

Investigating the efficacy of an attention training programme in children with foetal alcohol spectrum disorder

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Abstract

Objective: The current study investigated the efficacy of a direct intervention programme aimed at improving attention abilities in children with foetal alcohol spectrum disorder (FASD).

Methods: The Computerized Progressive Attention Training (CPAT) program is an intervention which targets proposed attention networks. CPAT task difficulty automatically adjusts based on participant performance. Ten children aged 6–15 with FASD completed an average of 16 hours of intervention over ~9 weeks at school, aided by a research assistant providing metacognitive strategies and support.

Results: Pre- and post-intervention assessments indicate significant improvement on several attention measures including sustained attention and selective attention. In addition, several measures of spatial working memory, math fluency, and reading fluency also significantly increased, suggesting that better attention leads to better cognitive performance.

Conclusion: Results provide support for the use of computerized attention training materials as part of an effective intervention for cognitive performance in children with FASD.

Keywords: *FASD, attention training, cognitive remediation, metacognitive strategies, process specific intervention*

Resumen

Objetivo: El presente estudio investigó la eficiencia de un programa de intervención directa dirigido a mejorar las habilidades de atención en niños con trastornos de espectro feto-alcohol (FASD).

Métodos: El programa Computerized Progressive Attention (CPAT) es una forma de intervención dirigida a redes de atención que han sido propuestas. El programa CPAT ajusta automáticamente la dificultad de las tareas según el desempeño del participante. Diez niños con edades entre los 6 y los 15 años con FASD completaron en promedio 16 horas de intervención durante 9 semanas en la escuela, auxiliados por un asistente de investigación proporcionando estrategias metacognitivas y apoyo.

Resultados: Las valoraciones y pre y post-intervención indican una mejoría significativa en varias medidas de atención incluyendo la atención sostenida y la atención selectiva. Así mismo, varias medidas de memoria de trabajo espacial, fluidez matemática y de fluidez en la lectura mejoraron significativamente, lo que sugiere que una mejor atención lleva a un mejor desempeño cognitivo.

Conclusión: Los resultados apoyan el uso de materiales informáticos de entrenamiento para la atención como parte de una efectiva intervención para mejorar el desempeño cognitivo de niños con FASD.

Palabras clave: *FASD, entrenamiento atencional, rehabilitación cognitiva, estrategias metacognitivas, intervención específica*

Introduction

In 1973, Jones and Smith [1] described the pattern of malformation associated with prenatal alcohol exposure as involving facial dysmorphology, central nervous system abnormalities, and growth retardation. The triad of symptoms was officially termed Foetal Alcohol Syndrome (FAS) [1–3]. Currently a broad range of effects caused by gestational alcohol

exposure are well documented and widely recognized [4]. As a result of the significant variability observed in this disorder, the term Foetal Alcohol Spectrum Disorder (FASD) is used as an umbrella term to encompass the wide range of cognitive deficits, psychosocial problems, behavioural effects, and physical abnormalities that can occur in individuals prenatally exposed to alcohol.

The majority of children with FASD experience considerable neurodevelopmental problems without the presence of physical anomalies [5]. Given that only a fraction of children with prenatal alcohol exposure exhibit the characteristic physical features for FAS, exact rates of FASD are not known. Health Canada [6] estimates that nine out of every 1000 children born in Canada, or $\sim 1\%$, are affected by FASD. In the US, estimated prevalence rates are even higher, ranging from 2–5%, although the prevalence of FAS is only thought to be 0.2–0.7% [7].

Prenatal alcohol exposure affects numerous areas of neurocognitive function. Children with FASD often have below average intelligence scores [8–10] and experience learning disabilities in academic areas, particularly in mathematics [9, 11] and reading [12]. Other areas of difficulty include memory and the ability to learn and encode new information [13–15] and visual and verbal working memory [16–18]. Executive deficits are also frequently exhibited, such as impaired planning and inhibition [19–22], verbal and non-verbal fluency [23, 24], cognitive flexibility as well as concept formation and reasoning [25].

FASD and attention

Of particular relevance to this study, deficits in attention are common in children with FASD [26]. Indeed, there are extremely high rates of comorbid Attention Deficit Hyperactivity Disorder (ADHD), with ADHD–Primarily Inattentive being the most frequent sub-type [27], supporting the notion that attention difficulties are central for children with FASD [28–30]. Coles et al. [31] used neuropsychological measures designed to investigate further the nature of these attention deficits. In general, results indicated that FASD children experience greater difficulties with the more complex aspects of attention, particularly with the ability to shift the focus of attention and to encode new information.

Related to deficits in attention, longer reaction times [32, 33] and decreased information processing speed also have been associated with prenatal alcohol consumption [34]. Indeed, Burden et al. [34] determined that tasks requiring more effortful processing (rather than automatic) discriminated between those with and without FASD.

Process-specific intervention for deficits in attention

Given the prevalence of FASD and its negative impact on development, access to early treatment and interventions for those affected could improve long-term outcomes. Although use of psychostimulant medication has some success in treating attention problems, Doig et al. [35] found use of

stimulant medication often did not improve teacher rated or laboratory measured ratings of attention in children with FASD. Likewise, research suggests children with FASD may not respond as well to stimulant medications as children with just ADHD [36].

An alternative approach for remediation of deficits in attention may be a direct ‘process specific’ approach [37]. Specifically, process-specific cognitive remediation approaches aim to strengthen underlying attention abilities by performing repetitive tasks that uniquely exercise components of attention, while gradually increasing the attentional demands, processing speed and cognitive load. The theoretical basis for such an approach, from the work of Luria [38], suggests that the brain displays a high degree of plasticity and that functional reorganization of neural pathways can facilitate improvements in cognitive function. Indeed, evidence from neuroscience demonstrates that direct, process-specific attention training can enhance underlying cortical activity. Posner and Rothbart [39] demonstrated that typically-developing 4-year-old children benefited from completing merely 5 days of computerized attention exercises. In addition to gains on measures of executive attention and intelligence, EEG data suggested that the training altered activity in the anterior cingulate cortex to more closely resemble adult levels of activity. The use of process-specific training has largely been within the cognitive rehabilitation literature with individuals who have suffered some type of acquired brain injury, with effectiveness of the intervention measured by changes in performance on the training tasks, untrained and standardized psychometric measures of attention and, finally, changes in functional tasks requiring attention. Although the majority of the research has been with adult populations, more recent research has begun to demonstrate the efficacy of these types of interventions in child populations, particularly on the remediation of attention deficits in children.

Several studies have utilized the Amsterdam Memory and Attention Training for Children (AMAT-C), a set of materials which target areas of attention including sustained and selective attention, mental tracking (working memory) and memory (declarative and episodic). In an initial study, van’t Hooft et al. [40] utilized the AMAT-C in a small group of children with TBI. Results demonstrated improvements between pre- and post- measures on a sustained attention task, reaction time and a selective attention task. Later work by this same researcher [41, 42] employed a randomized clinical control trial with children 9–16-years-old with TBI. Relative to the control group, the training group demonstrated significant gains in measures of sustained attention,

selective attention and memory tests and in a 6-month follow-up study the improvements in attention and memory remained significant, indicating that process-specific training can have long-term effects on cognitive functions. More recently the AMAT-C was employed with children with TBI (ages 8–16) delivered in a school setting [43] with positive gains on measures of attention and memory, but no improvements on measures of executive function.

Researchers have also investigated treatment of children with developmental deficits in attention as a result of central nervous system (CNS) cancer or cancer therapies (for a review see [44]) using a process-specific training approach. Butler [45] describes the use of the Cognitive Remediation Programme (CRP) with a 9-year-old patient with brain tumour who demonstrated attentional difficulties due to radiation treatment. The CRP involves hierarchically graded activities that practice attentional, perceptual and non-verbal cognitive skills. After 6 months of CRP training once a week, significant improvements were documented in attention skills as well as an approximate two grade level increase in arithmetic skills. Butler and Copeland [46] continued this research conducting a randomized clinical control study employing the CRP with 21 paediatric cancer survivors with attention deficits. Relative to the control group of cancer patients, the treatment group showed significant improvement on all three of the sustained and auditory attention measures. More recently, a multi-site randomized clinical control trial [47] utilized CRP in 161 children, aged 6–17 years, who were survivors of cancer and were enrolled in seven sites nationwide. Following ~40 hours of intervention (over 4–5 months), all participants were assessed using a battery of neuropsychological and achievement tests as well as parent and teacher reports of attention. Results documented gains in measures of attention, working memory and parent/teachers reports of attentive behaviour.

Similarly, process-specific training has also been utilized with children with developmental attention disorders (ADHD). Semrud-Clikeman et al. [48] examined the efficacy of attention process training combined with problem-solving strategies in children aged 8–12. Training involved paper-and-pencil exercises of visual and auditory attention. Pre- and post-testing revealed significant changes for the ADHD intervention group on visual and auditory attention, whereas the ADHD control group showed no significant improvements. Kerns et al. [49] also investigated the efficacy of a process-specific set of intervention materials for a group of young children with ADHD. The *Pay Attention!* programme was designed to target sustained, selective, alternating

and divided attention in both visual and auditory domains. Using a randomized, blind clinical trial approach they found children in the intervention (aged 7–11), in comparison to a control group, performed significantly better on numerous non-trained measures of attention and academic efficiency and had improvements in teacher reports of attention. Similar results using the *Pay Attention!* were found by Tamm et al. [50] in their study assessing 19 children with ADHD (ages 8–14) pre- and post-intervention. More recently these training materials were found to be effective in a group of young children with FASD, with gains in measures of attention and non-verbal reasoning [51].

More recently, process-specific training materials for attention [52, 53] and working memory [54–57] have been developed for delivery using personal computers in a ‘game-like’ format. Shalev et al. [52] developed the Computerized Progressive Attention Training (CPAT) program and applied it in a sample of children with ADHD. The CPAT is comprised of four structured tasks uniquely targeting orienting attention, sustained attention, selective attention and executive attention. Tasks presented on the computer are advanced through hierarchical levels of difficulty based on improvements in speed and accuracy. In their randomized clinical control study, children with ADHD received CPAT training twice per week for 1 hour, for a total of 8 weeks, while children in the control group spent an equal amount of time using the program, but it did not advance attention demands hierarchically. Results demonstrated significant improvements in the treated group on non-trained measures of reading comprehension and passage copying. In addition, parents reported significant gains in attention only for the CPAT training group.

In general, studies of process-specific attention training demonstrate significant benefits for children receiving both non-computerized and computerized forms of intervention and with varying causes for their attention deficits including ADHD, TBI and cancer. As FASD children have been shown to experience difficulty with complex aspects of attention [31], applying a process-specific training intervention to ameliorate attention deficits in FASD children is hypothesized to result in significant gains in attentional abilities as well as facilitate gains in further academic areas.

The aims of the present study were 2-fold: (1) to evaluate whether attention deficits of children with FASD can be improved by a computerized training program involving tasks that target each of the attention networks and (2) to determine the feasibility of delivering such an intervention in a school

setting and as part of the child's school day curriculum.

Method

Participants

Participants were recruited with the help of Sooke School district personnel who distributed an invitation to participate to caregivers of children who have received a diagnosis of FASD from a qualified medical practitioner. A total of 12 students were identified and enrolled in the study. During the course of the intervention, two participants withdrew from the study. One 13-year old male participant was permanently expelled from the school, while one 13-year-old female decided she no longer wanted to participate. The final sample was comprised of 10 children (six males, four females) who completed the minimum 16 hour training requirement. Two participants (one male, one female) came from an elementary school and the other participants (three males, five females) came from two middle schools. The sample ages ranged from 8–15 years ($M = 12.3$, $SD = 2.67$) and IQ scores ranged from 60–107 standard points ($M = 91.00$, $SD = 13.17$).

Intervention procedure

The CPAT [52] is an intervention based on Posner and Petersen's [58] model of attention, wherein the attentional system is divided into three distinct networks, each represented in anatomical and functional terms: (1) the *vigilance network*, hypothesized to be situated in the right frontal and parietal areas, is responsible for maintaining a state of alertness; (2) the *visual orienting network*, thought to be located in the superior parietal lobe and temporal parietal junction, controls the selection of information from sensory input; and (3) the *executive attention network*, believed to be found in midline frontal areas and lateral prefrontal cortex, is responsible for resolving conflicts among responses.

The Computerized Progressive Attention Training (CPAT) program was specifically designed for use in children aged 6 years and older [52]. The materials aim to strengthen these three networks through massed practice on four tasks: an orienting attention task targets the vigilance network, a sustained and a selective attention task targets the visual orienting network and an executive attention task targets the executive attention network.

This intervention program was delivered via laptop computer and required the minimum completion of 16 training hours on the four tasks. In general, participants completed half-hour sessions four times per week, although session length and

number varied as a result of absences, suspensions, holidays, field trips and school assemblies. Children, teachers and parents were consulted to determine the best times for individual sessions. On average, children completed 30.5 sessions over 9.5 weeks.

One-to-one training sessions took place with either a research assistant for the middle school participants or the Learning Assistance Integration Support Teachers (LAIS) for the two elementary school children. Training occurred during the school day, in either the library or special education area.

Throughout the administration of the CPAT, the conscious and deliberate use of metacognitive strategies was emphasized. Metacognitive strategies are those that teach children to monitor their own thinking in order to effectively allocate attentional resources and employ additional strategies when performance is weak [59]. As the children advanced through the levels, the LAIS teacher or research assistant provided coaching to help each child reduce frustration, utilize successful strategies and ultimately develop his or her own self-regulation skills. For example, if the child failed to pass a level due to poor reaction time or accuracy, the trainer and child would discuss what techniques the child should employ to improve his or her chances of passing the level on the next attempt. Such actions included the use of visual cues (e.g. drawing on a cue card the mapping between each symbol and letter on the keyboard to reduce memory load), rehearsal strategies (e.g. repeating a sequence out loud before attempting the sequence) and reducing the speed of response when performance was lacking in accuracy.

Children accumulated points based on their performance of the training tasks. For every correct response ranging between 1 SD above or below the mean reaction time (RT) for the block, feedback was provided in the form of the word 'good!' on the screen, while every response faster than 1 SD above the mean received a 'well done!' No feedback was provided for any RT slower than 1 SD below the mean and children received an auditory 'beep' when the wrong key was pressed. Fast and accurate responding translated into points. Upon the accumulation of a certain number of points, participants received a small gift (e.g., \$5 gift card, movie rental), which motivated children to fully participate in the tasks. The CPAT tasks are hierarchical in that at first the tasks are simple and slowly increase in difficulty based on the participant's performance.

Outcome measures

Pre- and post-treatment assessments included descriptive, working memory, attention and academic measures. A brief measure of intellectual abilities (Kaufman Brief Intelligence Test–Second

Edition, KBIT-2) was administered prior to training. Additionally, to better understand the outcomes of the intervention, a short follow-up evaluation questionnaire was distributed to teachers and parents following the post-assessment.

Working memory. Psychometric evaluations of working memory included the Spatial Span task from the Wechsler Intelligence Scale for Children–Neuropsychological Investigation (WISC-III/NI). The spatial span task requires children to recall, in the correct order, a string of spatially presented blocks that have been tapped by the administrator and to repeat them either forward or backward. The Children’s Size Ordering Task (CSOT) [60] was used to measure working memory. In this task, children are read aloud progressively longer lists of common objects and are asked to repeat back the objects, but ordered by their size.

Attention. Measures of attention were administered from two computerized batteries, the Attentional Network Test adapted for Children (ANT-C) [61] and the Test of Attentional Performance for Children (KiTAP) [62].

On the KiTAP, the *Sad and the Happy Ghost* task provides a measure of distractibility, in which the child is instructed to press a key every time a frowning, but not a smiling, ghost appears, while simultaneously ignoring distracting stimuli appearing in the periphery of the visual field. Divided attention (visual and auditory) was assessed by *The Owls* task in which the child must monitor both a visual and an auditory stimulus and press a key under two circumstances: either when they hear an owl make an incorrect sequence of auditory tones, or when the owl presented on the screen closes its eyes. *The Ghosts’ Ball* task measures sustained attention. In this 10-minute task, ghosts of differing colours appear one at a time in different spatial locations (windows of a castle), and the child is required to press the key if the same colour ghost appears twice in a row. In all three of the above tasks, correct hits, commissions and omissions are recorded. Lastly, *The Dragons’ House* task requires attentional shifting and flexibility. In this task, participants must allow blue and green dragons into the castle in alternating colour order, but the dragons appear in alternating locations, requiring the children to flexibly monitor which button to press. The KiTAP provides summaries of errors and reaction times for all tasks.

Fan et al. [63] designed the Attentional Network Test that measures the efficiencies of three attention networks, proposed by Posner and Petersen [58], in a single behavioural task. The ANT-C, the

child-friendly version, is a combination of flanker and cueing paradigms developed to examine individual differences in the efficiency of the brain networks of alerting, orienting and executive attention by examining differences in reaction time (RT) between various conditions. Each trial begins with a cue (or a blank interval for the no-cue condition) to alert the participant that either a target will occur soon or where it will occur or both. The target is then presented either above or below fixation and consists of a central ‘fish’, surrounded by flankers (identical fish) that are either pointing in the same direction (congruent) or in opposite directions (incongruent) or in the neutral conditions appears as a single fish without flankers. The child is required to press a button indicating the direction that this central ‘fish’ is pointing.

Finally, auditory sustained attention was assessed with the Test of Everyday Attention for Children (TEA-Ch) sub-test ‘Score’, in which children heard irregular repetitions of a video-game-like sound and had to count them for a prolonged period of time.

Academic measures. Woodcock-Johnson (WJ-III) tests of *Math Fluency* and *Reading Fluency* were given to assess the impact of the intervention on academic efficiency.

Results

Pre- and post-treatment differences in attention, working memory and academic performance were evaluated using a paired samples *t*-test and Cohen’s *d* was calculated to determine effect size. Analyses were performed using SPSS 17.0.

Table I presents the pairwise comparisons of the attention, working memory and academic task scores pre- and post-training. Using Cohen’s guidelines for interpreting effect sizes [64], reductions in commission errors on the KiTAP were large for the distractibility task ($d=1.00$), medium for the divided attention task ($d=0.58$) and small-to-medium for the sustained attention task ($d=0.30$). Response time for the tasks increased, with a large effect for distractibility ($d=0.83$) and a small effect for divided attention ($d=0.22$) and sustained attention ($d=0.17$). This general increase in reaction time with fewer commission errors indicates children were being less impulsive in their responding. On the ANT-C there were no differences in accuracy in any of the neutral, congruent or incongruent conditions, but there were significant gains in reaction time and a large effect in the neutral and incongruent conditions ($d=1.01$ and $d=1.05$, respectively) and marginally significant gains in reaction time in the

Table I. Pairwise comparisons of attention, working memory and academic measures pre- and post-intervention.

	<i>t</i>	sig. (<i>p</i>)	Cohen's <i>d</i>
<i>Attention</i>			
Distractibility			
Commissions	3.16	0.012*	1.00
Reaction time	2.63	0.027*	0.83
Sustained			
Commissions–Visual Task	0.94	0.373	0.30
Total–Auditory Task	2.82	0.047**	1.26
Reaction time	0.47	0.651	0.17
Divided			
Commissions	1.82	0.102	0.58
Reaction time (Audio/Visual)	0.70	0.499	0.22
ANT-C Reaction Times			
Neutral Targets	3.466	0.007**	1.10
Congruent Targets	2.182	0.057	0.690
Incongruent Targets	3.400	0.008**	1.07
<i>Working Memory</i>			
Spatial span forward	1.63	0.138	0.51
Spatial span backward	1.99	0.078	0.63
CSOT	1.18	0.269	0.37
<i>Academic</i>			
Math fluency	2.29	0.048*	0.72
Reading fluency	4.42	0.002**	1.40

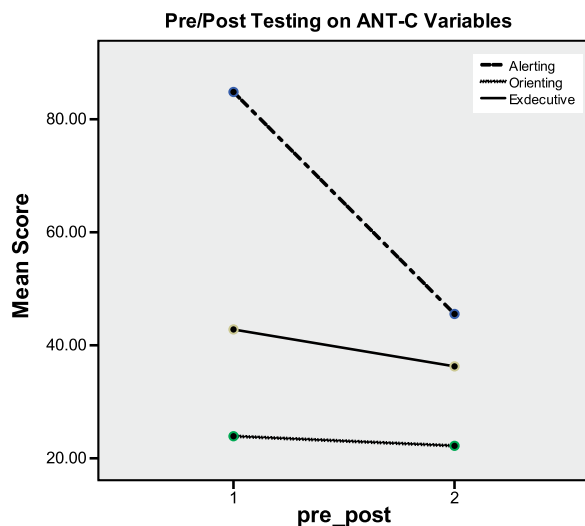
* $p < 0.05$; ** $p < 0.01$.

Figure 1. Changes from pre- to post-intervention performance in alerting, orienting and executive attention scores from the ANT-C.

congruent condition ($d = 0.63$). Indices of alerting, orienting and executive attention were also calculated from the ANT-C pre- and post-intervention. In general, participants had smaller indices (indicating quicker reaction times) for alerting, orienting and executive attention following the intervention. Utilizing a repeated measures analysis with two with-in subject factors (pre-/post-intervention and type of attention, see Figure 1), the intervention

resulted in marginally significant changes ($F(1,18) = 3.47$, $p = 0.095$, $\eta^2 = 0.28$). The auditory sustained attention task (from the TEA-Ch) also had a large effect size ($d = 1.26$), indicating a large increase in reaction time.

When examining improvement in working memory, spatial span forward (WISC-III/NI) had a moderate effect size ($d = 0.51$). Also with a moderate effect size ($d = 0.63$), the spatial span backward had slightly greater improvement. There was a medium effect size for the CSOT ($d = 0.37$). Reading fluency showed the greatest significant improvement overall ($t(9) = 4.42$, $p < 0.01$), with a large effect size ($d = 1.40$). Math fluency also showed statistically significant improvement ($t(9) = 2.29$, $p < 0.05$) with a moderate effect size ($d = 0.72$).

Discussion

Evaluation of attention training

This study evaluated the effects of computerized attention training on various cognitive abilities in a group of children with FASD. Results suggest that a short-term process approach intervention for attention using the CPAT program was effective for improving cognitive performance in children with FASD on measures of distractibility, sustained attention, divided attention, working memory, math and reading.

The greatest improvements in post-test attention measures were noted by decreased scores on the distractibility test (KiTAP), decreased reaction times on the ANT-C and increased scores on the auditory sustained attention test (TEA-Ch), all of which are essential to learning in a dynamic and changing environment in which many instructions are given orally by a teacher or parent. Gains in the non-attentional measures of working memory, maths and reading suggest that the attentional skills enhanced by the CPAT training facilitated the development of other abilities. In general, small increases in overall reaction time were noted across tasks, particularly with regards to the distractibility task. This increase in reaction time combined with fewer commission errors indicates children were less impulsive and sacrificed some speed to gain accuracy.

Working memory measures also showed a trend toward improvement, despite the fact that the CPAT doesn't directly train working memory. However, there are minimal working memory demands inherent in all four tasks, as the rules and mappings between symbol and letter keys must be remembered. Studies showing gains in non-trained tasks of working memory and attention suggest that these two key cognitive abilities are overlapping concepts [55, 65]. Indeed, many researchers have posited an

important relationship between working memory and attention, theorizing that working memory underlies the control of attention [66] and the ability to ignore distraction [67].

The significant improvements in non-trained measures of math fluency and reading fluency suggest that gains in attention mediated academic improvement in efficiency. Importantly, these fluency tasks were specifically chosen as both required low level conceptual skills (e.g. the math fluency is comprised of a page of single-digit addition and subtraction problems, followed by a page of single-digit multiplication and division problems) but do assess a child's efficiency in basic calculations. Likewise, the reading fluency task also requires minimal reading abilities, but both tasks are timed and the children instructed to work as quickly as they can without making mistakes. Hence, these tasks do not likely reflect true gains in core skills, but rather improved proficiency with the processing of basic mathematical operations and words probably secondary to better attention to the task. Therefore, systematic improvement in the attention processes trained in the CPAT may generalize to the academic environment by increasing 'on task' performance and efficiency.

Although only a few parents and teachers returned the short follow-up evaluation questionnaire, for those who did, written responses were positive. Overall, parents reported that their children understood why they were in the intervention and were not concerned about missing class time to do the attention training. On questions regarding their child's ability to pay attention across a number of domains, parents tended to see some improvement. In general, teachers were positive with regard to the impact of the intervention and indicated there was no concern about completing the intervention within the school day.

Children in the study appeared to enjoy the attention training materials, perhaps owing to the more engaging nature of computerized training rather than traditional table-top tasks. There was only one older participant who failed to complete the training due to a lack of interest. Participants did not appear to be distressed about missing class work and the amount of time necessary for the intervention did not significantly disrupt class work.

Shalev et al. [52] emphasize the important role of feedback in the success of CPAT training. First, unlike feedback in many daily activities and other forms of training in which reinforcing feedback is general, attention components in the CPAT are isolated so that every desired response is specifically and immediately reinforced with a visual stimulus of 'good!' or 'well done!' appearing on the computer screen immediately following a response. Secondly,

making the advancement of task difficulty contingent on the child's performance may facilitate self-regulation and self-control. Reid and Borkowski [68] found that by teaching impulsive children self-control and by attributing success to amount of effort, attention could be brought under some level of voluntary control. Given that effective responses within each difficulty level were within reach, children gain a sense of control and increase in self-esteem. Additionally, effective responding results in the accumulation of points, which tends to have a significant motivational influence and also a reciprocal effect on self-esteem.

The provision of meta-cognitive strategies and support from a research or learning assistance teacher as children played the CPAT games was crucial. The goal was to introduce metacognitive strategies and scaffold their use until the children employed them on their own accord, without prompting from the trainer. Indeed, metacognitive training has been combined with a cognitive-behaviour therapy programme to improve general problem-solving abilities in children aged 6–11 with TBI [69]. Results indicated significant improvements on untrained outcome measures of problem-solving skills. The authors suggest that, due to the metacognitive training, the children were better able to plan and organize their behaviour before commencing a task, which they theorized increased performance accuracy. Thus, merging process-specific attention training with meta-cognitive training generalizes to other settings and environments, which is a crucial aspect of the intervention.

In conclusion, results of this attention training project were positive in that the children made significant gains on psychometric measures of attention, working memory and academic efficacy. Importantly, many parents also noted positive changes in the home environment on behaviours requiring sustained attention. Additionally, delivery of a computerized attention intervention was feasible within the school setting, even when delivered by school personnel (supported with specific training for the intervention).

Limitations

There were two important limitations to the present study. First, due to the lack of a control group, the results are difficult to interpret, as observed changes could be due to CPAT training, or the effects of a general learning and developmental maturation process and 'practice effects' from having completed the outcome measures at pre-test. Pre- and post-tests which focused on working memory spans, continuous performance tasks and efficiency and

speed were chosen as these types of tasks are less prone to large practice effects. Further, pre- and post-assessments were administered within 3 months of each other and the majority of the sample were 'middle-school' aged. We would not anticipate significant changes on these types of tasks in this age range. Academic measures focusing on fluency were used to minimize the impact of classroom instruction and new learning on these measures. That stated, without an appropriate control group, any observed gains cannot be compared to that just due to development and re-test.

Secondly, originally the study was intended to be conducted primarily with children in primary school. Unfortunately, given past limitations in diagnostic services for FASD in younger children, very few elementary school children were identified as having FASD diagnosed by a qualified professional. As such, recruitment was then expanded to include middle school students, resulting in the majority of participants being older (13–15 years old). However, the attention pre- and post-assessment measures were designed for use in younger children, so they may have been less sensitive for detecting changes as some ceiling level performances were observed, most notably in the KiTAP measures.

Future investigations

Children likely experience a gain in self-esteem as they improve on the computer tasks; yet these gains are not directly assessed through psychometric measures of cognition. As these gains are beneficial in other aspects of life, they warrant further investigation. Future research in assessing cognitive remediation in child populations must also consider more effective ways to provide parents with information about the potential benefits of such interventions and promoting greater participation and communication between families and researchers. This could include a particular emphasis on having parents participate in encouraging the use of metacognitive strategies practiced during the intervention in situations where better attentive skills would be helpful at home (such as homework or completing a difficult project or task). Most families were fully supportive of their children being involved in the intervention, but there was relatively little communication directly with parents, as most contacts were between the researchers and the school, with the school often acting as liaison to the parents.

At present, computerized attention training programs with demonstrated efficacy are few and costly. A future goal is to develop an inexpensive and easy to use set of computerized materials targeting attention and working memory that can be provided within a school setting by school personnel.

One additional direction for future research endeavours is investigation considering long-term gains from such an intervention, as currently it is not known whether the observed improvements represent a lasting change in underlying ability.

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