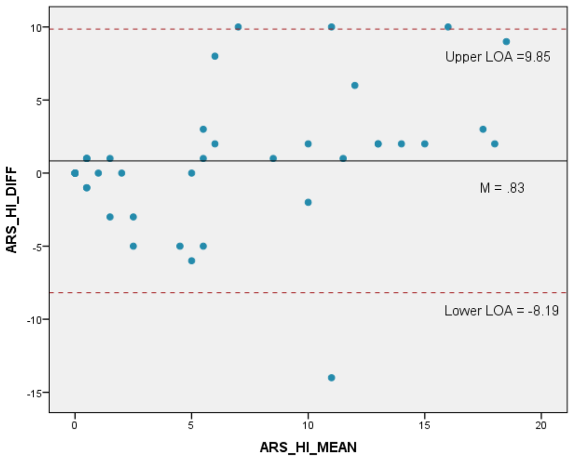


B. The ADHD Subscale from CBCL/TRF

C. ADHD-RS-IV - total



D. Inattention Subscale from ADHD-RS-IV



E. Hyperactivity Subscale from ADHD-RS-IV

Figure 4A-E. Bland-Altman LOA Plots

The Intraclass Correlation Coefficient (ICC), the Absolute Agreement, single measures, two-way mixed model was used for establishing the agreement between raters. The **SDQ-Hyperactivity subscale (T1)** had an acceptable value: ICC(2,1)=.56(95% CI: .45-.69). At T2 results are similar. The **CBCL/TRF-Hyperactivity subscale (T1)** had low value**,** ICC(2,1)=.39(95%CI:.28-.52). The **ADHD-RS-IV-T1** had medium inter-rater agreement, ICC(2,1)=.48(95%CI:.38-.61), a value close to the acceptable. The **inattention subscale** from the **ADHD-RS-IV-IN-T1** showed a fair agreement, ICC(2,1)=.55(95%CI:.44-.67). The **hyperactivity subscale** (T1) from ADHD-RS-IV-HI indicated medium value ICC(2,1)=.48(95%CI:.37-.61).

Consensus estimates of Interrater Reliability: Percent agreement and the Cohen's Kappa values were computed using SPSS, running the crosstabs procedure. According to results, consensus between parent and teacher ratings were low, the percent agreement (21.43% - 47.62%), and Cohen's Kappa coefficients (.16-.40) were small to medium.

Screening ADHD: To establish the ADHD diagnosis we used the following cut-off points: 1) SDQ (4 items) total score (average parents and teachers) 0-4: normal interval, score 5-6: subclinical interval, score ≥ 7: 2) at CBCL/TRF: score 0-6: normal range, score 7: subclinical interval, score ≥8: clinical interval, 3) ADHD-RS-IV-home and school version - for diagnosing ADHD according to DSM - *Diagnostic and Statistical Manual of Mental Disorders*, children should show at least 6 out of 9 symptoms, either inattention symptoms and/or symptoms of hyperactivity-impulsivity. These symptoms were present in at least 2 contexts.

Table 2 ADHD screening

SDQ_screening			ARS_ diagnosis			CBCL/TRF_screening		
	N	%		N	%		N	%
normal	31	73.8	normal	27	64.3	normal	36	85.7
subclinical	4	9.5	subclinical	7	16.7	subclinical	4	9.5
clinical	**7**	16.7	clinical	**8**	19.0	clinical	**2**	4.8
Total	42	100.0	Total	42	100.0	Total	42	100.0

**Note. SDQ=Strengths and Difficulties Questionnaire, CBCL-Child Behavior Checklist, TRF=Teacher Report Form, ARS=ADHD-Rating Scale IV*

As shown in *Table 2*, SDQ and ADHD-RS-IV results are very close, SDQ identified 7 children with ADHD, the ADHD-RS-IV identified 8 children with ADHD. The CBCL/TRF questionnaire, however, failed to identify children with ADHD.

Discussion

Internal consistency indicated by Cronbach's alpha coefficient was high at all subscales of the questionnaires used, which indicates a very good internal consistency of the measurement tools. Furthermore, a good predictive validity was found (indicated by test-retest correlations, at the initial assessment time -T1, and after a month-T2). In addition, good concurrent validity of the questionnaire SDQ - hyperactivity subscale was found, high values of Pearson correlation coefficients indicated a strong association between SDQ scores, CBCL/TRF, and ADHD-RS-IV, in both versions: parents (P) and teachers (T) at T1 - initial assessment and T2 – re-evaluation.

The current results were similar to previous studies. Meta-analysis conducted by Stone et al. (2010) examined the psychometric properties of the SDQ questionnaire in children aged between 4-12 years. According to the results from 48 studies (N = 131 223), the reliability and validity of the SDQ-T, SDQ-P are generally acceptable. Internal consistency Cronbach's alpha values were between α=.53-.85, especially fair for the hyperactivity subscale SDQ-P α = .76 and SDQ-T α = .83. Test-retest reliability was strong, correlations between r= .57 - .85, respectively high value of Pearson correlation r = .71 for SDQ-P-hyperactivity subscale and r = .85 for SDQ-T-hyperactivity subscale). Moreover, the inter-rater correlations weighted values were between .26 - .47, for the hyperactivity subscale r =.47. In sum, the results were generally satisfactory for both versions (teachers and parents). However, reliability of the SDQ-T - teacher version seemed stronger compared to SDQ-P- parent version. Correlations with other instruments, for example SDQ-CBCL correlations, were generally high.

In the present study, paired samples t test was used to analyze the differences between evaluators. Significant differences were found between evaluators, using SDQ and CBCL/TRF – hyperactivity subscale, except ADHD-RS-IV with no statistically significant differences between raters. Mean scores were higher for SDQ-T, teachers reported more ADHD symptoms compared to parents. Previous studies (Vaz et al., 2016) reported higher scores of parents' evaluations compared with teachers.

According to Bland-Altman LOA Plots analysis, all questionnaires used showed low inter-rater consistency. There were systematic differences between evaluators (parents and teachers) using the SDQ -hyperactivity subscale, CBCL/TRF, ADHD-RS-IV -total and hyperactivity and inattention subscales.

Inter-rater agreement was also low indicated by ICC, Intraclass Correlation Coefficient (single measures, two-way mixed model, absolute agreement). In addition, consensus among evaluators (parents and teachers) was low, indicated by the percent agreement and Cohen's kappa coefficients. These results were similar to results from the study by Vaz et al. (2016).

Previous studies (Achenbach, 2006; de Los Reyes, Kazdin, 2004, 2005, 2006; de Los Reyes et al., 2009) found similar results: there were discrepancies between the ratings of teachers and parents. One possible explanation for the disparity between teachers and parents may be the different context (de Los Reyes et al., 2009; Youngstrom et al., 2000; Vaz et al., 2016). The study by Vaz et al. (2016) examined the inter-rater agreement and concordance between parents and teachers using the SDQ questionnaire. Analysis was conducted on scale, subscale and item level in order to identify items that showed the greatest discrepancies and determine the concordance between the reports of parents and teachers (N=299). The results of the study indicated acceptable ICC on individual level: ICC (2,1) = .44 (.34 -.53 95%), on the item level ICC (2,1) = .96 (.91 -.98 95%), these values showed very good agreement. Percent agreement values were between 98.32% - 45.61, showing a fair consensus between teachers and parents, 11 items percentage agreement were higher than 70%. Cohen's weighted Kappa coefficients were low, with values between .18 - .36. All these results suggest that SDQ is not optimized for use on normal population and psychometric properties of the SDQ are still justified (Vaz et al., 2016).

The diagnosis using the SDQ was quite accurate, the hyperactivity subscale identified 7 children with ADHD, furthermore, the ADHD-RS-IV identified 8 children with ADHD. The CBCL/TRF questionnaire, however, failed to identify children with ADHD.

In conclusion, the psychometric properties of the SDQ questionnaire were generally satisfactory with acceptable values. These results suggest the use of the SDQ questionnaire in future studies.

3.2.2. Study IIb. Values and limits of the SDQ questionnaire among Hungarian population of Transylvania

Objectives

The overall objective of this study was to evaluate the SDQ questionnaire among typically developing children. The instrument was used for a general screening to identify children with ADHD symptoms. Another objective was to evaluate the predictive value of the SDQ questionnaire for ADHD screening. The values and limits of the questionnaire based on the Hungarian population of Transylvania were analyzed.

Methods

Participants

A total of 207 children were evaluated, 3 were excluded due to lack of data (N = 204). Teachers completed the SDQ questionnaire for 119 children, parents completed for 140 children and a total of 103 children (N = 103) were evaluated by parents and teachers. The sample consisted of 57.3% female, 42.7% male participants, age 6 to 10 years, mean age M(SD)=7.55(1.54). All children come from Cluj County, from preparatory classes and grades II-III.

Measurements

Evaluation of ADHD symptoms: The Hungarian version of SDQ (Goodman, 1997, Goodman, Meltzer, Bailey, 1998, Goodman et al., 2004), SDQ-T and SDQ-P versions, for pupils aged 4-17. SDQ includes 25 items, grouped in 5 subscales: 1) emotional disorder, 2) conduct disorder, 3) hyperactivity, 4) peer problems, 5) prosocial behavior. Items can be labeled on a Likert scale from 0 = rare / never to 3 = very often. To confirm the ADHD diagnosis, the semi-structured interview (ADHD Child Evaluation-ACE) was used with parents based on the DSM-5 scale. The interview was conducted by a clinical psychologist.

Procedure

The participants were recruited with the help of teachers from Cluj County, from several Hungarian-language schools: "Báthory István" Theoretical High School, "János Zsigmond"

Unitarian High School, "Brassai Sámuel" Theoretical High School. Teachers have completed the questionnaire for students (generally 1 teacher for the whole class: 20-30 students): children with typical or atypical development. Parents also completed questionnaires for all children.

Results

For data analysis and processing, the SPSS (Statistical Package for Social Sciences) 20 version was used.

The SDQ-T version had very good **internal consistency** indicated by high Cronbach Alpha values. The subscales of SDQ-P version had lower internal consistency values, although the Hyperactivity subscale had acceptable Cronbach Alpha value ($\alpha = .76$).

Construct Validity

We conducted an **Exploratory Factorial Analysis** in the SPSS, based on the 25 items from the SDQ-T (teacher version). We tested, according to the original model, whether we can identify 5 factors by factor analysis (according to the results of previous studies). The 5 identified factors explain 72.22% of the total variance.

The first step was to analyze the existence of a sufficiently large correlation between the variables: the Bartlett sphericity test $\chi 2$ (df) = 2049.1 (300), the anti-image correlation matrix and the Kaiser-Meyer-Olkin index (KMO) Measure of Sampling Adequacy = .88 was used. All these results indicated that items are appropriate for factorial analysis. We used the “varimax” orthogonal method, which minimizes the number of variables. Items had medium to high factorial saturations (values ranging from .53 to .88).

The **1st Factor** explains 41.7% of the variance and consists of a total of 11 items; in the original questionnaire the negative values represent the prosocial behavior subscale, composed of the following items: 1, 4, 9, 17, 20. In this study, these items were delimited by negative values, because the prosocial behavior subscale contains only positive statements, all the other statements being negative. The remaining items were the following: 5, 7, 12, 14, 18, 21 they relate in particular to behavioral problems, conduct disorder. In the original questionnaire, the conduct disorder subscale is composed of the following items: 5, 7, 12, 18, 22. From these items 4 match our results, but 1 item does not match. So, according to our results, factor I in this study could be called “***behavioral factor***”.

The **2nd Factor** explains 14.39% of the variance and consists of a total of 6 items: 3, 8, 13, 16, 24, representing the scale of emotional problems, referred to in the original as the subscale of emotional disorder: composed of the above mentioned items. Therefore, according to our results, factor II contains 5 items (as in the original questionnaire) and can be defined as “***emotional disorder***”.

The **3rd Factor** explains 6.27% of the variance and is composed of a total of 4 items, which are the following: 2, 10, 15, 25, representing the ADHD subscale, referred to in the original as the hyperactivity subscale, composed of the items: 2, 10, 15, 21, 25. Therefore, according to our results, factor III contains 4 items instead of 5, and can be labeled as “hyperactivity and inattention problems”.

The **4th Factor** explains 5.28% of variance and contains 3 items: 6, 11, 23, which belong to the peer problems scale. Therefore, according to our results, factor IV contains 3 items, instead of 5 (in the original questionnaire) and can be named “relational problems”.

The 5th Factor explains 4.58% of the variance and contains 2 items: 19, 22, which represent items from the conduct disorder subscale (22) and peer problems (19) subscale.

Ultimately, the 5th factor containing the items 19 and 22 was taken out from the analysis. The remaining four factors identified explained 70.59% of the total variance. The Bartlett sphericity test $\chi 2$ (df) = 1922.84 (253); the anti-image correlation matrix; and the Kaiser-Meyer-Olkin index (KMO) Measure of Sampling Adequacy = .89 indicated that items are appropriate for factorial analysis.

Table 3 Factor Saturation Matrix (**Extraction Method: Principal Component Analysis,* Rotated Component Matrix, *4 components extracted)*

	1	2	3	4
SDQ T1	-0.86	-0.35	0.05	-0.13
SDQ T2	0.61	0.67	-0.05	-0.04
SDQ T3	0.05	-0.16	0.59	0.33
SDQ T4	-0.81	-0.13	-0.15	-0.12
SDQ T5	0.73	0.35	0.15	-0.18
SDQ T6	0.04	0.10	0.39	0.61
SDQ T7	0.80	0.37	-0.01	0.02
SDQ T8	-0.06	-0.08	0.87	0.06
SDQ T9	-0.82	-0.04	0.12	-0.31
SDQ T10	0.52	0.70	-0.06	-0.08
SDQ T11	0.39	0.47	-0.07	0.65
SDQ T12	0.85	0.16	0.00	-0.18
SDQ T13	0.08	0.19	0.75	-0.21
SDQ T14	0.63	0.41	0.21	0.35
SDQ T15	0.25	0.74	0.22	0.15
SDQ T16	0.00	0.25	0.71	0.25
SDQ T17	-0.74	-0.20	0.19	-0.33
SDQ T18	0.78	0.15	0.16	0.05
SDQ T20	-0.80	-0.24	0.06	-0.28
SDQ T21	0.69	0.57	-0.03	0.13
SDQ T23	0.11	0.01	0.36	0.55
SDQ T24	-0.03	0.07	0.69	0.17
SDQ T25	0.38	0.69	0.23	0.28

The factor loadings vary between .55-.86 (see Table 3).

The **1st Factor** remained as previous (items: 5, 7, 12, 14, 18, 21- relate in particular to behavioral problems, and all other to prosocial behavior), explained 44,23% of the variance. Therefore, this factor was labeled as ***"behavioral and prosocial problems".***

The **2nd Factor** explains 15.18% of the variance and consists of a total of the following 4 items: 2, 10, 15, 25, representing the "***ADHD subscale***" -symptom of hyperactivity and inattention, referred to in the original as the hyperactivity subscale.

The **3rd Factor** explains 5.95% of variance and is composed of the following items: 3, 8, 13, 16, 24, which represents the scale of emotional problems, referred to in the original emotional disorder. Therefore, this factor was defined as "***emotional disorder***".

The **4th Factor** explains 5.23% of the variance and contains 3 items: 6, 11, 23, which belong to the peer problems subscale. Therefore, this factor was labeled as "***peer problems***".

A **Confirmatory Factor Analysis (CFA)** was conducted using the SPSS AMOS package. The 25 items of the SDQ-T (Teacher Version) 5 factor structure model was tested. The Maximum Likelihood procedure was used. The CFA led to the maintenance of a 4-factor model (see *Figure 5*).

Model Fit Indices: The chi-square test shows the difference between the estimated parameter matrix and the sample matrix: $\chi 2$ (224) = 598.14, p = .00 – the p value must be insignificant so as to be considered acceptable (N = 102). There are a variety of guidelines for interpreting the results that match a particular model based on these indices. For the CFI-Comparative Index (CFI, Bentler, 1990) and the GFI-goodness-of-fit index (GFI, Joreskog, Sorbom, 1986), acceptable values are close to or greater than 0.95. The RMSEA values- the root-mean-square error of approximation (RMSEA, Steiger, Lind, 1980) must be less than 0.05, indicating a good fit of the model, and the values less than or equal to 0.08 indicate a reasonable match. According to the results of the current study, the 4 factor structure model is not quite adequate, indicated by poor model fit indices: CFI = .80, PCFI = .71, RMSEA = .13, TLI rho2 = .77. Taking into consideration the low sample size, the model can be accepted.

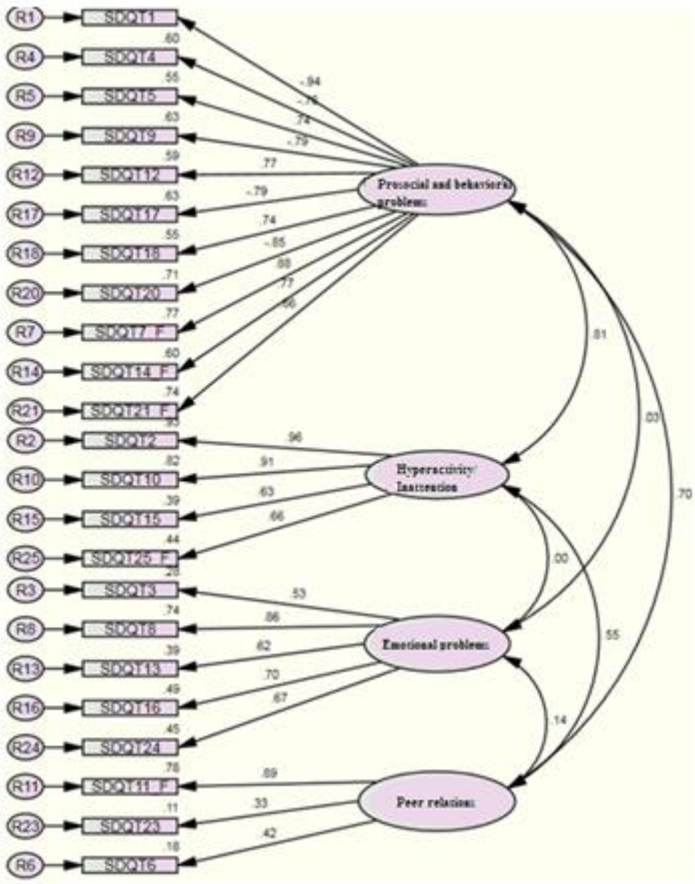


Figure 5. Confirmatory Factor Analysis - AMOS Graphics CFA

The results of the **paired samples t test** indicate statistically significant differences between the two groups of evaluators (teachers and parents), at item and scale level, except for items 2 and 10, symptoms of hyperactivity [teachers: M (SD) = 1.45 1.7), parents: M (SD) = 1.59

(1.40), t (df) = - 97 (102), p = 0.33. Therefore, the symptoms of inattention [teachers: M (SD) = 1.65 (1.07), parents: M (SD) = 1.18 (1.43), t (df) = 3.43 (102, p = Df) = -2.73 (102), p = .01] reported by parents and teachers differ significantly. To illustrate the differences between evaluators the **Bland-Altman Limits of Agreement Analysis (LOA)** was used (https://www.medcalc.org/manual/blandaltman.php).

Table 4 Descriptive data concerning inter-evaluator agreement when using Bland-Altman LOA analysis

	Δ M (SD)	95 % CI Δ M		95 % lowerLOA	95 % upperLOA
ADHD subscale - total	-.61 (2.28)	3.86	-5.08	-1.06	-.17
Items referring to hyperactivity symptoms (2,10)	-.15 (1.52)	2.83	-3.13	-.44	.15
Items referring to inattention symptoms (15,25)	-.47 (1.38)	2.23	-3.17	-.74	-.20

**Note.* *Δ = difference of Teacher and Parents evaluations, LOA = limits of agreement, CI = confidence interval*

The Bland-Altman LOA analysis (see Table 4, Figure 6 A-C) showed systematic differences between evaluators (parents and teachers) in the ADHD subscale and the items that refer to symptoms of inattention. The Bland-Altman LOA analysis is in agreement with the paired samples t tests, which show significantly different scores among the evaluators (parents and teachers) on the ADHD subscale and inattention symptoms.

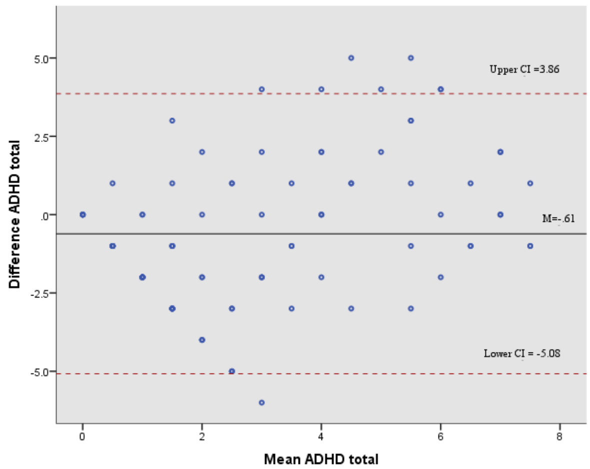
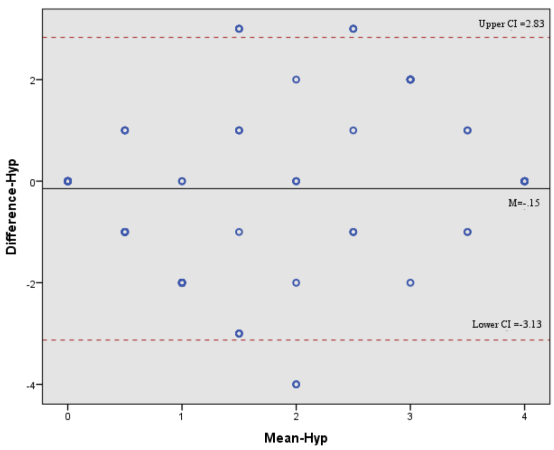


Figure 6A. Hyperactivity Subscale



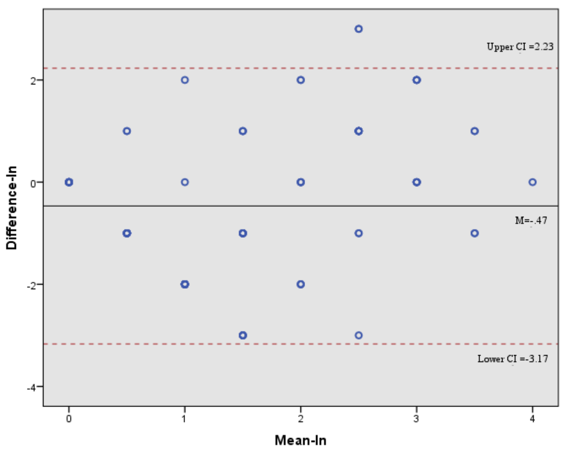


Figure 6B. Symptoms of Hyperactivity (items 2,10)

Figure 6C. Symptoms of Inattention (items 15,25)

Figure 6 A–C. Bland-Altman LOA Plots

To analyze the inter-evaluator agreement, the ICC-Intraclass Correlation Coefficient, Absolute Agreement, single measures (2,1) was used. For hyperactivity symptoms (items 2, 10): Cronbach alpha was α =. 85, and the ICC, = 59 (95% CI: .50-68), a quite acceptable value. For symptoms of inattention (items 15, 25) the Cronbach alpha was α = .72, and the ICC= 36 (95% CI: .26-.47) was low. For ADHD total symptoms Cronbach alpha was α = .87, ICC= 44 (95% CI: .36-.53) an average value. These results indicate low to medium ICC values, ranging from .36 to .59. The Average Measures values were high, between .70-.86.

According to the results, the consensus among evaluators: parents and teachers was low, the percent of agreement (16.5% -38.83%) and Cohen Kappa coefficients (.07 -.20) were very low.

Screening ADHD: the average scores were obtained from the sum of items based on reports from the SDQ to predict the diagnosis of ADHD. Three categories were generated 1) normal interval= scores between 0-4, 2) subclinical group= scores between 5-6; 3) clinical group= scores ≥7. Of the 103 evaluated children, 75 (72.8%) belong to the normal range, 16 children (15.5%) to the subclinical interval and 12 children (11.7%) to the clinical range of ADHD.

To confirm the ADHD diagnosis, the semi-structured interview (ADHD Child Evaluation-ACE) was used with parents based on the DSM-5 scale. The interview was conducted by a clinical psychologist.

Discussions

The SDQ-T version had a very good Cronbach Alpha value, so the questionnaire has a high internal consistency. The results of the current study are similar to results of the meta-analysis conducted by Stone et al. (2010). In the SDQ-P version the internal consistency of the scales is low, except the Hyperactivity subscale (α = .76), whereas the Cronbach Alpha index is acceptable.

In the validation study of Turi, Tóth and Gervai (2011), the three SDQ-T, SDQ-P, SDQ-self-reported (N = 286) versions were used in Hungarian adolescents from Hungary, aged between 12-17 years old. The internal consistency of the scales was generally acceptable, with a few exceptions, the teacher version showed higher internal consistency, compared to the UK norms, there were no significant differences between the two populations.

The construct validity was tested using the factorial analysis. An EFA factorial analysis of the teachers' version of SDQ-T led to the identification of 5 factors (Becker et al., 2004, He et al., 2013, Sanne et al., 2009, Stone et al., 2010, van Leuween et al. 2006, Van Roy et al., 2008). The 5th factor was deducted: items 19, 22. The remaining four factors explained 70.59% of the total variance.

The CFA has led to the preservation of a 4-factor model. Results indicate low model fit indices, however, because the low sample size, the values can be considered acceptable, therefore this model was kept and further research was conducted based on the hyperactivity subscale of SDQ.

A single study was found based on the Romanian population using the SDQ version of the self-reported measure (N = 1086), children aged 9-17, including 4 counties from Romania (Iasi, Botosani, Vaslui, Bacau). The results show low internal consistency of the subscales, CFA tend to the 5-factor structure, but none of the tested models was statistically acceptable (Sharratt et al., 2014).

The current study's paired samples t test results for the hyperactivity subscale of SDQ indicate statistically significant differences between the two groups/raters, except for items 2 and 10, the symptoms of hyperactivity. So the results reported by parents and teachers differ significantly; generally, parents reported much more inattentive symptoms than teachers. Furthermore, the Bland-Altman LOA analysis argues that the two versions of the SDQ-P and SDQ-T questionnaire offer results with low concordance, with discrepancies between teacher and parental assessments, except for items 2, 10, which refer to the symptoms of hyperactivity. The Bland-Altman LOA analysis was in agreement with the results of paired sample t test, which showed significantly different scores between evaluators (parents and teachers). Analysis of the inter-evaluator agreement led to the same result, ICC (2,1) single measures were low or medium: .36-.59; and the ICC, Average Measures were high: between .70-86. To sum up, the multimodal approach is the best for assessing ADHD and for diagnosing this disorder: at least 2 evaluators are needed for the diagnosis, only one evaluator seems to be unreliable, and it is not enough. The following benefits of the SDQ tool should be considered: it is cost effective, and time reducing. The 4 items of the hyperactivity subscale of the SDQ can be used for predicting ADHD diagnosis.

General Conclusions

In Study IIa and IIb the SDQ as a screening tool was tested for detecting ADHD symptoms. In Study IIa the results showed that both versions of the SDQ-T questionnaire and SDQ-P have acceptable psychometric properties, which led us to the decision to use SDQ in the next study (Study IIb). The internal consistency of the SDQ, CBCL/TRF and ADHD-RS-IV questionnaires were high, with values between α=.75-.97. The hyperactivity subscale of the SDQ correlated significantly with ADHD-RS-IV (ADHD-Rating Scale-IV) and with the CBCL/TRF scale, Pearson correlation values were between r=.85-95, indicating a strong association of the variables. The inter-evaluator agreement was medium, therefore acceptable, but the consensus among parents and teachers regarding the behavior of the children was low. In Study IIb the internal consistency of the subscales was low for the SDQ-P and there were significant differences between the assessment of parents and teachers. One of the reasons for the differences between evaluators might be that parents spend very little time with the children, so they may not properly fill in the questionnaire. For example, items can be supplemented with questions about the children-parent relationship.

3.3. Study III. Neurocognitive evaluation of children with ADHD symptoms compared to those with typical development

Introduction

Several studies have shown neurocognitive deficiencies in ADHD (Kofler et al., 2008, Rapport et al., 2008, Sergeant, 2000, Sonuga-Barke, 2005). According to the results of the meta-analysis of van Lieshout et al. (2013), children with ADHD generally showed lower performance in tasks requiring neurocognitive functioning compared to children with typical development (the results were obtained from 18 studies). Neurocognitive deficiencies appear to play a key role in ADHD: many children have deficiencies in cognitive control, information processing and processing speed (Castellanos, Tannock, 2002, Durston et al., 2011; Sonuga-Barke et al., 2010; Wahlstedt et al., 2009). Intelligence, attention, processing speed of information/visual information processing are cognitive domains in which children with ADHD have significant differences compared to children with typical development (Martinussen et al., 2005; Nazari et al., 2010). Some studies have shown a relatively lower level of intelligence in children with ADHD (Frazier et al., 2004). Larger effect sizes were reported for verbal IQ compared to IQ performance. According to the results of Brocki et al. (2007), IQ has predicted the symptoms of ADHD.

Objectives and hypotheses

The objective of this study was to explore the neurocognitive dimensions that differentiate children with typical development from those with ADHD symptoms.
Hypothesis: There is an association between ADHD and the following cognitive functions: verbal working memory, visuospatial working memory, processing speed. Children with ADHD show a lower performance in tasks requiring neurocognitive functioning compared to children with typical development.

Methods

Participants

A total of 207 children were evaluated, but 3 were excluded due to lack of data (N = 204), with an average age M(SD)=7.55 (1.54), aged 6 to 10 years. All children who were evaluated come from Cluj-Napoca, from the preparatory classes and grades I-III. Distribution by gender was 57.3% (N = 59) male and 42.7% (N = 44) female participants.

Measurements

Evaluation of ADHD symptoms: The SDQ-T and SDQ-P (Goodman, 1997, Goodman et al., 2004), Hungarian version was used.
Assessment of Intelligence and other neurocognitive functions:
Raven Progressive Matrices Color and Standard version of the Intelligence Test - Total Intelligence Coefficient shows the child's overall intellectual abilities. The Raven Color version was used in grades 0-II, and the Standard version for grades III-IV.
Wechsler Intelligence Scale for Children - WISC-IV (Wechsler, 2003a): Assessment of the verbal working memory capacity through the **Digit span** (forward and backward order), the assessment of the visuospatial working memory capacity: **CBTT (Corsi Block Tapping Task**, Kessels et al., 2000) - Corsi cubes adapted by us. (The visuospatial WM capacity of the participants was estimated by the number of the longest series of correct elements: for example if a child has retained a series of 4 elements, the capacity of the participant's visuospatial working memory is 4. The cognitive load was calculated by the following formula: backward minus forward condition). In addition, for the evaluation of the processing speed the **Coding** and **Symbol Search** subtest was used. The ability to process visual information was calculated using the following formula: (number of correct items - number of incorrect items) / time-sec). These subtests from the WISC-IV require several cognitive processes including

selective/focused attention, short-term memory, motor output, visual-spatial associative learning.

Procedure

The first test was the Raven Intelligence Test (approximately 20-30 minutes), then the children were evaluated by digit span subtest (10 minutes), forward and backward condition, followed by the Coding subtest (6 minutes = 3 Times * 120 seconds) and the Search for Symbols subtest (6 minutes = 3 times * 120 seconds) from the WISC-IV. The performance of the Coding and Symbol Search tasks was calculated by the following formula: (number of correct elements minus the number of incorrect elements) divided by the total solving time in seconds*100. Performance = (Number of Correct Elements - Number of Incorrect Elements)/ resolution time*100. Finally, we measured the capacity of the visuospatial WM through the Corsi- cubes-CBTT (10-15 minutes) that we have adapted. The evaluation of a child lasted for about 60 minutes.

Results

Factor Analysis

An Exploratory Factor Analysis of the assessed cognitive functions was performed. The EFA led to the identification of 3 factors, which explains 72.41% of the total variance.

The Bartlett sphericity test $\chi2$(df)=111.48(15), the anti-image correlation matrix (see Table 5), the Kaiser -Meyer-Olkin (KMO) Measure of Sampling Adequacy=.71 indicated that the items are suitable for factorial analysis.

Table 5 Anti-image correlation Matrix

digit span_forward	0.69	-0.46	-0.21	-0.12	0.02	0.04
digit span_backward	-0.46	0.68	-0.22	-0.08	-0.18	0.09
corsi_forward	-0.21	-0.22	0.81	-0.08	-0.08	-0.03
corsi_backward	-0.12	-0.08	-0.08	0.76	-0.21	-0.24
WISC-Coding	0.02	-0.18	-0.08	-0.21	0.73	-0.25
WISC-Symbol Search	0.04	0.09	-0.03	-0.24	-0.25	0.61

The main component analysis (Hotteling), the factor extraction method: main axis factoring was chosen. The varimax orthogonal method was used, which follows the criterion of simplification of the factorial matrix columns, maximizing the variance given by the saturation square for each factor, minimizing the number of variables with high factorial saturations for each factor (see Table 6), thus simplifying the factor interpretation. It analyzes the matrix of linear correlations between variables and evaluates the existing common variance and extracts the factor that encompasses the greatest amount of variability. Factors are defined by the degree of loading ("saturation"). The higher saturation a factor has in relation to certain variables, the more "cohesive" these variables are, and have more consistent common meaning.

Table 6 Matrix of factorial saturations

**Extraction Method: Principal Component Analysis,* Rotated Component Matrix, *3 components extracted*

	1	**2**	**3**
digit span_ forward	**.84**	.12	-.07
digit span_ backward	**.83**	.02	.17
corsi_forward	**.69**	.08	.19
corsi_backward	.30	**.85**	.02
WISC– Symbols	-.15	**.70**	.43
WISC- Coding	.22	.18	**.90**

The **1st Factor** is composed mainly of the following: digits span_forward (.84), span_backward (.83), corsi_forward (.69). Factor I explains 39.67% of the variance. So, according to our results, factor I contains 3 items and it can be defined as ***"verbal working memory".***

The **2nd Factor** is composed of the WISC-Symbols (.70), corsi backward (.85), explains 21.69% of the variance. Factor II can be labeled as the ***"visuospatial working memory"***. The WISC encoding and Symbol search subtest measures the information processing speed, the task focuses on the processing capability of visual information, in each row the participant must look for the target symbol(s). This requires multiple cognitive functions: besides short-term memory, information manipulation is needed, so visuospatial working memory is needed.

The **3rd Factor** is composed of the WISC coding item (.90), which explains 11.05% of the variance. Factor III can be defined as the "***processing speed of visual information***".

Cluster Analysis

The iterative partitioning analysis (K-Means Cluster) was computed. The grouping is based on the assessment of the similarity/disparity between cases. The k-means clustering technique, the iterative approach starts from a fixed number of clusters declared by the researcher. In this study, several options 2, 3, 4 clusters were tested. In the end, based on the previous factorial analysis and taking into account the three factors: verbal WM, visuospatial WM and processing speed, the participants of this study were allocated into 3 clusters.

Table 7 Descriptive data related to clusters

		Cluster 1 N=39	Cluster 2 N=14	Cluster 3 N=50
Gender	Male	22 (56.4%)	7 (50%)	30 (60%)
	Female	17 (43.6%)	7 (50%)	40 (40%)
Age	M (SD)	6.56 (1.10)	7.14 (1.46)	8.43 (1.36)
IQ	M (SD)	108.28 (14.53)	113.57 (12.23)	113.24 (11.85)
ADHD total Symptoms	M (SD)	2.81 (2.07)	2.68 (2.44)	3.11 (2.29)
Hyperactivity Symptoms	M (SD)	1.50 (1.28)	1.43 (1.58)	1.56 (1.39)
Inattention Symptoms	M (SD)	1.31 (.99)	1.25 (1.12)	1.55 (1.09)
Digit span_forward	M (SD)	5.69 (1.10)	4.57 (.76)	6.42 (1.07)
Digit span_backward	M (SD)	3.41 (1.09)	3.00 (1.57)	4.80 (.93)
Corsi_forward	M (SD)	1.62 (1.04)	1.43 (.94)	2.58 (1.03)
Corsi _backward	M (SD)	1.41 (1.41)	1.50 (1.16)	1.24 (1.02)
WISC-codare	M (SD)	15.19 (5.12)	29.01 (10.82)	25.70 (5.92)
WISC-simboluri	M (SD)	13.71 (4.13)	19.45 (2.87)	13.85 (3.38)
	0 –normal interval	30 (76.9%)	11 (78.6%)	34 (68%)
ADHD Diagnosis	1 – subclinical interval	5(12.8%)	1 (7.1%)	10 (20%)
	2 –clinical interval *ADHD	4(10.3%)	2 (14.3%)	6 (12%)

Figure 7 graphically shows the center of the clusters in the final stage.

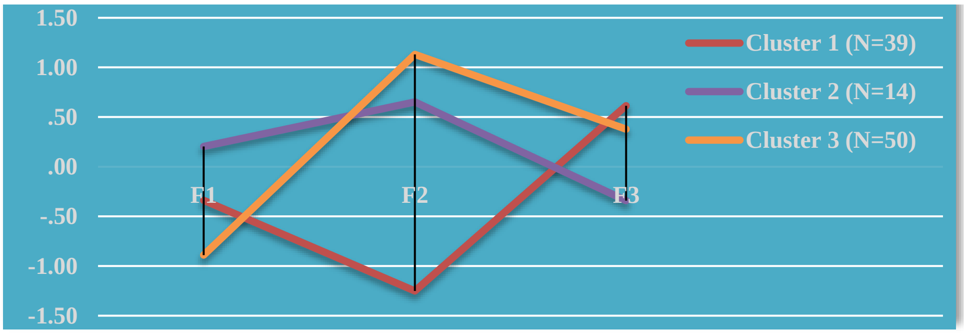


Figure 7. Final cluster centers

The obtained clusters highlight types of pupils with different cognitive functioning.

Cluster 1 includes children (N = 39) with a low verbal WM capacity (factor I), a very low visuospatial WM (factor II), and a high processing speed (factor III), mean age M (SD) = 6.56 (1.1) years, 56.4% male gender (N = 22), 43.6% (N = 17) female gender, M: SD (108.28). In this cluster 76.9% (N=30) of the participants were assigned to the normal group, 12.8% (N=5) to the subclinical group and 10.3% (N=4) were allocated to the clinical ADHD group.

Cluster 2 consists of 14 children with low verbal WM capacity (factor I), average visuospatial WM capacity (factor II), low processing speed (factor III). The level of intelligence of children in this cluster is average: M(SD)=113.57(12.23), mean age M=7.14 years, 50% (N=7) male and 50% (N=7) female participants. 78.6% of the participants (N=11) were assigned to the normal group, 7.1% (N=1) to the subclinical group and 14.3% (N=2) were allocated to the clinical ADHD group.

Cluster 3 (N=50) out of the assigned children 68% (N=34) were grouped into the normal interval, 20% (N=10) were assigned to the subclinical group and 12% to the ADHD clinical group (N=6). The 3rd cluster includes children with a low verbal WM capacity (factor I), a medium visuospatial WM capacity (factor II), and a high processing speed (Factor III). The mean age of the participants was M=8.43 years, 60% of the participants were male (N=30) and 40% female, with medium intelligence indicated by average of M(SD)=113.24(11.85).

To validate the cluster analysis, *Table 8* presents the results of the ANOVA test.

The comparisons made by the ANOVA test confirm the hypothesis partially. Thus, participants with ADHD symptoms have significantly different levels of neurocognitive functions, they are not clearly delineated by children with typical development. Therefore, children's performance differ according to the three factors based on which children were allocated into the clusters: the capacity of verbal WM, the visuospatial WM and the processing speed.

Table 8 Results of the ANOVA test (based on the cluster centers)

		Factor I	Factor II	Factor III
	N	M (SD)	M (SD)	M (SD)
1	39	-.34 (.79)	.20 (.99)	-.89 (.52)
2	14	-1.25 (.90)	.65 (.83)	1.13(1.14)
3	50	.61(.68)	-.34(.93)	.38 (.62)
total	103			
		F(2,100)=39.89 p=.00	F(2,100)=7.56 p=.00	F(2,100)=60.58 p=.00

Discussion

The EFA factorial analysis led to the identification of 3 factors- the 1st Factor: verbal WM, 2nd Factor: visuospatial WM, 3rd Factor: the processing speed of visual information.

Based on these factors, a cluster analysis allocated children into 3 different clusters. The obtained clusters highlight types of pupils with different cognitive functioning.

Cluster 1 includes 4 children who were allocated to the clinical ADHD group, children with a low verbal WM capacity, a very low visuospatial WM capacity, and a high processing speed.

Cluster 2 includes 2 children with ADHD, with low verbal WM capacity, average visuospatial WM capacity and low processing speed.

Cluster 3 includes 6 children with ADHD with a low verbal working memory capacity, average visuospatial WM capacity and a high processing speed. These results confirmed our assumptions partially.

The majority of studies (Castellanos, Tannock, 2002, Durston et al., 2011, Frazier et al., 2004, Martinussen et al., 2005, Nazari et al., 2010, Sonuga-Barke et al., 2010, Wahlstedt et al., 2009) reported negative impact of ADHD symptoms on cognitive abilities. Our study confirms this hypothesis, children with clinical ADHD were assigned to different clusters. Some children have a significantly better level of performance in verbal WM, some have a lower level of visuospatial WM. The symptoms of ADHD affect these cognitive functions in a particular way, and confirm the variability of the typology. Our results highlight the results of previous studies, according to which some children with typical development have few neurocognitive deficits (Hudziak et al., 1999). According to the results of Sjöwall et al. (2012), only 1/5 of the children with typical development had neurocognitive difficulties. Other studies generally did not find significant differences in the neurocognitive functions of children with ADHD compared to those with typical development (Nigg et al., 2005, Sjöwall et al., 2012).

Summarizing the results of the studies, they attest the dimensional approach (Hudziak et al., 2007): ADHD is not a category clearly delineated by, it can be rather defined as the normal distribution of various factors - behavioral and cognitive factors - perceived as a constellation (Nigg, 2001; Nigg et al., 2005). Studies have shown WM deficits in children with ADHD, which may indeed be an affected factor, but the problem is that the specificity of WM deficits is low, deficits occur at almost all developmental disorders (Arnsten, Rubia, 2012; Martinussen, Tannock, 2006; van de Voorde, 2009; Willcutt et al., 2010).

Studies show that all three forms of ADHD are characterized by various cognitive difficulties, the profiles of the predominantly inatenttive (ADHD-N) children are not similar to the predominantly hyperactive-impulsive (ADHD-HI) and combined ADHD (ADHD-C). It is suggested that cognitive impairments are more pronounced in ADHD-C (Nigg et al., 2005), 35-50% of this group showed cognitive difficulties. But there are few studies that directly compare the effects of the predominant types on cognitive functions.

3.4. Study IV. Development of an assessment and intervention program focused on visuospatial working memory. Cognitive restructuring of the visuospatial system in children with ADHD by individualized intervention. A pilot study

Introduction

Given that only a subset of children have specific cognitive dysfunctions, significant deficits in the visuospatial WM appear only in some children with ADHD (Fair et al., 2012). Some studies (Holmes et al., 2010, Lambek et al., 2011) have tried to identify and delineate these children with WM deficits in the ADHD population. The results indicate a fairly large subgroup: 29-47% of children with ADHD have deficits of visuospatial WM (Lambek et al., 2011).

According to Martinussen, Tannock (2006), the ADHD-C (combined) group had lower performance in all tasks requiring short-term memory and working memory, compared to the control group. The ADHD-N (predominantly inattentive) group showed deficiencies in tasks related to visuospatial WM and executive functions. The ADHD-HI (predominantly hyperactive-impulsive) group showed no significant deficits.

The relationship between cognitive processes, working memory and motivational processes has been investigated only in some studies (Huang-Pollock et al., 2008). According to Diamond's results (2005), children in the ADHD-N subtype showed motivational deficits in interaction with cognitive functioning. Carlson et al. (2002) found similar results in both subtypes: ADHD-C and ADHD-N.

According to the results of Dovis et al. (2012) in both ADHD-C and ADHD-N subtypes, motivational deficits were found, which had an effect on the performance of short-term and working memory. The ADHD-N subtype appears to be unaffected in terms of visual and spatial short-term memory, but deficits occur at the central executive component and motivational level (Dovis et al., 2012). These results are consistent with the results of van Ewijk et al. (2015). They showed significant visuospatial WM deficits in patients with ADHD compared to the control group and their typically developing peers.

Objectives and hypotheses

The overall objective was to develop and test a computerized assessment and intervention gamified program (with game elements) targeting the visuospatial WM. The main aim was to identify the values and limits of the evaluation and intervention program developed in a specific population: children with ADHD.
Hypothesis: As a result of the intervention with the gamified program focusing on the training of visuospatial WM, children with ADHD will show higher performance in neurocognitive functions: verbal WM, visuospatial WM and processing speed. The intervention program aims at the cognitive restructuring of the visuospatial system.

Methods

Pre-test and post-test evaluation was used. The intervention consisted of 10 sessions, 15 min/session with the gamified program.

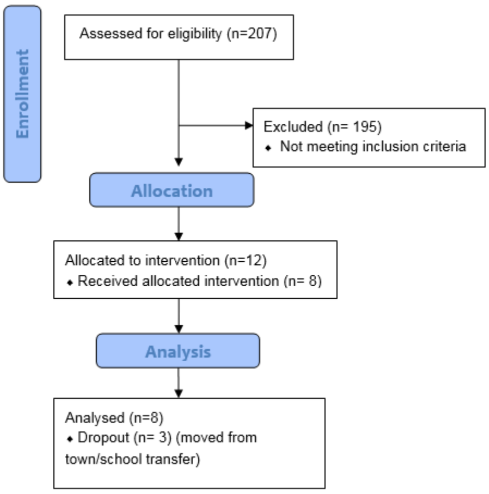


Figure 8. CONSORT Flow chart

Participants

Out of the 207 assessed children with typical development, 195 children were excluded because they did not have ADHD diagnosis. Twelve participants were assigned to this study, but only 8 children had ADHD, all male (see *Figure 8* – for the selection procedure), out of which 7 had ADHD-C -combined diagnosis, except one child: ADHD-N-predominantly inattentive.

Measurements

Evaluation of ADHD symptoms: 1) the hyperactivity subscale from the SDQ-T,-P (Goodman, 1997, Goodman et al., 2004), Hungarian version, 2) the CBCL/TRF questionnaire (Achenbach, Rescorla, 2001, Perczel Forintos et al. Al., 2007), 3) the Conners Teacher and Parent Rating Scale - CTRS-R, CPRS-R (Conners, 2008; In: Perczel Forintos et al., 2007) was used. To confirm the ADHD diagnosis, the semi-structured interview ADHD Child Evaluation (ACE)[3] was used based on the DSM-5. The interview with parents was conducted by a clinical psychologist.

Evaluation of neurocognitive functions:

1. Intelligence Assessment with Raven Progressive Matrices
2. Corsi Block-Tapping Task (CBTT) digital assessment - adapted by us
3. Evaluation of verbal WM by the digit span subtest from WISC-IV
4. Evaluation of processing speed by Coding and Symbols subtest from WISC-IV

The **Corsi Block Tapping Task (CBTT)** first version (Corsi, 1972) has often been used to measure the capacity of the visuospatial WM. There have been adapted several computerized digital versions of the test (Nelson et al., 2000, Vandierendonck et al., 2004). The program developed by us is a multifunctional computerized one, containing an evaluation component: firstly, the assessment of the current WM level and the intervention component: aimed at developing or increasing the capacity of the visuospatial WM, the cognitive restructuring of the visual-space system.

[3] https://www.psychology-services.uk.com/resources.htm#resource-14

Task description: There are 9 shapes/objects (4x4 cm) positioned on the screen. A sequence is displayed in random order (for example 2- 3 - 4 shapes/elements). The task is to repeat this sequence in the presented order. If a sequence is reproduced correctly, the length of the sequence increases (from a sequence of 2 elements to a sequence of 3 and so on). Another task is to reproduce the sequence in reverse order (backward condition), measuring the capacity of the working memory. The mouse from the computer/laptop can be used or the touchscreen of the tablet or phone. The program is an online platform (http://terviz-robfejerdev.rhcloud.com/), so users only need an internet connection (or wifi) and a digital device of any kind (laptop, tablet, phone).
Learning phase: contains 2 samples x 3 elements (3 elements are lit, 2 times), forward and backward condition. You cannot go through the learning phase unless the answer was correct (see *Figure 9A*).

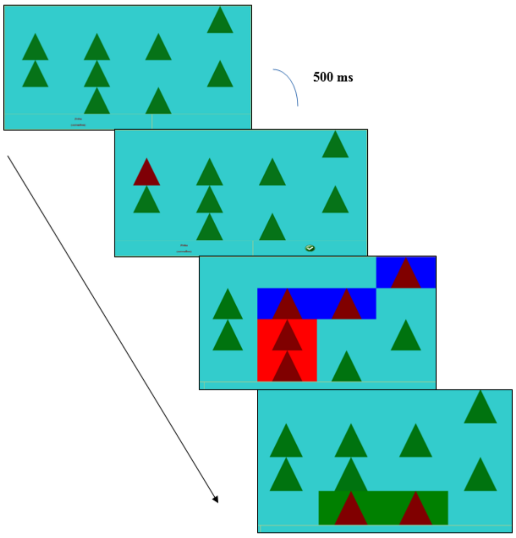


Figure 9A. Examples from learning phase items

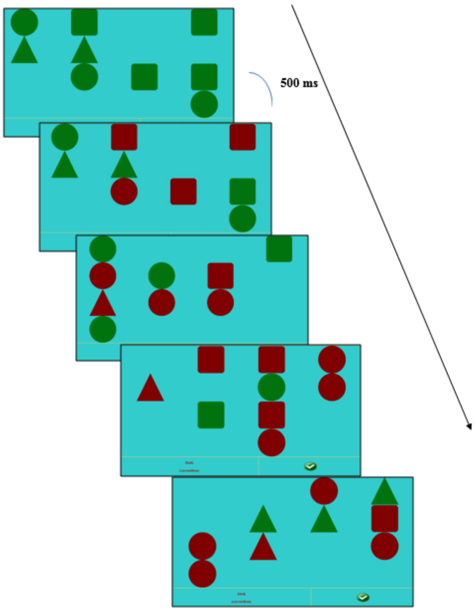


Figure 9B. Evaluation phase

After the learning phase, the assessment phase follows (see *Figure 9B*).
The program measures: 1) the correct answers - global level: the number of sequences recalled correctly, in the correct order, 2) the wrong answers - global level: the number of sequences recalled in the wrong order, 3) the correct answers: the number of positions/locations recalled correctly, 4) the incorrect answers - number of positions/locations rendered incorrectly, 5) partially correct answers: number of positions/locations recalled correctly without the correct order, 6) reaction time (RT): first response time -) Total Response time (TRT).
Therefore, the following **measurable factors** can be identified: a) sequential processing - the order factor: the forward condition, b) spatial processing - the factor location: how many times the subject has chosen the correct location during the task, c) simultaneous processing - the order factor and the location factor combined, d) the processing speed - the time factor: Reaction time + Solving time; e) difficulty level (level 1 - 2 elements, up to level 8 - 9 shapes/elements). During the evaluation phase, participants do not receive feedback. If participants fail 2 consecutive times, the program moves to the next stage.

The intervention component (assessment phase)

The features of the classic intervention program are: sequential processing, recall forward and backward condition (see *Figure 10A*). The level of difficulty is always adapted to the current workload and WM capacity of children. Reducing cognitive load can be achieved by using cognitive load optimization strategies (Ayres, 2006, Paas et al., 2003).

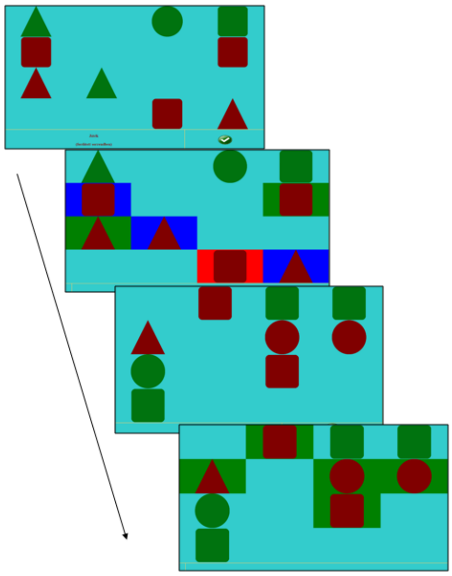


Figure 10A.Example of items of the classical intervention program

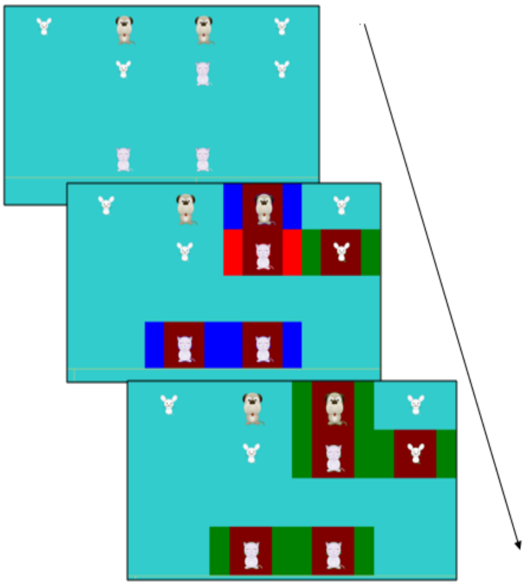


Figure 10B. Example of items from the gamified intervention program

The gamified intervention program

The gamified intervention program (see *Figure 10B.*) is similar to the classic one, but it has some features in addition. The features of the gamified program (which contains game elements) are: storyline, rewards, visual and auditory feedback. The visual feedback consists of the projection of each result (see *Figure 10A-B.*), 3 colors are projected: for the correct answer the green color is used, for the incorrect response the red color and for the expected response blue color (what the participant should have selected for the correct answer). This feedback appears in the first phase, in the learning phase, where all participants are familiarized with the meaning of the colors. During the evaluation phase, participants receive no feedback at all.

Procedure

Initial session. In this session, teachers and parents completed the Conners Scale, the SDQ and the CBCL/TRF questionnaires, and the semi-structured interview was conducted. The first session included the behavioral and neurocognitive assessment of the participants.

Intervention session. Participants were familiarized with the intervention to be received: 10 sessions, with a minimum of 15 minutes/session. All participants benefited from cognitive restructuring of the visuospatial system. The intervention component increased up to 8 levels of difficulty, a sequence of up to 9 elements.

The final session. The neurocognitive functions of the participants were evaluated again.

Results

No significant differences were found between the three clusters. One reason could be the low number of participants from the different clusters. This result may indicate that intervention could be equally effective for all participants.

The nonparametric Wilcoxon test (because there are few participants in this study and the distribution is not normal) was used to highlight the differences between pre- and post-test (see Table 9). The effect sizes were computed using the following equation in Excel: $r=Z/\sqrt{N}$

Table 9 Results of the Wilcoxon test and the effect size

		corsi_fw_NCP_total	corsi_fw_TRT_total	WISC-Coding-total nr. of correct elements	WISC-Coding-average of correct elements	WISC-Symbol Search - total nr. of correct elements
Wilcoxon	Z	-1.97	-1.96	-2.02	-2.1	-1.99
Sig.	p	.049	.05	.043	.036	.046
Effect size	r	-0.4925	-0.49	-0.505	-0.525	-0.4975

According to the results of the current study, we found significant differences between pre- and post-test for the following variables (see *Figure 11 A-E*):

A. CBTT -corsi-forward condition-NCP = the total number of correct positions (see *Figure 11B*), spatial processing: (Z = -1.97, p = .049), the performance of the participants decreased at the post-test. One of the explanations could be that the CBTT pre-test and post-test contains only abstract elements, geometric shapes, with no feedback and no rewards. The intervention contained game elements, the participants received feedback and the elements were closer to everyday life: sequences of animals, plants, vehicles, which also increased the children's motivation and performance during the sessions/intervention;
B. CBTT - corsi-forward-TRT= the total reaction time (see *Figure 11A*), the time factor - the processing speed of the visuospatial information: (Z = -1.96, p = .05);
C. WISC-Coding (see *Figure 11E-F*) - the total number of the correct elements: (Z = -2.02, p = .043), and the average of the correct elements (Z = -2.1, p = .036);
D. WISC-Symbol search (see *Figure 11D*) –Total number of the correct elements (Z = -1.99, p = .046).

With mean effect sizes, values ranging from r = .49 to .53 (see *Table 10*).

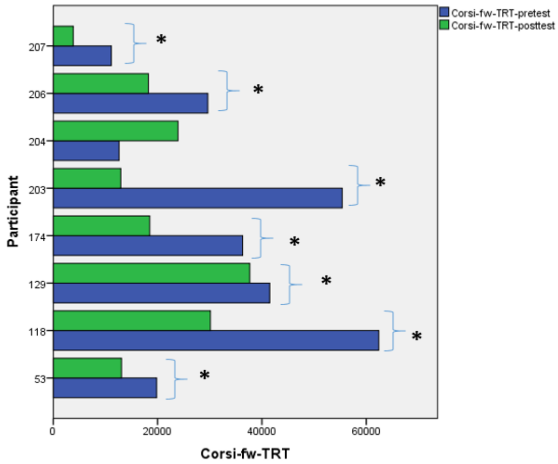


Figure 11A.

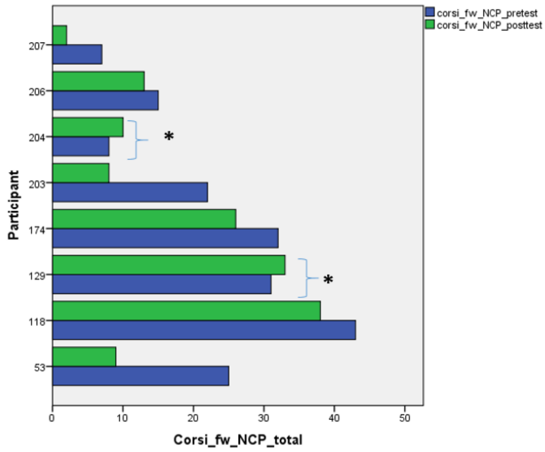


Figure 11B.

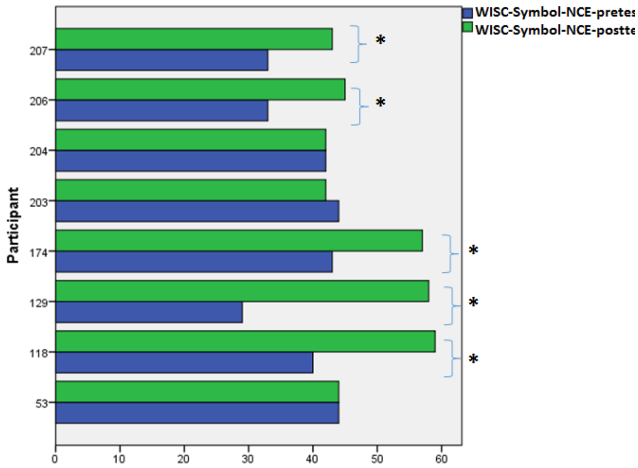


Figure 11C.

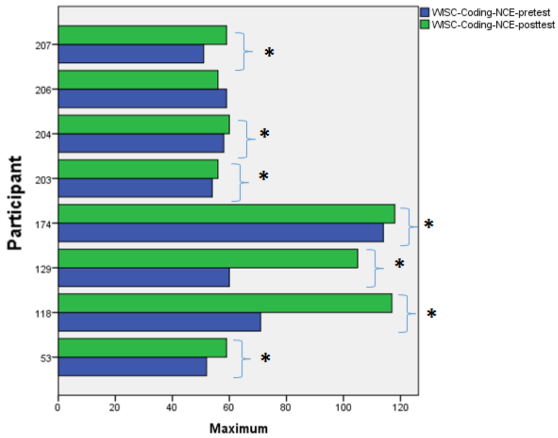


Figure 11D.

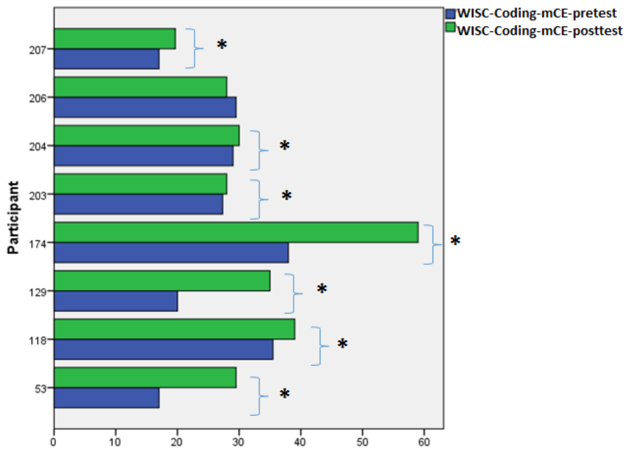


Figure 11E. *Figure 11F.*

Figure 11. A-E. Effect of intervention on neurocognitive functions

The cognitive load was calculated by the following formula: backward condition-forward condition, these scores varied between 0 and -3. We did not find any significant differences between the pre- and post-test on cognitive workload.

To illustrate pre- and post-test differences when using the gamified intervention, the differences between participants' actual visuospatial WM capacity and the maximum capacity they reached during the intervention was calculated. *Figure 12A* shows the pre- and post-test differences in forward condition, and *Figure 12B* shows pre- and post-test differences in backward condition. The Wilcoxon nonparametric test results indicate statistically significant differences between pre-post-test on WM (see *Table 10 A-B*).

Table 10 A-B. Results of the WILCOXON Test

A.Means and standard deviations (N=8)

		M (SD)
1	training pre- forward	2.00 (1.20)
	training post- forward	5.88 (1.13)
2	training pre- backward	3.00 (1.31)
	training post- backward	6.63 (.74)

B. Results of the ***WILCOXON*** *and effect sizes*

	training pre-post forward	training pre-post backward	Effect size fw	Effect size bw
Z	-2.56	-2.59		
Sig.	.011	.010	-0.91	-0.92

Note. fw=forward, bw=backward

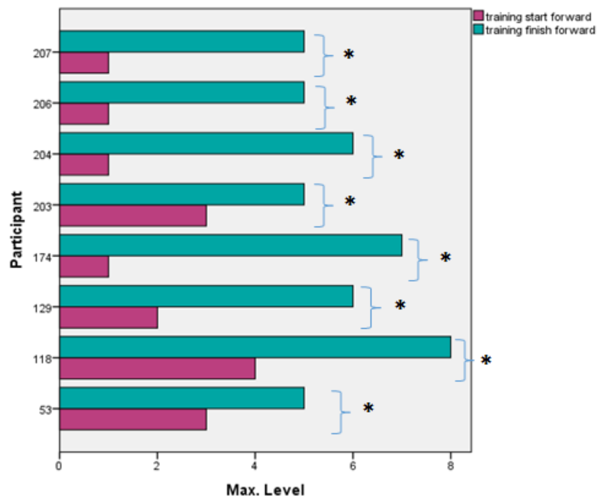


Figure 12A CBTT–fw

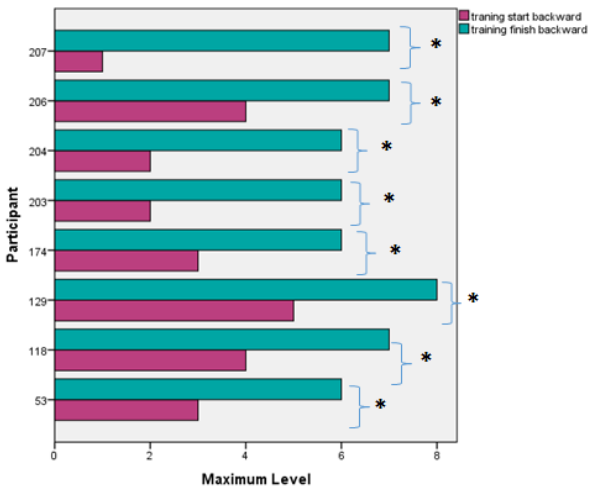


Figure 12B.CBTT–bw

Figure 12. Differences between pre-post-test – visuospatial WM capacity
*Note. fw=forward, bw=backward, *-significant differences*

Discussions

According to the hypothesis of this study, as a result of intervention with the gamified program focused on the training of visuospatial WM, children with ADHD will show higher performance in neurocognitive functions: verbal WM, visuospatial WM and processing speed. The intervention program aims at the cognitive restructuring of the visuospatial system. This hypothesis was partially confirmed.

The results of the current study, indicated by the Wilcoxon nonparametric test show statistically significant differences between pre-post-test on diverse cognitive functions. Previous studies using interventions with game elements (Prins et al., 2011, Dovis et al., 2015) have shown beneficial results. The results of Prins et al. (2011) showed that interventions containing game elements have contributed to the high cognitive performance of children and to a higher motivational level.

In conclusion, the intervention can be considered beneficial for the cognitive restoration of the visuospatial system, diminishing the cognitive deficits associated with ADHD and can be considered a complementary treatment.

In the literature, the effects of cognitive interventions are contradictory and the findings of studies are inconsistent (Sonuga-Barke et al., 2013), but the results show the benefits of well-designed cognitive intervention programs, as they recognize that ADHD affects various aspects of executive attention and working memory capacity (Beck et al., 2010, Tucha et al., 2011). More studies are needed for evaluating the effectiveness of these interventions. Some studies have been promising (Beck et al., 2010), but appear to have no long-term transfer effects (Shipstead, Hicks, Engle, 2012). Some studies that have used interventions focused on executive functions with meta-cognitive components, have found beneficial effects on ADHD (Tamm, Nakonezny, Hughes, 2014).

CHAPTER IV. CONCLUSIONS AND GENERAL DISCUSSIONS

4.1. Original contributions of the thesis

The results obtained in **Study I (meta-analysis)** indicate a minimal effect of cognitive interventions targeting working memory on ADHD. Regarding the effect of the overall intervention, the post-test and the follow-up, an insignificant effect was found. The interventions were very mixed, not as homogeneous as expected, few studies have used the same interventions, so they were very difficult to compare. Outcomes were tested at 4 levels: cognitive performance, behavioral level, socio-emotional level and academic performance. A small but significant effect size indicated the beneficial effect of intervention on cognitive performance (as a moderator variable), post-intervention and follow-up results. At the behavioral level, the socio-emotional level and the effect of intervention on academic performance, no statistically significant effect was found. So these interventions seem to have a very low clinical impact. The results of this meta-analysis seem to confirm and at the same time invalidate some assumptions of previous studies.

The results of Melby-Lervag, Hulme (2013), Cortese et al. (2015) confirm the beneficial effect of interventions on ADHD symptoms of inattention and hyperactivity (small effect size). In addition, previous studies using game elements (Prins et al., 2011, Dovis et al., 2015) have shown beneficial results.

Generalizing these results is problematic. Causal factors remain unidentified, but many factors may be the cause of the lack of long-term effects. In conclusion, by the current meta-analysis (Study I) we have failed to show the beneficial results of gamified interventions focused on core WM in children with ADHD.

In **Study II.** the SDQ questionnaire was used as a screening tool for detecting ADHD symptoms. The results of **Study IIa.** showed that both versions of the SDQ-T and -P have acceptable psychometric properties, which led us to the decision to use only SDQ in the next study (Study IIb.). The internal consistency of the ADHD subscale of the SDQ was high, with values between α = .75-.97. The ADHD subscale of the SDQ correlates significantly with ADHD-RS-IV and with the CBCL/TRF scale, Pearson correlation values are between r=.85-95, indicating a strong association of the variables. The inter-evaluator agreement is medium, therefore acceptable, but the consensus among parents and teachers is low. The factor analysis of the SDQ led to the maintenance of the ADHD subscale of the SDQ, consisting of 4 items: 2, 10, 15, 25.

Previous studies (Castellanos, Tannock, 2002, Durston et al., 2011, Frazier et al., 2004, Martinussen et al., 2005, Nazari et al., 2010, Sonuga-Barke et al., 2010, Wahlstedt et al. , 2009) reported negative impact of ADHD symptoms on cognitive abilities. **Study III** partly confirms this hypothesis. During the cluster analysis children with and without ADHD were assigned to different clusters. Some children with ADHD have had significantly higher levels of performance in verbal WM, some have had a lower level of visual-spatial WM. These results indicate that the symptoms of ADHD affect these cognitive functions in a particular way, and confirm the variability of the typology. Our results highlight the results of previous studies, according to which some children with typical development have few neurocognitive difficulties (Hudziak et al., 1999). According to the results of Sjöwall et al. (2012) 1/5 of the children with typical development had neurocognitive difficulties. Other studies generally did not find significant differences in the neurocognitive functions of children with ADHD compared to those with typical development (Nigg et al., 2005, Sjöwall et al., 2012).

Summarizing these results, the dimensional approach is attested (Hudziak et al., 2007, Nigg, 2001; Nigg et al., 2005). Studies have shown WM deficits in children with ADHD, which may indeed be an affected factor, but the problem is that the specificity of WM deficits is low, deficits occur almost in all developmental disorders (Arnsten, Rubia, 2012; Martinussen, Tannock, 2006; van de Voorde, 2009; Willcutt et al., 2010).

Studies show that all three types of ADHD are characterized by a variety of cognitive difficulties, the dysfunctions of the predominantly inattentive (ADHD-N) type are not similar to the predominantly hyperactive-impulsive (ADHD-HI) and the combined (ADHD-C) type. In the literature it is suggested that cognitive impairments are more pronounced in ADHD-C (Nigg et al., 2005), 35-50% of this group showed cognitive difficulties. But there are few studies that directly compare the effects of these types on cognitive functions.

Based on the results of Study III, no significant differences were found between the performance of the children allocated to the 3 clusters. According to the results of **Study IV**, there were significant differences between the pre- and post-test, the participants with ADHD showed a better performance after the intervention, indicated by the Wilcoxon nonparametric test.

Theoretical Contributions

In this thesis, we sought to identify ways of integrating the theories from different domains: cognitive, neurocognitive and clinical domains, so that we can then, on the basis of an integrative perspective on ADHD, design programs, effective cognitive restructuring interventions of the visuospatial system.

Methodological/practical contributions

From a methodological and practical point of view, this thesis contributes to the specialized literature investigating the efficiency of WM based interventions through computerized programs. Although there are many studies that have investigated the effectiveness of intervention programs, in this thesis we have proposed a multifunctional computerized program for children with ADHD. Even if it has its limits, it can be considered for future studies.

The results obtained in Study II also have methodological implications. The psychometric properties of the ADHD subscale are acceptable, the SDQ questionnaire can be used as an ADHD screening tool, it is cost-effective, time reducing for practitioners and school or clinical psychologists, although the multimodal assessment is the best.

The cluster analysis in Study III has highlighted that individuals with ADHD symptoms have been distributed in different clusters based on their neurocognitive performance, some children have a significantly better level of performance, others lower. In conclusion, these results indicate that the symptoms of ADHD affect these cognitive functions in a particular way (Hudziak et al., 2007, Nigg , 2001; Nigg et al., 2005).

The beneficial effect of the core training based on visuospatial WM was highlighted in Study IV. The results indicated a significant effect on neurocognitive functions. Participants with ADHD showed better performance after the intervention: the current capacity of the participants' visuospatial WM, the response time, the processing speed increased. These results partly confirm the overall hypothesis, however the intervention did not have any effect on verbal memory.

The computerized program developed and adapted by us is a tool that can be used or applied in the educational field by teachers for the purpose of prevention, intervention or just for evaluation, that is to check the current level of visuospatial working memory. Since this program is very easy to use, it can be used by involving parents, as home-training or teachers, as school-based training. At the same time, besides the educational purpose, it can also be used for research purposes. In this thesis, the program was used only in children with ADHD, but it can be used for any disorder involving working memory deficits. To sum up, this online platform is also cost effective and can be used by teachers or practitioners as prevention, intervention or just for assessment.

4.2. Implications for future studies

We believe that further studies are needed to understand the impact of such interventions on the symptoms of ADHD. Future implications may include improving interventions of this type and/or developing and testing new intervention procedures. Previous studies have focused on several executive functions.

Future studies could further examine the differences between the three types of ADHD in terms of neurocognitive functions and psychopathological particularities of children with ADHD. Further studies should be developed, including assessments even more complex than those of this thesis. Of course, such studies would involve a significantly greater number of participants and the tools used, but the benefits of identifying several neurocognitive factors would be very high as it would allow the early detection of cognitive impairments with a high risk factor for the development of a disorder, in particular ADHD.

4.3. Study limitations

The most important limitations of Study I, meta-analysis: 1) the low number of studies included, 2) most studies used different control groups: placebo group, waitlist, or treatment-as-usual group. Through the current meta-analysis we have failed to show the beneficial far transfer effects on different outcomes of the gamified intervention, which focused on core WM training in children with ADHD. Generalizing the results is problematic.

Limits of Study II: In **Study IIa** and **IIb** we tested SDQ as a screening tool for detecting ADHD symptoms. In Study IIa the results show that both versions of the SDQ-T,-P have acceptable psychometric properties, which led us to the decision to use the SDQ only in the next study (IIb). The most important limit of Study IIa is the small number of participants. It's just a pilot study.

The limits of **Study III** refer to the use of only one questionnaire to select children with or without ADHD symptoms, so the screening was done using the SDQ-T,-P. Only those children were selected and assigned to the ADHD clinical group, who showed severe symptoms from the perspective of parents and teachers, so the criterion of manifestation of ADHD symptoms was met in at least 2 contexts (at home and at school). If the differences between evaluators were significant, and very high, the children were generally assigned to the subclinical group. The cut-off points used for allocation in the normal, subclinical and clinical groups were available for the Hungarian population from Hungary, but we did not have normative scores for the Hungarian minority population in Transylvania.

The most important limitation of **Study IV** is the low number of participants with ADHD. More research is needed to demonstrate the beneficial effect of the intervention based on visuospatial WM. Another important limit of the study was that behavioral assessment by scales and questionnaires was not used at post-intervention. The intervention focused only on the training of the visuospatial WM and was very short, the participants had only 10 sessions of 15 minutes.

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Appendix 1. Characteristics of Studies Included in the Meta-Analysis

Study	Training						Outcomes		
	N/ Age	Type	Control	Training type /setting	Game elements	Length/ duration	Behavior/ ADHD symptoms	Included Neuropsychological Outcomes	Academic functioning
Chacko et al., 2014	N=85/ Age: 7-11	2 groups, randomized blinded	N=41 Placebo: low-level NA WMT	N=44, CogMed WMT active, adaptive / home	Contingent reinforcement integrated within the program, external reward system: earning stickers	25 days, 5 days, 30-45 min.	• parent and teacher ratings of ADHD symptoms • DBDRS	• 4 task from AWMA: Dot Matrix, Spatial Recall, Digit Recall, Listening Recall • Actigraphs • A-X Continuous Performance Test	WRAT4-PMV: Word Reading, Sentence Comprehension, Spelling, and Mathematical Computation
Dahlin et al., 2013	N=57/ Age: 9-12	2 groups	N=15	N= 42, CogMed WMT, adaptive/school	- feedback thermometer	5 weeks, 30-40 min, 5 days a week		• Digit span from WISC III • Span board from WAIS-NI • Raven CPM	Basic Number Screening Test (BNST) Addition and subtraction skills
Dovis et al., 2015	N=89/ Age: 8-12	3 groups, double blinded	N=30 placebo NA T	N=31, adaptive Braingame Brian full active T., partially active N=28/ home	- feedback thermometers, exploring, getting more elaborate inventions, and making more friends in the game world - in addition an external reward system was used: stickers, ribbons and medals	25 session, 35-50 min.	DBDRS-P DBDRS-T BRIEF-P SPSRQ-C PedsQL-P, C HSQ	• Stop task • Stroop Color & Word Test • CBTT-forward, backward • Digit span from WISC-III • TMT • Raven CPM	
Egeland et al., 2013	N=67/ Age: 10-12	2 groups randomized	N=34, TAU	N=33 CogMed WMT, RoboMemo/ school	-daily verbal and visual feedback, external reward (RoboRacing game) + individualised	5–7 weeks, for 30–45 min.	ADHD-RS-IV-P, -T SDQ BRIEF - P BRIEF -T	• 2 subtest from D-KEFS: CW, TMT • CCPT-II: CAVLT-2 • BVRT	Key math: the Mental computation subtest, Problem-solving subtest LOGOS (reading ability: word decoding and quality of decoding)
Green et al., 2011	N=26/ Age: 7-14	2 groups randomized double blinded	N=14 Placebo NA,	N=12 CogMed WMT active, adaptive	-auditory and visual feedback after each trial, optional reward game	25 sessions, 25 min. per day	CPRS-P	• working memory Index (WMI) from WISC-IV • CPRS-R • RAST	
Hovik et al., 2013	N=67/ Age: 10-12	2 groups randomized	N=34, Control = TAU	N =33 CogMed / school	-daily verbal and visual feedback - external reward (RoboRacing game) + individualized reward	25 days, 5 days/week, 30-40 min/day		• Digit span – forward, backward, WISC-IV • Leiter–R: Visual WM: The Remembering Game (Visual span, forward), and The Backwards Game (Visual span, backward), • Letter-Number Sequencing task, • the Sentence Span task	

Note. NA=non-adaptativ, TAU= Treatment as Usual, AWMA=Automated Working Memory Assessment, CPT= Continous Performance Test, WRAT4-PMV= Wide Range Achievement Test 4 Progress Monitoring

Study	**Training**						**Outcomes**		
	N/ Age	**Type**	**Control**	**Training type /setting**	**Game elements**	**Length/ duration**	**Behavior/ ADHD symptoms**	**Included Neuropsychological Outcomes**	**Academic functioning**
Johnstone et al., 2010	N=29/ Age: 7-13	2 groups, randomized double blinded	N=14 low intensity NA	N=15 High intensity Adaptive ''Go Go Nogo'' ''Feed the Monkey''/ home	-visual feedback, score -external reward	25 session, 5 days/week, 5 weeks, 20 min.	CPRS-R CBCL-P, CBCL–T	• Go/Nogo task • Raven SPM • EEG	
Klingberg et al., 2005	N=53/ Age: 7-12	2 groups, randomized blinded	N=26 Comparison group: low intensity NA	N=27 CogMed WMT RoboMemo Adaptive/ home/school	-auditory and visual feedback	25 session, 5 weeks, 40 min	CRS-T, CRS-P Motor activity (infrared camera recording head movements)	• The span-board task from WAIS-RNI • Digit-span from WISC-III • The Stroop interference task • Raven CPM	
Prins et al., 2011	N=51/ Age: 7-12	2 groups, randomized	N=24 WMT	N=27 gamified WMT	-animation, story line -feedback, rewards -competition, exploration	3session, 3 weeks, 1 day/week, 35 min (5 min. pretraining+ 2x15)		• CBTT • Motivation level; objective + subjective, absence time, number of sequences performed, exit questionnaire	
Van der Oord et al., 2014	N=40 Age: 8-12	2 groups randomized	N=22 waitlist	N=18 adaptive "Braingame Brian" /home	-animation, story line -feedback thermometer -rewards -competition, exploration -external reward system: stickers, ribbons and medals	25 session, 5 weeks, 40 min.	BRIEF -P DBDRS-P DBDRS-T		
Van Dongen-Boomsma et al., 2014	N=47 Age: 5-7	triple-blind, randomized placebo-controlled study	N=24 placebo NA	N=27 CogMed JM WMT active adaptive/ home	-auditory and visual feedback -external rewards	25 session, 5 days a week, 15 min.	ADHD-RS-I ADHD-RS-T BRIEF-P BRIEF-T	• Adapted Digit Span WISC-III • Knox Cubes LDT • Sentences WPPSI-RN • Shortened Raven CPM • DNST • SA-DOTS-02K • Shape School, CGI-I	

Version (Word Reading, Sentence Comprehension, Spelling, and Mathematical Computation), WISC= Wechsler Intelligence Scale for Children, WAIS= Wechsler Adult Intelligence Scale, DBDRS = Disruptive Behavior Disorder Rating Scale, T= Teacher rated, P= Parent rated, LNST= Letter-Number Sequencing task, CBTT= Corsi Block-Tapping Test, Raven CPM = Raven's Colored Progressive Matrices, Raven SPM= Raven Standard Progressive Matrices, BRIEF= Behavior Rating Inventory of Executive Functioning, SPSRQ-C = Sensitivity to Punishment and Sensitivity to Reward Questionnaire for children, PedsQL =Pediatric Quality of Life Inventory, parent and child version, HSQ = The Home Situations Questionnaire, SDQ= Strengths and Difficulties Questionnaire, D-KEFS= Delis-Kaplan Executive Function System, CW= Color Word, TMT= Trail Making Test, CCPT-II= Conners' Continuous Performance Test II, CAVLT-2= Children's Auditory Verbal Learning Test-2, BVRT= Benton Visual Retention Test, RAST= Restricted Academic Setting Task, TAU=treatment as usual, Leiter–R: The Leiter international Performance Scale-Revised, CPRS-R= Conners Parent Rating Scale-Revised, CBCL= Child Behavior Checklist, ADHD-RS–I= ADHD Rating Scale completed by the Instructor, ADHD-RS –T= ADHD Rating Scale completed by the teacher, DNST=Day-Night Stroop task, SA-DOTS-02K= sustained attention dots task, version 02K, CGI-I=Clinical Global Impressions-Improvement.