Revista AMAzônica, LAPESAM/GMPEPPE/UFAM/CNPq
ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

Vol. 17, número 1, jan-jun, 2024, pág. 401-428

Analysis of the Effectiveness of Computerized Cognitive Training in Children: a meta-analytic review

Análise da Eficácia de Treinos Cognitivos Computadorizados em Crianças: uma revisão meta-analítica

Alanny Nunes de Santana[1]
Antonio Roazzi[2]
Jéssica Daniele Silva de Vasconcelos Marques[3]
Alena Pimentel Mello Cabral Nobre[4]

ABSTRACT

It is believed that Computerized Cognitive Training (CCT) programs promote improvements in cognitive performance; however, there still needs to be more consensus on its effectiveness and limitations. This study aimed to present CCT programs for children used in the last five years, identifying their effectiveness and the impact of design factors. A systematic review with meta-analysis was carried out by searching for papers in SciELO, PubMed, CAPES, and ScienceDirect. Twenty studies were analyzed for quality, risk of bias, and effect sizes, covering 2.116 participants. The intervention programs varied considerably, with Cogmed and Braingame Brian being the most commonly used. The overall effect size of the interventions was medium and significant both for the trained cognitive domains and for related skills, which were also better after training, such as academic performance, executive functions, and symptoms. The most effective designs were interventions in a game format,

[1] Alanny Nunes de Santana – PhD student, PPG in Cognitive Psychology, Federal University of Pernambuco (UFPE). E-mail: alanny.santana@ufpe.br or alanny46@gmail.com. https://orcid.org/0000-0001-9505-3508. http://lattes.cnpq.br/0810849700298282. https://www.researchgate.net/profile/Alanny-Santana.

[2] Antonio Roazzi. D.Phil - D.Phil, Department of Psychology, Federal University of Pernambuco (UFPE)
E-mail: roazzi@gmail.com. https://orcid.org/0000-0001-6411-2763.http://lattes.cnpq.br/6108730498633062. https://www.researchgate.net/profile/Antonio_Roazzi.

[3] Jéssica Daniele Silva de Vasconcelos Marques – Master's student, PPG in Cognitive Psychology, Federal University of Pernambuco (UFPE). E-mail: jessica.daniele@ufpe.br. https://orcid.org/0000-0002-0869-1016. http://lattes.cnpq.br/5506490734808241.

[4] Alena Pimentel Mello Cabral Nobre – Ph.D. in Cognitive Psychology, Pernambuco University (UPE).
E-mail: alena.nobre@upe.br. https://orcid.org/0000-0001-7459-5770. http://lattes.cnpq.br/3437049863442139

with motivational and applied feedback at school, which indicates the relevance of the insertion of CCT in the school curriculum. It is suggested that CCT is effective in improving cognitive performance in children, but its effectiveness varies across domains and is influenced by design choices.
Keywords: Computerized Cognitive Training, Cognition, Working Memory, Academic Performance, Cognitive Intervention, Facet Theory.

RESUMO

Acredita-se que os programas de Treinamento Cognitivo Computadorizado (TCC) promovam melhoras no desempenho cognitivo, todavia, persiste a falta de consenso quanto a sua eficácia e limitações. Este estudo objetivou apresentar os programas de TCC para crianças utilizados nos últimos cinco anos, identificando sua eficácia e o impacto de fatores de design para tal. Realizou-se uma revisão sistemática com meta-análise a partir da busca por artigos nas bases SciELO, PubMed, CAPES e ScienceDirect. Vinte estudos foram analisados quanto a sua qualidade, risco de viés e tamanhos de efeito, abrangendo 2.116 participantes. Os programas de intervenção variaram consideravelmente, sendo Cogmed e Braingame Brian os mais utilizados. O tamanho dos efeitos das intervenções foi médio e significativo tanto para os domínios cognitivos treinados quanto para habilidades relacionadas, que também melhoraram após o treino, como o desempenho acadêmico, funções executivas e sintomas. Os designs mais eficazes foram intervenções em formato de jogo, com feedbacks motivacionais e aplicadas na escola, o que indica a relevância da inserção dos TCC no currículo escolar. Sugere-se que o TCC é eficaz na melhoria do desempenho cognitivo em crianças, mas a eficácia varia entre domínios e sofre influência de escolhas de design.
Palavras-chave: Treino Cognitivo Computadorizado, Cognição, Memória de Trabalho, Desempenho Acadêmico, Intervenção Cognitiva, Facet Theory.

Neuroplasticity is at the basis of all processes of cognitive and neuropsychological stimulation and rehabilitation, based on the conviction that the brain is a non-static organ and that it is constantly in the process of adaptation, restructuring itself according to new environmental requirements or imposed functional limitations (Haase & Lacerda, 2004; Weyandt et al., 2020). Thus, it is assumed that neuroplasticity alters neural connections, which is reflected in the performance of cognitive skills or behaviors, and this effect is known as transference (Rossignoli-Palomeque et al., 2018).

It is stated that cognitive training generally causes performance improvements in training tasks and/or activities based on similar procedures, characterizing near-transfer, however, far-transfer, marked by improvement in

ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

skills not directly practiced during the intervention, is not so frequently reported in studies, even though it has important implications (Zelechowska et al., 2017). Thus, although several recent studies report cognitive training as efficient in promoting skills, others still need to demonstrate or affirm this merit (e.g., Melby-Lervag & Hulme, 2013), and the effectiveness of near and far transfer is still controversial.

Notably, neuroplasticity is more clearly operative in young brains, being higher in childhood and early adolescence (Bikic et al., 2018; Weyandt et al., 2020). It is understood that children may be especially benefited by cognitive training due to the significant changes in the brain and cognitive functioning during this phase, with the infant brain being more susceptible to environmental impact (Bikic et al., 2018; Sala & Gobet, 2017; Weyandt et al., 2020). In this sense, a better understanding of the neural bases necessary for cognitive development during childhood, as well as the findings on the induction of plasticity, have supported the assumption that cognitive training in this population has positive effects (Ottersen & Grill, 2015; Sala & Gobet, 2017).

It should be noted that the key for cognitive change to happen is repeated practice in a given domain so that the continuous reproduction of new patterns of experience results in improvements in efficiency within the trained domain and also transfer such improvements to skills not directly trained (Bikic et al., 2018; Kirk et al., 2016), as academic skills (e.g., Soderqvist & Nutley, 2015). According to Ottersen and Grill (2015), numerous studies have concluded that cognitive functions such as Working Memory (WM) can be positively influenced at higher levels from training.

In addition, cognitive training has received increasing attention from educators, researchers, and other professionals, as it is a non-pharmacological intervention approach for children and adolescents with learning disorders (Rosa et al., 2017; Kirk et al., 2016). Dealing specifically with the educational context, it is pointed out that the use of cognitive training

Revista AMAzônica, LAPESAM/GMPEPPE/UFAM/CNPq
ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

has led to improvements in the academic performance of typical and atypical children, and an interesting alternative is to insert them as specific interventions or even as an integral part of the school curriculum (e.g., Karbach et al., 2015; Landis et al., 2019).

Ottersen and Grill (2015) state that cognitive intervention is effective through different types of training, highlighting that computerized cognitive training (CCT) programs can improve cognitive performance in groups of children and adults. In addition to WM, CCT programs can improve cognitive flexibility (Blakey & Carroll, 2015), attention (Zelechowska et al., 2017), inhibitory control (Lee et al., 2018), and other cognitive abilities. Although there may be fears of exaggerations regarding efficiency, cognitive training generates great expectations among researchers and the general public, who perceive electronic software as promising resources that are increasingly accepted and used in today's society (Rabipour & Davidson, 2015).

In this context, CCT is understood as the use of specific software to train/improve cognitive functions. According to Harvey et al. (2018), its effectiveness has been tested in several populations and reported in many scientific studies encompassing healthy subjects and those with various clinical conditions. Also, according to these authors, the interest in CCT has been increasing faster than in other areas due to the growing evidence of the effectiveness, sophistication, and accessibility of the systems on different platforms.

However, inconsistent findings are pointed out in this field of study, which suggests the need for an interdisciplinary consensus, analyses, and debates on the real benefits of CCT and its possible generalization (Webb et al., 2018). Therefore, evaluating the efficacy and limitations of this promising interventional modality is necessary, but it is still controversial for researchers in the area. In addition, in recent years, there has been a significant technological advance in the health field, specifically concerning clinical

Revista AMAzônica, LAPESAM/GMPEPPE/UFAM/CNPq
ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

rehabilitation (Lorenzetti et al., 2012), so the current CCT software has evolved, and the effectiveness of these new resources needs to be evaluated.

In this context, the present paper aims to present an overview of computerized cognitive training programs for children developed and used by researchers in the last five years, presenting data on the effectiveness of interventions, the impact of design factors on the effects produced, as well as an analysis of the results of near and far transfer to specific cognitive domains. It is noteworthy that evaluating whether currently applied CCT programs can improve children's cognition, discriminating between more and less responsive cognitive domains, and identifying the most efficient design factors will help design new and more adequate cognitive training programs (Motter et al., 2016).

METHOD

This is a systematic literature review with meta-analysis following the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).

Sources of Information and Search Strategy

The SciELO, PubMed, CAPES Journal Portal, and ScienceDirect databases were consulted using the terms "computerized cognitive training," "cognitive training," AND computerized and "computer training." The reference lists of the included studies were also examined. The search was conducted in September 2020 and was restricted to including studies published between 2015 and 2020. Two researchers performed the exact search independently and compared the numbers at the end, verifying the conformity of the data found.

Eligibility Criteria

Two independent examiners conducted the study analysis with a third evaluator to resolve any disagreements, which represented less than 5% of the cases. Eligibility was initially assessed based on the titles and abstracts of

ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

the papers, and the following inclusion criteria were considered in this first screening: (1) papers; (2) peer-reviewed; (3) with human participants; (4) published between 2015 and 2020; (5) written in English or Portuguese; (6) reporting interventions; (7) who have participants with a mean age of 12 years or less; and (8) dealing with the transfer of the effects of the intervention. Based on titles and abstracts, the following studies were excluded: (1) that do not refer to the theme "cognitive training"; (2) theoretical; (3) with participants in other age groups; (4) in other languages; and (5) repeated (counting only once then repeated).

After reading it in full, the other exclusion criteria were considered, namely: (6) studies that report the intervention as computerized psychotherapeutic care (remote care); (7) that they do not analyze the results of cognitive training separately from other interventions performed concomitantly; (8) with a sample of fewer than 10 participants per analysis group; (9) that analyze the effects of training lasting less than 4 hours and (10) that do not present mean and/or standard deviation data in their results (which does not allow the calculation of the size of the effects found).

Quality Analysis and Risk of Bias

After selecting the papers, their quality was analyzed using an adapted version of the Physiotherapy Evidence Database (PEDro) (Maher et al., 2003). This study considered five scale items: specified eligibility criteria, random allocation to groups, similar groups at baseline, blinding of the evaluator, and statistical comparisons between groups. "Yes" or "No" was assigned to the presentation of each item in the studies. Each "Yes" assigned corresponds to 1 point (minimum 0 and maximum 5).

Considering that a study can be conducted with the highest possible standards of quality but still present a significant risk of bias, we assessed it separately using the recommendations of Cochrane's Collaboration's risk of bias tool (Higgins & Green, 2008). The following six aspects are considered in

Revista AMAzônica, LAPESAM/GMPEPPE/UFAM/CNPq
ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)
the tool: description of the method used for allocation, blinding of participants, blinding of evaluators, completeness of data and results, reporting of selective results, and other sources of bias. "Yes" was assigned for low risk of bias, "No" for high risk of bias, and "Not clear" for unclear or unknown risk of bias. In order to enable the classification of the data, each "No" was considered one point and "Not clear" half a point, with the highest number of points indicating more partiality in the studies (minimum 0 and maximum 6). The studies were classified as low risk of bias (scores between 0 and 2 points), medium (between 3 and 4 points), and high (between 5 and 6 points). The corresponding inversion of the numbers was performed to perform the statistical analysis. It is emphasized that both the quality and risk of bias assessments were performed by two examiners.

Effect Sizes

Effect sizes were calculated for each study that reported significant differences ($p<0.05$) in the post-intervention period (more details, see Schmidt & Hunter, 2015). For studies without a control group, pre-test and post-test data were included (Ottersen & Grill, 2015; Minder et al., 2019), while for papers that reported more than one experimental or control group, the data of the group with more significance were entered for the effect size analysis, according to the authors (Vries et al., 2015; Ang et al., 2015; Dovis et al., 2015; Boivin et al., 2019; Boivin et al., 2016). In cases where lower scores/scores represented a gain in skill (e.g., a decrease in the number of errors or in response time), the corresponding inversion was performed.

In studies that presented more than one score for the same variable (e.g., scores for selective attention, attentional control, sustained attention, and general attention span), the score representative of the total (e.g., general attention span) was selected to calculate the effect. Near transfer effect sizes were calculated for all abilities reported in the studies. On the other hand, the far transfer effects were calculated for the following skills: Academic

Revista AMAzônica, LAPESAM/GMPEPPE/UFAM/CNPq
ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

Performance, Symptoms, and Executive Functions. Notably, these were only some of the skills under analysis in the papers. However, given the insufficient number of studies reporting significant results for these cognitive domains (e.g., only one outcome for intelligence was presented), the skills reported more than twice were selected. Insignificant (<0.19), small (0.20-0.49), medium (0.50-0.79), and large (0.80-1.29) effects were considered for interpretation (Cohen, 1988, p. 40).

Data collection and analysis

Data collection was performed independently by two researchers, and the following information was extracted from the papers: sample size, gender, age, duration of the interventions, place of study (country), place of application of the intervention (home, school, clinic or others), skills trained, instruments used, quality of the studies, risk of bias, results identified, transfer, limitations, means and standard deviations for the outcomes. It is noteworthy that when information regarding gender and number of hours of training was not provided directly in the papers, the calculation was performed by the authors (e.g., number of hours not informed, only in minutes per session, or only the number of female participants and not the percentage).

Data analysis was performed using RevMan version 5.4.1 (The Cochrane Collaboration, 2020) and the Statistical Package for the Social Sciences (SPSS) software. The random-effects model and the standardized mean difference (SMD) were used due to the heterogeneity of population conditions and tests used in the included studies. The heterogeneity index (I^2) was classified as: non-heterogeneous (values near to 0%), low (near to 25%), moderate (near to 50%), and high (near 75%) (Higgins et al., 2003). The 95% confidence interval was calculated for each effect size. Sensitivity analysis was performed by excluding or including studies that indicated they were outliers. If certain studies strongly affected the results, they were excluded, and the analysis was repeated without them. Analyses were conducted for all

ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

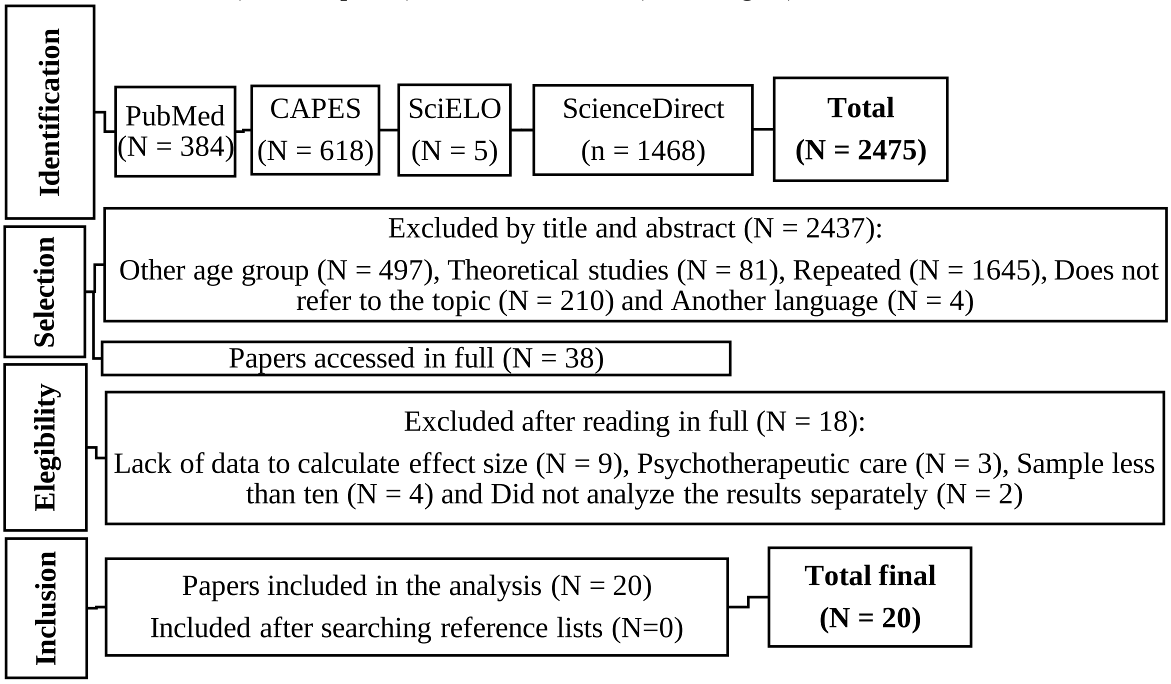
outcomes combined, showing an overall effect of the interventions and for each cognitive domain, resulting in domain-specific effects.

In order to examine the relationship between CCT design choices and training outcomes, we evaluated the effectiveness of the intervention in predefined subgroups, namely: duration of the intervention in hours (longer and shorter duration), number of sessions per week (more and less sessions per week), place of application (home and school), age of the children (more and less age), motivational elements (training with and without) and intervention strategy (game and task). The effect size analysis was performed for the subgroups' place of application, age, and training strategy since they contain a similar and sufficient number of studies, which allowed the comparison. In order to understand the structural organization between the cognitive domains that presented significant frequencies (Attention, Executive Functions, Working Memory, Academic Performance) and the different types of training design (With Motivation, Without Motivation, Task Strategy, Game Strategy), a Similarity Structure Analysis was performed using Jaccard's binary similarity coefficient or index (SSA – Roazzi & Souza, 2019). Jaccard's coefficient is extremely useful when it is necessary to deal with binary data, making it possible to produce distance metrics between the investigated observations.

RESULTS

The initial search of the databases resulted in the identification of 2,475 studies. Of this total, 2,437 were excluded based on titles and abstracts, and 18 were excluded after reading them in full, resulting in the final inclusion of 20 studies, as shown in the diagram below (Figure 1).

ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)



NOTE: a single study could be excluded on more than one criterion but appears only once in the diagram.

Figure 1. Summary of the identification and selection of studies.

The 20 included datasets encompassed 2,116 participants, with a mean of 105 children per study. Samples covered participants of both sexes with a mean age of nine years, ranging from 4 to 12 years. Most of the sample was composed of European children (50%), followed by children from Oceania (20%), Africa (10%), Asia (10%) and America (10%). Most of the studies were of high quality, with scores between 4 and 5 (70%) on the PEDro scale. The risk of bias was low in most of the included studies (65%), followed by medium (30%) and high (5%) risks. The general characteristics of the studies are shown in Table 1.

Table 1. General Characteristics of the Included Studies

Study	Authors	Year	M. Age	Gender F	Local	Q	R.Bias	N
1	Bikic et al.	2018	9.95	15%	Denmark	5	Low	70

2	Sarzyńska et al.	2017	8	44%	Poland	3	Medium	50
3	Ottersen and Grill	2015	10,18	49%	Norway	4	Low	21
4	Quach et al.	2018	6,9	No	Australia	3	Low	452
5	Phillips et al.	2016	11,82	50%	Australia	4	Low	23
6	Lotfi et al.	2020	8,2	25%	Iran	3	Medium	35
7	Landis, Hart and Graziano	2019	4,52	29%	USA	4	Low	49
8	Vries et al.	2015	10,5	11%	Holland	4	Low	121
9	Zelechowska, Sarzynska and Necka	2017	8,84	53%	Poland	2	Medium	69
10	Söderqvist and Nutley	2015	9,85	56%	Sweden	3	Medium	41
11	Mansur-Alves and Flores-Mendoza	2015	11,1	58%	Brazil	4	Low	53
12	Ang et al.	2015	6,8	38%	Singapore	4	Medium	111
13	Dovis et al.	2015	10,4	77,5%	Holland	5	High	89
14	Boivin et al.	2016	8,9	51,5%	Uganda	5	Low	159
15	Karbach, Strobach and Schubert	2015	8,4	50%	Germany	4	Low	28
16	Kirk et al.	2016	8,2	43%	Australia	4	Low	75
17	Grunewaldt et al.	2015	5,6	67%	Norway	5	Low	37
18	Boivin et al.	2019	6,9	39%	Uganda	5	Low	150
19	Minder et al.	2019	10	32%	Germany	3	Medium	31
20	Roberts et al.	2016	6,9	55,9%	Australia	5	Low	452

Note: Q = Quality of the study; M. Age = approximate mean age; Gender F = approximate mean number of female participants; N = sample.

Regarding the CCT programs used, the following stood out: Cogmed working memory training (CWMT), present in 30% of the studies, programs without a specific name elaborated by the authors of the papers (25%), Braingame Brian and Captain's Log, the last two present in two studies each. The most used training strategy was based on a game (60% of the studies), followed by training based on specific cognitive tasks of Working Memory (WM) and Non-Verbal Reasoning (NVR) (40%). Most programs include motivational feedback for players (85%), while the others do not explicitly (Captain's Log and Braintwister – Karbach et al., 2015; Boivin et al., 2016; Boivin et al., 2019). As for the place where the interventions were applied, the

ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

children's homes (35%) and schools (35%) stood out. Table 2 presents a description of the CCT programs identified.

Table 2. Intervention Programs.

Name	Program Description (Developers)	Strategy (Local)	Studies
ACTIVATE	Integrated computer games that aim to improve performance in Executive Functions (C8Sciences, 2016).	Game (Home)	1
Unnamed	Three tasks for Working Memory training (Mansur-Alves and Flores-Mendoza, 2015).	Task (School)	11
Unnamed	Four games aimed at training different aspects of Attention, with adjustment of difficulty (Sarzyńska et al., 2017).	Game (No)	2
Unnamed	Working Memory Tasks developed by Cogmed Systems and Nonverbal Reasoning Tasks (Pearson, Inc.; Bergman et al., 2011).	Task (School)	3
Unnamed	Four games based on the *keep track* and *n-back* paradigms for Working Memory training (Yntema, 1963).	Game (Lab)	9
Cogmed	Online Working Memory Training Program, with adjustment of difficulty (CWMT - Pearson, Inc).	Game (No)	4, 5, 7, 10, 17 and 20
BrainWare Safari	Electronic game for Working Memory training, with increasing level of difficulties (*Learning Enhancement Corporation*, 2005).	Game (Clinic)	6
Braingame Brian	Game to improve performance in Executive Functions (Prins et al., 2013).	Game (Home)	8 and 13
Captain's Log	Games to improve Attention, Memory, Non-Verbal Reasoning and Problem Solving, with adjustment of difficulty (BrainTrain Corporation).	Game (Home)	14 and 18
Braintwister	Tasks to improve performance in Working Memory (Buschkuehl et al., 2008).	Task (School)	15
TALI	Tasks to improve performance in Attention skills (Health Pty Ltd.).	Task (Home)	16
CogniPlus	Tasks to improve performance in Attention, Working Memory, and Inhibition, with adjustment of difficulty (Schuhfried, 2012).	Task (School)	19

Note: No = does not inform the application place.

Revista AMAzônica, LAPESAM/GMPEPPE/UFAM/CNPq
ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

As for the duration of the training, 55% occurred in a period of 4 to 7 weeks, 40% in 8 weeks or more, and 5% in 3 weeks or less. The number of hours varied considerably between studies (between 5 and 41 hours), with an average of 5.5 hours in total. The training occurred in medium five times a week, ranging between 3 and 6 times. The most trained skills in the studies were Working Memory and Attention. The most frequently used instruments for pre- and post- CCT assessments were Raven's Progressive Matrices (RPM), Automated Working Memory Assessment (AWMA), and the Wechsler Intelligence Scale for Children in versions III and IV.

Table 3. Characteristics of Applied Interventions

Study	Hours (weeks)	Skills	Instruments
1	No (8)	Attention and EF	CANTAB and BRIEF.
2	5,5 (5)	Attention	RPM, D2 Attention, and two SDT-based measures.
3	No (10 to 23)	WM and NVR	AWMA, WPPSI, NEPSY and WISC.
4	24 (5 to 7)	WM	AWMA
5	14,5 (5)	WM	WISC, AWMA, TEA-Ch and WIAT.
6	30 (6)	WM	WMTB-C, N-back, R&D, VOT and VAT-CPT.
7	5,2 (5)	WM	WPPSI, WJ, Head-Toes-Knees-Shoulders and AWMA.
8	41,5 (6)	WM and CF	WISC, CBT, Gender-emotion switch-task, N-back, Number-gnome switch-task, Stop-task, SART and BRIEF.
9	5,5 (*3)	WM	RPM, WISC and OSPAN.
10	8,3 (5)	WM	AWMA.
11	13,3 (8)	WM	RPM and Brazilian Battery of Cognitive Reasoning.
12	14 (8)	WM and Updating	Block Recall task, Animal Updating, Letter Rotation task, Backward Digit Recall task and RPM.
13	13,5 (5)	WM and EF	Stroop Test, CBT, WISC, TMT, RPM and BRIEF.
14	24 (8)	WM and Attention	KABC, CogState, TOVA and BRIEF.
15	8 (8)	WM	Stroop Test, Task-switching paradigm and WISC.
16	8,3 (5)	Attention	Wilding Attention battery.

Revista AMAzônica, LAPESAM/GMPEPPE/UFAM/CNPq
ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

17	5,2 (5)	WM	WISC and NEPSY
18	24 (8)	WM and Attention	KABC, BRIEF, and CogState.
19	26,2 (10)	WM	TAP, D2 Attention, WISC, CBT, Stop Signal and BRIEF.
20	16.8 (5 to 7)	WM	AWMA.

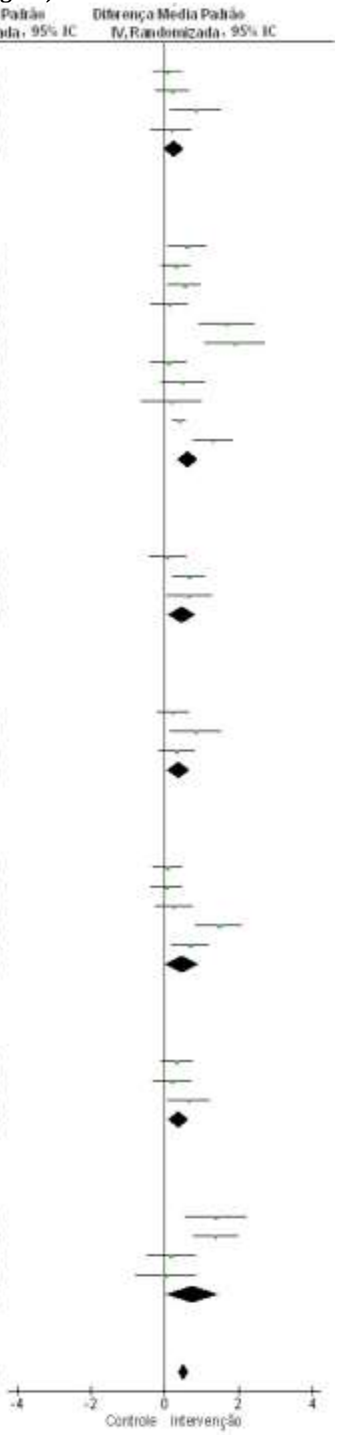
Note: *approximate number of times per week; No=does not inform; Skills=trained skills; EF=Executive Functions; WM = Working Memory; NVR=Non-verbal reasoning; CF=Cognitive Flexibility; AWMA= *Automated Working Memory Assessment*; BRIEF=Behavior rating inventory of executive function; NEPSY=Developmental Neuropsychological Assessment; WISC=Wechsler Intelligence Scale for Children; WPPSI=Wechsler Preschool and Primary Scale of Intelligence; TEA-Ch=Test of Everyday Attention for Children; WIAT=Wechsler Individual Achievement Test; WMTB-C= *Working Memory Test Battery for Children*; IVA-CPT=Integrated Visual and Auditory Continuous Performance Task; WJ=Woodcock Johnson Test of Achievement; KABC= *Kaufman Assessment Battery for Children*; TAP=Test for Attentional Performance; CBT=Corsi block task; CANTAB= *Cambridge Neuropsychological Test Automated Battery*; RPM=Raven's Progressive Matrices; SART= *Sustained attention response task*; OSPAN= *Operation span*; SDT= *Signal Detection Theory*; R&D = *Reading and Dyslexia Scale*; VOT= *Visual Oddball Task*; TMT = Trail Making Test.

Of the 20 studies included, 17 reported significant effects of CCT, while three affirmed the verification of non-statistically significant effects on cognitive abilities after the intervention (Mansur-Alves & Flores-Mendoza, 2015; Quach et al., 2018; Bikic et al., 2018). Therefore, specifically for the purpose of effect size analysis, this study included 1,541 participants. The overall effect of the interventions was medium and statistically significant (SMD= 0.50, 95% CI [0.36-0.65], p<0.001; Figure 2), with moderate heterogeneity between studies (62%). The overall sensitivity analysis excluded four studies because they significantly affected the results (*outliers*) (Boivin et al., 2016; Karbach et al., 2015; Landis et al., 2019; Soderqvist & Nutley, 2015). After exclusion, heterogeneity, and overall effect size were reduced (before SMD=0.67 and heterogeneity 84%).

.

Revista AMAzônica, LAPESAM/GMPEPPE/UFAM/CNPq
ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

Estudo ou Subgrupo	Experimental Media	Experimental DP	Experimental Total	Controle Media	Controle DP	Controle Total	Ponderação	Diferença Media Padrão IV, Randomizada, 95% IC
Atenção Próxima								
Bowin et al. (2019)	2.9	2.7	54	2.7	2.6	45	3.8%	0.07 [-0.32, 0.47]
Kirk et al. (2016)	4.3	7.5	37	3.1	3.6	38	3.5%	0.20 [-0.25, 0.66]
Lotfi et al. (2020)	78	19	15	61	20	20	2.4%	0.85 [0.15, 1.55]
Barzyńska et al. (2017)	264	63	27	253	54	23	3.0%	0.18 [-0.37, 0.74]
Subtotal (95% IC)			133			126	12.7%	**0.24 [-0.03, 0.52]**
Heterogeneidade: Tau² = 0.01; Chi² = 3.61, df = 3 (P = 0.31); I² = 17%								
Teste de efeito geral: Z = 1.73 (P = 0.08)								
Memória de Trabalho								
Ang et al. (2015)	8.2	2.2	32	7	1.6	26	3.1%	0.61 [0.08, 1.14]
Bowin et al. (2019)	0.52	0.46	54	0.4	0.34	45	3.8%	0.29 [-0.11, 0.69]
De Vries et al. (2015)	6.3	1	41	5.7	1.2	40	3.6%	0.54 [0.09, 0.98]
Dovis et al. (2015)	60	9.3	28	59	6.6	30	3.2%	0.12 [-0.39, 0.64]
Grunewaldt et al. (2015)	10	2.3	20	6.2	2.1	17	2.1%	1.68 [0.92, 2.44]
Lotfi et al. (2020)	29	2.9	15	21	4.8	20	2.0%	1.91 [1.09, 2.73]
Minder et al.(2019)	3.8	4	31	3.4	3.3	31	3.3%	0.11 [-0.39, 0.61]
Ottersen, & Grill (2015)	10.8	4.3	21	8	6.4	21	2.7%	0.50 [-0.11, 1.12]
Phillips et al. (2016)	128	115	10	104	110	13	1.9%	0.19 [-0.64, 1.02]
Roberts et al. (2016)	102	15	226	96	14.6	226	4.9%	0.40 [0.22, 0.59]
Zelechowska, Barzynska, & Necka (2017)	9.5	4.5	42	4.3	2.8	27	3.1%	1.31 [0.78, 1.84]
Subtotal (95% IC)			520			496	33.7%	**0.63 [0.35, 0.91]**
Heterogeneidade: Tau² = 0.15; Chi² = 36.56, df = 10 (P < 0.0001); I² = 73%								
Teste de efeito geral: Z = 4.40 (P < 0.0001)								
Outros								
Ang et al. (2015)	34	10	32	33	13	26	3.2%	0.09 [-0.43, 0.60]
De Vries et al. (2015)	96	58	41	62	42	40	3.5%	0.66 [0.22, 1.11]
Ottersen, & Grill (2015)	24.8	4.8	21	21.4	5.3	21	2.7%	0.66 [0.04, 1.28]
Subtotal (95% IC)			94			87	9.4%	**0.47 [0.09, 0.85]**
Heterogeneidade: Tau² = 0.04; Chi² = 3.19, df = 2 (P = 0.20); I² = 37%								
Teste de efeito geral: Z = 2.41 (P = 0.02)								
Atenção Distante								
De Vries et al. (2015)	216.8	61	41	203	61	40	3.6%	0.22 [-0.21, 0.66]
Lotfi et al. (2020)	78	19	15	61	20	20	2.4%	0.85 [0.15, 1.55]
Minder et al.(2019)	36	20	31	30	16	31	3.3%	0.33 [-0.17, 0.83]
Subtotal (95% IC)			87			91	9.2%	**0.38 [0.06, 0.70]**
Heterogeneidade: Tau² = 0.01; Chi² = 2.24, df = 2 (P = 0.33); I² = 11%								
Teste de efeito geral: Z = 2.34 (P = 0.02)								
Funções Executivas								
Bowin et al. (2019)	56	53	54	52	49	45	3.8%	0.08 [-0.32, 0.47]
De Vries et al. (2015)	157	22	41	156	18	40	3.6%	0.05 [-0.39, 0.48]
Dovis et al. (2015)	58	7	28	56	9	30	3.2%	0.24 [-0.27, 0.76]
Landis, Hart, & Graziano (2019)	58	2	24	55	2	25	2.6%	1.48 [0.84, 2.11]
Minder et al.(2019)	101	20	31	89	13	31	3.2%	0.70 [0.19, 1.22]
Subtotal (95% IC)			178			171	16.4%	**0.47 [0.01, 0.93]**
Heterogeneidade: Tau² = 0.21; Chi² = 17.57, df = 4 (P = 0.001); I² = 77%								
Teste de efeito geral: Z = 2.01 (P = 0.04)								
Sintomas								
De Vries et al. (2015)	27	10	41	24	8	40	3.6%	0.33 [-0.11, 0.77]
Dovis et al. (2015)	13	5.2	30	12	4.5	28	3.2%	0.20 [-0.31, 0.72]
Landis, Hart, & Graziano (2019)	0.9	0.17	24	0.8	0.13	25	2.9%	0.65 [0.08, 1.23]
Subtotal (95% IC)			95			93	9.6%	**0.37 [0.08, 0.66]**
Heterogeneidade: Tau² = 0.00; Chi² = 1.36, df = 2 (P = 0.51); I² = 0%								
Teste de efeito geral: Z = 2.51 (P = 0.01)								
Desempenho Acadêmico								
Karbach,Strobach, & Schubert (2015)	93	2.8	14	89	2.8	14	1.9%	1.39 [0.55, 2.23]
Landis, Hart, & Graziano (2019)	95.5	3	25	91.3	3	25	2.7%	1.38 [0.76, 2.00]
Lotfi et al. (2020)	81	16	15	78	17	20	2.5%	0.18 [-0.49, 0.85]
Phillips et al. (2016)	95	91	10	93	88	13	2.0%	0.02 [-0.80, 0.85]
Subtotal (95% IC)			64			72	9.0%	**0.75 [0.02, 1.48]**
Heterogeneidade: Tau² = 0.41; Chi² = 11.92, df = 3 (P = 0.008); I² = 75%								
Teste de efeito geral: Z = 2.01 (P = 0.04) diff								
Total (95% IC)			1171			1136	100.0%	**0.50 [0.36, 0.65]**
Heterogeneidade: Tau² = 0.10; Chi² = 84.35, df = 32 (P < 0.00001); I² = 62%								
Teste de efeito geral: Z = 6.84 (P < 0.00001)								
Teste para diferenças de subgrupos: Chi² = 4.82, df = 6 (P = 0.57), I² = 0%								



Note: Effect estimates are based on a random-effects model and studies are arranged in alphabetical order.

Figure 2. Overall effectiveness of interventions across all cognitive outcomes.

Revista AMAzônica, LAPESAM/GMPEPPE/UFAM/CNPq
ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

There was a near transfer to Working Memory (in 11 studies), attention (in 4 studies), and other domains, including specific components of Executive Functions (EF; Cognitive Flexibility and Updating) and Non-verbal Reasoning. The overall effect of near transfer was medium and statistically significant (SMD = 0.51, 95% CI [0.32-0.71], $p<0.001$), with moderate heterogeneity (64%). Far transfer effects were identified for Academic Performance (in 4 studies), Executive Functions (5 studies), Attention (3 studies), and Symptoms (3 studies), with the overall far transfer effect being medium and statistically significant (SMD = 0.50, 95% CI [0.27-0.73], $p<0.001$), with moderate heterogeneity (62%).

Specifically concerning the relationship between CCT design choices and training outcomes, it was observed that the effect sizes of the studies are larger when the intervention strategy used is game (SMD = 0.55, 95% CI [0.35-0.75], $p<0.001$) compared to task (SMD = 0.41, 95% CI [0.24-0.58], $p<0.001$), when training is performed in a school setting (SMD = 0.41, 95% CI [0.20-0.61], $p<0.001$) compared to home (SMD = 0.37, 95% CI [0.19-0.55], $p<0.001$) and when it is performed with younger children (SMD = 0.64, 95% CI [0.40-0.88], $p<0.001$) compared with older children (SMD = 0.41, 95% CI [0.25-0.57]),
$p<0.001$).

From the SSA analysis, presented in Figure 3, it was observed in relation to the types of training design that while the interventional strategy in game format presented a high correlation with the presence of motivational elements (Jaccard .59), the interventional strategy in task format presented a high correlation with the absence of motivational elements (Jaccard .58). Regarding the interrelationship between the Game and Task Strategies and the different cognitive domains, there is a high correlation between the game strategy and the cognitive domain Working Memory (Jaccard .53) and a low correlation between the game strategy and the other three (Jaccard .12, .06 and .06, for Executive Functions, Attention and Academic Performance,

Revista AMAzônica, LAPESAM/GMPEPPE/UFAM/CNPq
ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

respectively). On the other hand, the Task Strategy showed low correlations with the four cognitive domains (Jaccard .12, .12, .12, and .06, for Working Memory, Executive Functions, Attention, and Academic Performance, respectively). Therefore, interrelationships were verified between the intervention strategy in game format, the presence of motivational elements, and larger effect sizes in the cognitive domain of working memory.

Figure 3. SSA (Jaccard's coefficient) analysis of the interrelationship between trained cognitive domains and training design (2d; 1x2; Disposal Coefficient 0.145).

Regarding domain-specific efficacy, four studies reported attention outcomes (near transfer). The pooled effect size was small and not statistically significant (SMD = 0.24, 95% CI [-0.03-0.52], p=<0.08), with low heterogeneity (17%). Eleven studies reported significant Working Memory (near transfer) results, with a statistically significant mean combined effect size (SMD = 0.63, 95% CI [0.35-0.91], p<0.001) and high heterogeneity (73%). Three papers reported results of different measures (other- near transfer), two of which were specific executive components, Cognitive Flexibility (Vries et al., 2015) and Updating (Ang et al., 2015), and one was Nonverbal Reasoning (Ottersen & Grill, 2015). The size of the pooled effect was small and statistically significant (SMD = 0.47, 95% CI [0.09-0.85], p=<0.02), with low heterogeneity (37%). However, it is observed that the Updating skill alone has a negligible effect size (<0.19).

Three studies reported significant results for attention after training other cognitive skills or other attentional components (far transfer). The size of the combined effect was small and statistically significant (SMD = 0.38, 95% CI [-0.06-0.70], p=<0.02), with low heterogeneity (11%). Five studies reported significant results for EF after training other cognitive skills (far transfer). The pooled effect size was small and statistically significant (SMD = 0.47, 95% CI [0.01-0.93], p=<0.004), with high heterogeneity (77%).

Three studies reported significant results, after cognitive skills training (far transfer), on the symptoms of “Attention Deficit Hyperactivity Disorder” (ADHD) and problems related to various behaviors in children (Dovis et al., 2015; Landis et al., 2019; Vries et al., 2015). The pooled effect size was small and statistically significant (SMD = 0.37, 95% CI [0.08-0.66], p =<0.01), with non-heterogeneous data (0%). Finally, four studies reported better academic performance outcomes after cognitive skills training (far transfer). The combined effect size was mean and statistically significant (SMD = 0.75, 95% CI [0.02-1.48], p=<0.04), with high heterogeneity (75%).

DISCUSSION

This meta-analysis study aimed to expose the CCT programs for children used in the last five years, identifying their effectiveness in transferring to specific domains and the impact of design factors. The results showed, in a similar way to previous meta-analyses with other populations (e.g., Lampit et al., 2014; Sala & Gobet, 2017), the prevalence of studies of reasonable quality and with low risks of bias. Among the CCT programs used Cogmed (CWMT), which includes WM training tasks, the Brian Braingame, training aimed at stimulating Executive Functions, and the Captain's Log, which trains the domains of memory, attention, perception, reasoning, planning, judgment, learning, and EF. All three programs have difficulty levels that are adaptable to the child's abilities, last between 5 and 10 weeks, and are in game format[5].

It is noteworthy, therefore, that there is a tendency to develop algorithm-supported adaptive activities that are molded to the individual's capacity. Thus, the level of difficulty is calibrated response after response to match the child's extent of ability, so that the child continuously works close to his limits, advancing only when the skill increases, which can guarantee more gains after training (Phillips et al., 2016). However, even though there is a tendency to value adaptive training, its real difference in effectiveness in relation to non-adaptive training is still controversial, with divergences in results (e.g., Karbach et al., 2015; Landis et al., 2019; Ottersen & Grill, 2015).

Regarding the effectiveness of these programs, the CWMT has been shown to improve participants' performance in WM, nonverbal reasoning, and reading tasks but does not increase performance in mathematical calculation and inhibition (Phillips et al., 2016; Karbach et al., 2015). Regarding the Braingame Brian, clinically significant changes in the participant's visual WM, attention, flexibility, and intellectual level were observed, with no distant transfer to EF and ADHD symptoms (Dovis et al., 2015; Vries et al., 2015). On

[5] The three tasks mentioned are not provided free of charge and require prior training or education to enable use.

ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

the other hand, after applying the *Captain's Log*, the gain in attention, memory, planning, and EF skills was verified without reduction of symptoms (Bovin et al., 2016; Bovin et al., 2016).

Among the programs applied, four did not have a specific name. The game developed by Zelechowska et al. (2017), also used in the study by Ottersen and Grill (2015), trains WM and effectively improves it but does not cause significant increases in intelligence. The game used in the study by Ang et al. (2015) trains WM and updating and produces only marginal improvements in the immediate post-test in the skills training, with no performance improvement in mathematics. The other two programs, presented in the task model, train Working Memory. Mansur-Alves and Flores-Mendoza (2015) did not find significant differences in the post-test for any cognitive and school performance measures, while Ottersen and Grill (2015) found improvements in non-verbal reasoning and WM.

Explicitly addressing the effect size (ES) of the interventions, a statistically significant mean overall effect was evidenced, revealing, in line with studies evaluating adult and elderly individuals (see Lampit et al., 2014), that CCT is efficacious in improving cognitive functions, but significant effect sizes are not expected. The training revealed that both near and far transfers occurred and that both ES were medium and statistically significant. Such a far transfer result implies acknowledging the possibility of generalizing specific effects to domains beyond the trained ones (Zelechowska et al., 2017).

However, it should be emphasized that the heterogeneity among the studies was moderate, which reflects the need for caution when producing generalizations on the subject. Corroborating, Walton et al. (2018) highlight that the field of cognitive training has struggled with high levels of methodological heterogeneity, low competence in defining improvement in functional capacity, and small sample sizes, which limit generalizations. We also add here the fact that there is a prevalence of studies carried out with European samples in this field, which also generates the production of training

ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

programs and interpretation parameters centered on a population with specific characteristics.

It was observed from the results that some CCT design choices can moderate the effectiveness of interventions; for example, the effect sizes of the studies are larger when the CCT has specific characteristics. In this sense, it was found that when training is performed in a school environment, there is a tendency for better results compared to training performed at home, which is less effective, corroborating the results of Lampit et al. (2014) with the elderly population. Thus, including CCT as a school activity may be more beneficial. Studies already indicate that CCT programs implemented as part of the school curriculum, explicitly dealing with working memory, are effective (Holmes & Gathercole, 2014; Wiest et al., 2020).

The game/game training strategy was also more related to better performance than the isolated task strategy, especially in WM. In this sense, by converging playfulness and challenges in the exercise of cognition, games facilitate the improvement of skills (Ramos, 2013), which may be related to the familiar presence of motivational elements in games, also evidenced in this study, and which, according to Minder et al. (2019), represents a critical aspect that can affect successful transfer.

Age was also relevant, and interventions developed with younger children had the most significant effect sizes. This result may be related to neuroplasticity, which is more active in younger brains (Sala & Gobet, 2017). However, given the high heterogeneity (74%) of studies with younger children (8 to 8.4 years), this difference may be less relevant. Furthermore, from the SSA analysis, it was observed that, as stated by Lampit et al. (2014), the effectiveness of CCT depends on particular design choices and the cognitive outcome of interest.

In this sense, it was evidenced that there are interrelationships between game strategy, the presence of motivational elements, and larger effect sizes in the specific cognitive domain of working memory. This result indicates that

ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

WM training interventions presented in a game format and with motivational elements, such as positive feedback, stars, awards, and rankings of best players, tend to produce more significant effects. Therefore, because they involve the child in a plot with characters, challenges, and prizes, the games are more thought-provoking and have proven more efficient than decontextualized training tasks that do not include motivational elements. It is noteworthy that no interrelationships were found with other cognitive domains or other design characteristics of CCT, such as time in hours and duration in weeks of the intervention, highlighted as relevant for the occurrence of transfer in studies with samples in other age groups on specific domains, such as WM (e.g., Schwaighofer et al., 2015).

Regarding efficacy by domain, it was evidenced that the effects on working memory and academic performance were medium and statistically significant. Corroborating data from previous meta-analyses specific to WM (Sala & Gobet, 2017; Schwaighofer et al., 2015; Melby-Lervag & Hulme, 2013) indicate that training produces reliable short-term improvements in this skill. However, as Melby-Lervag and Hulme (2013) have observed, the heterogeneity between the summarized studies is moderate. There is no consensus on the studies that have already been conducted regarding academic performance. For example, Soderqvist and Nutley (2015) corroborate our findings by identifying that performance in reading and mathematics is positively impacted by CCT, with medium and significant effects. On the other hand, Sala and Gobet (2017) emphasize that the effects of far transfer on academic performance are very modest.

The effects for the EF and Symptoms domains were small and significant, corroborating Webb et al. (2018). However, high heterogeneity was observed, which, as we have already reported in this study, may be associated with the methodological variation and the measurement instruments used (Walton et al., 2018), a variety that, in the specific case of EF is already widely recognized (Santana et al., 2019). As for the effects of far transfer on symptom

ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

reduction, the literature provides few data, indicating the need for more research to explore them (Cintoli et al., 2019). In an attempt to compile and analyze recent available results, this study identified that CCT has small but significant effects on the reduction of symptoms such as ADHD, dyslexia, and intellectual disability. In addition, it was found that the data do not present heterogeneity, even when dealing with symptoms of different disorders.

Concerning attention, both the effects of near and far transfer were evaluated, showing that both were small and that it was statistically significant for far attention. This result indicates that training other skills, such as WM and Cognitive Flexibility (Vries et al., 2015; Lotfi et al., 2020; Minder et al., 2019) significantly benefits attention skills. However, direct attention training did not generate a significant overall effect (p=0.08). According to Kirk et al. (2016), there is a need for further refinement of attention training programs so that they can promote more significant and more global direct improvements. It is also noteworthy that the data identified for near attention and the heterogeneous results in other domains may reflect the non-use of performance instruments (e.g., Boivin et al., 2019; Dovis et al., 2015). According to Walton et al. (2018), the lack of consistent evidence for the transfer of CCT may be associated more with insensitive tests than with totally ineffective training.

In the case of the three studies that reported non-significant effects of CCT (Mansur-Alves & Flores-Mendoza, 2015; Quach et al., 2018; Bikic et al., 2018), the authors stated that this result may be associated with specific limitations of the intervention and the study methodology, such as the small sample size, the way the groups were divided by the researchers, and the tasks used. For example, Bikic et al. (2018) state that outcome measures were based on questionnaires evaluated by parents and teachers (hetero-reports) and that this likely left the study with insufficient power to detect small to moderate changes in cognitive abilities. In addition, most of the children were trained for only half of the recommended period, and there were few participants.

ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

In sum, the results of this meta-analysis suggest that CCT for children effectively promotes gains for both directly trained and non-trained skills, with the overall effect size of the interventions being average, statistically significant, and influenced by design choices. However, the present study has some limitations that deserve attention. This review focused on changes immediately after the end of the CCT and did not provide indications about the durability of the gains. We emphasize that the choice to exclude data from postponed post-tests (*follow-ups*) is due to the limited number of studies (15) that performed this testing within an already reduced contingent of papers. In addition, other potential moderators were not considered in the meta-analytic models due to the limited number of data for calculating effect sizes, and although we searched for literature in relevant databases and consulted reference lists, the research undertaken was restricted to the databases used, and the languages included.

According to Melby-Lervag and Hulme (2013), a generic criticism of meta-analyses is that studies that differ in their characteristics are grouped, creating a summary of the results that can ignore essential differences. However, the authors state that the decisive point is that the differences can be formally addressed by examining the effects of variables that can moderate the results. In this sense, the present review presented an analysis of the impact of variables influencing the results, such as age and intervention strategies. In addition, it is highlighted that the survey and analysis of CCT programs and the identification of their flaws and potentialities are ways to direct future studies since we have discriminated against the most and least responsive cognitive domains and identified the efficient design factors. Therefore, as Ottersen and Grill (2015) point out, survey research is needed for future studies to pay attention to factors that moderate transfer and to discover how these can be manipulated to make training more effective.

FINAL THOUGHTS

ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

Currently available and used computerized cognitive training (CCT) interventions have been investigated in various studies involving children with typical and atypical development. The most used programs were *Cogmed*, Braingame Brian*, and* programs without a specific name*,* with working memory being the most trained domain with the most significant effect size. The meta-analysis revealed that WM and attention training programs elicit transfer effects for directly trained skills, cognitive abilities, and untrained aspects, such as academic performance, symptoms, and EF. The analyses also showed that effectiveness varies according to the cognitive domain and is partly influenced by design choices, such as application in a school environment, which has been shown to be more effective. It is worth emphasizing that this article leaves the question regarding the duration of the effects of CCT open over time and hopes that future studies will answer this.

REFERENCES

Ang, S. Y., Lee, K., Cheam, F., Poon, K., & Koh, J. (2015). Updating and working memory training: Immediate improvement, long-term maintenance, and generalisability to non-trained tasks. *Journal of Applied Research in Memory and Cognition,* *4*(2), 121-128. https://doi.org/10.1016/j.jarmac.2015.03.001

Bikic, A., Leckman, J. F., Christensen, T. O., Bilenberg, N. & Dalsgaard, S. (2018). Attention and executive functions computer training for attention-deficit/hyperactivity disorder (ADHD): results from a randomized, controlled trial. *European Child & Adolescent Psychiatry 27*(11), 1-26. https://doi.org/10.1007/s00787-018-1151-y

Blakey, E., & Carroll, D. J. (2015). A short executive function training program improves preschoolers' working memory. *Frontiers in Psychology, 6*(1827), 1 – 8. https://doi.org/10.3389/fpsyg.2015.01827

Boivin, M. J., Nakasujja, N., Sikorskii, A., Opoka, R. O., & Giordani, B. (2016). A randomized controlled trial to evaluate if computerized cognitive rehabilitation improves neurocognition in Ugandan children with HIV. *AIDS Research and Human Retroviruses,* *32*(8), 743-755. https://doi.org/10.1089/AID.2016.0026

Boivin, M. J., Nakasujja, N., Sikorskii, A., Ruiseñor-Escudero, H., Familiar-Lopez, I., Walhof, K., & Giordani, B. (2019). Neuropsychological benefits of computerized cognitive rehabilitation training in Ugandan children surviving severe malaria: a randomized controlled trial. *Brain Research Bulletin, 145*, 117-128. https://doi.org/10.1016/j.brainresbull.2018.03.002

Cintoli, S., Radicchi, C., Noale, M., Maggi, S., Meucci, G., Tognoni, G., & Maffei, L. (2019). Effects of combined training on neuropsychiatric symptoms and quality of life in patients with cognitive decline. *Aging clinical and experimental research*, 33(5), 1-9. https://doi.org/10.1007/s40520-019-01280-w

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2.ª ed.). Hillsdale: Lawrence Erlbaum Associates.

Dovis, S., Van der Oord, S., Wiers, R. W., & Prins, P. J. (2015). Improving executive functioning in children with ADHD: Training multiple executive functions within the context of a computer game. A randomized double-blind placebo controlled trial. *PloS one, 10*(4), e0121651. https://doi.org/10.1371/journal.pone.0121651

Haase, V. G., & Lacerda, S. S. (2004). Neuroplasticidade, variação interindividual e recuperação funcional em neuropsicologia. *Temas em Psicologia, 12*(1), 28-42. http://pepsic.bvsalud.org/scielo.php?script=sci_arttext&pid=S1413-389X2004000100004&lng=pt&tlng=pt.

Harvey, P. D., McGurk, S. R., Mahncke, H., & Wykes, T. (2018). Controversies in Computerized Cognitive Training. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging November, 3*, 907–915. https://doi.org/10.1016/j.bpsc.2018.06

Higgins J., & Green S. (2008). *Cochrane handbook for systematic reviews of interventions.* The Cochrane Collaboration.

Higgins J.P, Thompson S.G, Deeks, J.J et al (2003). Measuring inconsistency in meta-analyses. *BMJ, 327*(7414), 557-560. https://doi.org/10.1136/bmj.327.7414.557

Holmes, J., & Gathercole, S. E. (2014) Taking working memory training from the laboratory into schools. *Educational Psychology, 34*(4), 440 – 450. https://doi.org/10.1080/01443410.2013.797338

Karbach, J., Strobach, T., & Schubert, T. (2015). Adaptive working-memory training benefits reading, but not mathematics in middle childhood. *Child Neuropsychology, 21*(3), 285-301. https://doi.org/10.1080/09297049.2014.899336

Kirk, H. E., Gray, K. M., Ellis, K., Taffe, J., & Cornish, K. M. (2016). Computerised attention training for children with intellectual and developmental disabilities: a randomised controlled trial. *Journal of Child Psychology and Psychiatry, 57*(12), 1380–1389. https://doi.org/10.1111/jcpp.12615

Lampit, A., Hallock, H., & Valenzuela, M. (2014). Computerized cognitive training in cognitively healthy older adults: a systematic review and meta-analysis of effect modifiers. *PLoS Med, 11*(11), e1001756. https://doi.org/10.1371/journal.pmed.1001756

ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)
Landis, T. D., Hart, K. C., & Graziano, P. A. (2019). Targeting self-regulation and academic functioning among preschoolers with behavior problems: Are there incremental benefits to including cognitive training as part of a classroom curriculum?. *Child Neuropsychology, 25*(5), 688-704. https://doi.org/10.1080/09297049.2018.1526271

Lee, H., Espil, F.M. Bauer, C.C., Siwiec, S. G. & Woods, D.W. (2018). Computerized Response Inhibition Training for Children with Trichotillomania. *Psychiatry Res., 262*, 20-27. https://doi.org/10.1016/j.psychres.2017.12.070

Lorenzetti, J., Trindade, L. L., Pires, D. E. P., & Ramos, F. R. S. (2012). Tecnologia, inovação tecnológica e saúde: uma reflexão necessária. *Texto & Contexto - Enfermagem, 21*(2), 432-439. https://dx.doi.org/10.1590/S0104-07072012000200023

Lotfi, S., Rostami, R., Shokoohi-Yekta, M., Ward, R. T., Motamed-Yeganeh, N., Mathew, A., S., & Lee, H. J. (2020). Effects of computerized cognitive training for children with dyslexia: An ERP study. *Journal of Neurolinguistics, 55*, 100904. https://doi.org/10.1016/j.jneuroling.2020.100904

Maher, C. G., Sherrington, C, Herbert, R.D., Moseley, A.M., & Elkins M. (2003). Reliability of the PEDro scale for rating quality of randomized controlled trials. *PhysTher 83*, 713-721. https://pubmed.ncbi.nlm.nih.gov/12882612/

Mansur-Alves, M., & Flores-Mendoza, C. (2015). Working memory training does not improve intelligence: Evidence from Brazilian children. *Psicologia: Reflexão e Crítica, 28*(3), 474-482. https://doi.org/10.1590/1678-7153.201528306

Melby-Lervag, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. *Developmental psychology, 49*(2), 270. https://doi.org/10.1037/a0028228

Minder, F., Zuberer, A., Brandeis, D., & Drechsler, R. (2019). Specific effects of individualized cognitive training in children with attention-deficit/hyperactivity disorder (ADHD): the role of pre-training cognitive impairment and individual training performance. *Developmental neurorehabilitation, 22*(6), 400-414. https://doi.org/10.1080/17518423.2019.1600064

Motter, J. N., et al. (2016). Computerized cognitive training and functional recovery in major depressive disorder: A meta-analysis. *Journal of Affective Disorders, 189*, 184-191. https://doi.org/10.1016/j.jad.2015.09.022

Ottersen, J. & Grill, K. (2015). Benefits of extending and adjusting the level of difficulty on computerized cognitive training for children with intellectual disabilities. *Frontiers in Psychology, 6*, 1-11. https://doi.org/10.3389/fpsyg.2015.01233

Phillips, N. L., Mandalis, A., Benson, S., Parry, L., Epps, A., Morrow, A., & Lah, S. (2016). Computerized working memory training for children with moderate to severe traumatic brain injury: a double-blind, randomized,

placebo-controlled trial. *Journal of neurotrauma, 33*(23), 2097-2104. https://doi.org/10.1089/neu.2015.4358
Quach, J., Spencer-Smith, M., Peter J., Anderson, P.J. & Robert, G. (2018). Can working memory training improve children's sleep? *Sleep Medicine, 47*, 113-116. https://doi.org/10.1016/j.sleep.2017.11.1143
Rabipour, S., & Davidson, P.S.R. (2015). Do you believe in brain training? A questionnaire about expectations of computerised cognitive training. *Behavioural Brain Research, 295*, 1-7. https://doi.org/10.1016/j.bbr.2015.01.002
Ramos, D. K. (2013). Jogos cognitivos eletrônicos na escola: exercício e aprimoramento dos aspectos cognitivos. *Seminário Jogos Eletrônicos, Educação e Comunicação, 9*, 1-9. http://www.comunidadesvirtuais.pro.br/seminario-jogos/files/Jogos%20cognitivos%20eletr%C3%B4nicos%20na%20escola.pdf
Roazzi, A., & Souza, B. C. (2019). Advancing Facet Theory as the Framework of Choice to Understand Complex Phenomena in the Social and Human Sciences. In S. H. Koller (Ed.), *Psychology in Brazil: Scientists Making a Difference* (pp. 283-309). New York: Springer. https://doi.org/10.1007/978-3-030-11336-0_16
Rosa, V. D. O., Schmitz, M., Moreira-Maia, C. R., Wagner, F., Londero, I., Bassotto, C. D. F., ... & Rohde, L. A. P. (2017). Computerized cognitive training in children and adolescents with attention deficit/hyperactivity disorder as add-on treatment to stimulants: feasibility study and protocol description. *Trends in psychiatry and psychotherapy, 39*(2), 65-76. https://doi.org/10.1590/2237-6089-2016-0039
Rossignoli-Palomeque, T., Perez-Hernandez, E., & González-Marqués, J. (2018). Brain Training in Children and Adolescents: Is It Scientifically Valid? *Front Psychol., 9*(565), 1-23. https://doi.org/10.3389/fpsyg.2018.00565
Sala, G., and Gobet, F. (2017). Working memory training in typically developing children: A meta-analysis of the available evidence. *Developmental Psychology, 53*(4), 671. https://doi.org/10.1037/dev0000265
Santana, A. N., Melo, M. R. & Minervino, C. A. S. M. (2019). Instrumentos de Avaliação das Funções Executivas: Revisão Sistemática dos Últimos Cinco Anos. *Aval. psicol., 18*(1), 96-107.http://dx.doi.org/10.15689/ap.2019.1801.14668.11
Schmidt, F. L., & Hunter, J. E. (2015). Methods of meta-analysis: Correcting error and bias in research findings (3rd ed.). Newbury Park, CA: Sage.
Schwaighofer, M., Fischer, F., & Buhner, M. (2015). Does working memory training transfer? A meta-analysis including training conditions as moderators. *Educational Psychologist, 50*, 138–166. http://dx.doi.org/10.1080/00461520.2015.1036274

Soderqvist, S., & Nutley, S. B. (2015). Working memory training is associated with long term attainments in math and reading. *Frontiers in psychology, 6*, 1711. https://doi.org/10.3389/fpsyg.2015.01711

Vries, M., Prins, P.J., Schmand, B.A., & Geurts, H.M. (2015). Working memory and cognitive flexibility-training for children with an autism spectrum disorder: A randomized controlled trial. *Journal of Child Psychology and Psychiatry, 56*(5), 566 – 576. https://doi.org/10.1111/jcpp.12324

Walton, C. C., Keegan, R. J., Martin, M., & Hallock, H. (2018). The potential role for cognitive training in sport: more research needed. *Frontiers in psychology, 9*, 1121. https://doi.org/10.3389/fpsyg.2018.01121

Webb, S. L., Loh, V., Lampit, A., Bateman, J. E., & Birney, D. P. (2018). Meta-analysis of the effects of computerized cognitive training on executive functions: a cross-disciplinary taxonomy for classifying outcome cognitive factors. *Neuropsychology review, 28*(2), 232-250. https://doi.org/10.1007/s11065-018-9374-8

Weyandt, L. L., Clarkin, C. M., Holding, E. Z., May, S. E., Marraccini, M. E., Gudmundsdottir, B. G., ... & Thompson, L. (2020). Neuroplasticity in children and adolescents in response to treatment intervention: A systematic review of the literature. *Clinical and Translational Neuroscience, 4*(2). https://doi.org/10.1177/2514183X20974231

Wiest, D. J., Wong, E. H., Bacon, J. M., Rosales, K. P., & Wiest, G. M. (2020). The effectiveness of computerized cognitive training on working memory in a school setting. *Applied Cognitive Psychology, 34*(2), 465-471. https://doi.org/10.1002/acp.3634

Zelechowska, D., Sarzynska, J., & Necka, E. (2017). Working Memory Training for Schoolchildren Improves Working Memory, with No Transfer Effects on Intelligence. *J. Intell. 5*(36), 2-20. https://doi.org/10.3390/jintelligence5040036

About authors and contact:

Alanny Nunes de Santana
PhD student, PPG in Cognitive Psychology, Federal University of Pernambuco (UFPE)
E-mail: alanny.santana@ufpe.br or alanny46@gmail.com
https://orcid.org/0000-0001-9505-3508
http://lattes.cnpq.br/0810849700298282
https://www.researchgate.net/profile/Alanny-Santana

Antonio Roazzi
D.Phil, Department of Psychology, Federal University of Pernambuco (UFPE)
E-mail: roazzi@gmail.com
https://orcid.org/0000-0001-6411-2763
http://lattes.cnpq.br/6108730498633062

Revista AMAzônica, LAPESAM/GMPEPPE/UFAM/CNPq
ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)
https://www.researchgate.net/profile/Antonio_Roazzi

Jéssica Daniele Silva de Vasconcelos Marques
Master's student, PPG in Cognitive Psychology, Federal University of Pernambuco (UFPE)
E-mail: jessica.daniele@ufpe.br
https://orcid.org/0000-0002-0869-1016
http://lattes.cnpq.br/5506490734808241

Alena Pimentel Mello Cabral Nobre
Ph.D. in Cognitive Psychology, Pernambuco University (UPE)
E-mail: alena.nobre@upe.br
https://orcid.org/0000-0001-7459-5770
http://lattes.cnpq.br/3437049863442139