Attention training in children with Autism Spectrum Disorder improves academic performance

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SHORT REPORT

Attention training in children with autism spectrum disorder improves academic performance: A double-blind pilot application of the computerized progressive attentional training program

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Abstract

Atypical attention has been reported in individuals with autism spectrum disorder (ASD) with studies pointing to an increase in attention deficit and hyperactivity disorder-like symptomatology. Individuals with ASD may also present academic difficulties and it is possible that they face a double-barrier for academic attainment from both core ASD symptomatology and from attention atypicalities, which are directly linked to academic performance. This raises the possibility that academic difficulties in ASD may benefit from cognitive training targeting attention. To test this possibility, we used the computerized progressive attentional training (CPAT) intervention in a double-blind, active control with follow-up intervention study in Brazil. The CPAT is a computerized attention training program that was recently piloted with schoolchildren with ASD in the UK. Twenty-six participants (8–14 years) with ASD in the São Paulo's ASD Reference Unit were assigned to either the CPAT ($n = 14$) or active control group ($n = 12$), which were matched at baseline. Two 45-min intervention sessions per week were conducted over a 2-month period. School performance, attention, fluid intelligence, and behavior were assessed before, immediately after and 3 months following the intervention. Significant group by time interactions show improvements in math, reading, writing and attention that were maintained at follow-up for the CPAT (but not the active control) group, while parents of children from both groups tended to report behavioral improvements. We conclude that attention training has the potential to reduce obstacles for academic attainment in ASD. Combined with the previous pilot study, the current results point to the generality of the approach, which leads to similar outcomes in different cultural and social contexts.

Lay Abstract

Attention difficulties tend to occur in ASD and are linked to academic performance. In this study, we demonstrate that school performance in math, reading and writing in children with ASD can improve following an intervention that trains basic

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attention skills (the CPAT intervention). The improvements we report are stable and were maintained 3-months following the intervention. This study, which was conducted in a public-health setting in Brazil, extends previous research in schools in the UK pointing to the cross-cultural and cross-settings efficacy of the intervention.

KEYWORDS
attention, autism spectrum disorders, cognitive training, intervention, school performance

INTRODUCTION

Attention atypicality is often found in individuals with autism spectrum disorder (ASD), with reports of initial difficulties in attention related to the development of core ASD symptoms (Keehn et al., 2013). Attention difficulties such as in disengagement are present from the first year of life in children with ASD (Bryson et al., 2018) and may extend to the Broader Autistic Phenotype (Spaniol, 2018, Spaniol, Shalev, & Mevorach, 2018). Difficulties are also exhibited in sustained attention (Chien et al., 2015), selective attention (Keehn et al., 2017) and executive functions such as inhibition, planning, set-shifting and cognitive flexibility (Craig et al., 2016). Importantly, attention capacity is closely linked to learning and academic performance (Erickson et al., 2015), including in the context of ASD children (May et al., 2013, 2015) and adults (Dijkhuis et al., 2020), who tend to show difficulties in writing and reading comprehension (Keen et al., 2016) and math (Keen et al., 2016). Thus, children with ASD may face a double barrier to academic success in schools both from their core ASD symptomatology and their attention atypicalities.

However, most intervention programs in ASD target core symptomatology in the syndrome (Reichow et al., 2013) and may therefore miss-out on the potential benefit training attention may have in ASD. Few attention training programs in ASD have been introduced but these tend to focus first and foremost on developing joint attention skills (Murza et al., 2016), which are not necessarily relying on low-level attention functions. Some other cognitive training programs can indirectly train attention, when training working memory and flexibility (de Vries et al., 2015), but it is less clear whether core attention skills are improved or if this contributes to improved academic performance. Consequently, a unique and complementary approach to improving academic attainment in ASD is to use intervention that directly targets attention functions. One such attention training program is the computerized progressive attentional training (CPAT) program developed by Shalev et al. (2007). Initially tested in a group of children with attention deficit and hyperactivity disorder (ADHD; Shalev et al., 2007) the CPAT intervention yielded improved academic performance and decrease in inattention symptoms compared to a matched active control group. The potential benefit of CPAT in children with ASD was recently demonstrated in a pilot study conducted in two primary schools in Birmingham, UK (Spaniol et al., 2018). Compared to an active control group, the children undergoing the CPAT intervention tended to show improvements in school performance (math, writing, and reading) and non-verbal intelligence. These preliminary findings suggest that an intervention program that specifically targets core low-level attention processes in ASD can support academic attainment and cognitive function.

The main objective of the current study was, therefore, to provide a further test of the efficacy of the CPAT intervention program for children with ASD in relation to academic performance. Thus, we conducted a pilot study applying the CPAT program in a public health setting in São Paulo - Brazil with children with ASD to specifically ask whether the application of CPAT can lead to attention improvements that can transfer to non-trained academic skills. Consequently, this pilot study was also able to provide a test for the viability of CPAT in a different socio-cultural environment to its original and previous applications.

METHODS

This study was conducted at the ASD Reference Unit CAISM Vila Mariana, linked to the State Health Department in São Paulo, Brazil, that treat children with a valid ASD diagnosis. Ethical approval for the study was granted by the Research Ethics Council of the Santa Casa de Misericórdia Hospital 72809517.3.0000.5479. Informed consent was obtained from all participants and their parents before taking part.

Participants

Thirty-four participants were recruited. Following baseline testing, eight participants were excluded from further participation and analyses as follows: two participants exhibited behavioral issues that prevented them from completing the baseline assessment; five participants scored zero on two or more of the academic assessments and one participant left the Unit after starting the intervention. The remaining 26 participants were divided into an experimental (CPAT) and active control (computer games) groups (Figure 1). Groups were constructed so that they would match on the outcome measures

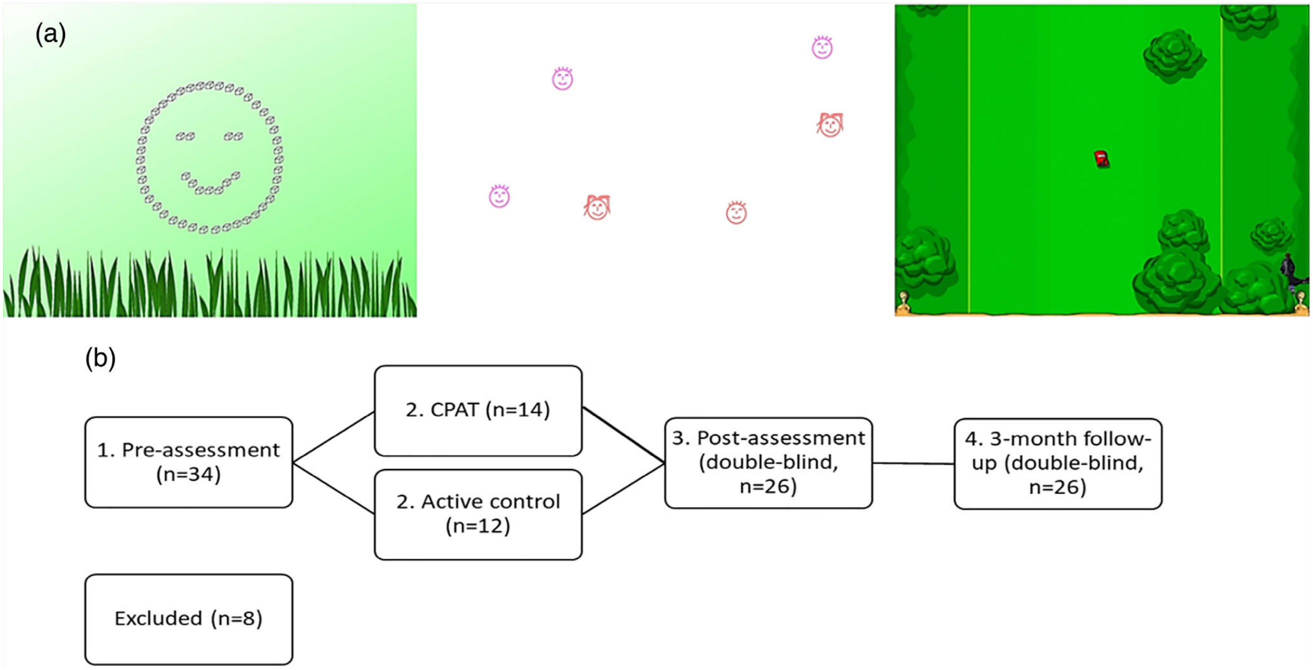

FIGURE 1 (a) Example of the three training tasks from the CPAT (level 1. Left: Global–local task: Executive attention. Children need to respond to the global (big) smiley face and inhibit the local (small) figures. Middle: Search task: Selective attention. Children need to look for a red smiley boy and press different keys if it's present or absent, while inhibiting response to other stimuli. Right: CPT task: Sustained attention. Participants need to respond to the red car, inhibiting responses to other objects. (b) Schematic of the intervention: 1. Baseline measures; 2. CPAT or computer games intervention; 3. Post-training assessment; and 4. 3-month follow-up, all portraying the number (*n*) of participants that completed each stage. Eight participants were excluded from the study. CPAT, computerized progressive attentional training

(academic and cognitive test), age and symptom severity at baseline. Group assignment (CPAT or control) was done blindly and randomly by a researcher using Excel with a 1:1 allocation using random block sizes of 2. The researcher that randomly divided the groups did not participate in data collection. The research assistants that conducted the assessments with the children were not aware of group affiliation. Detailed information regarding participants' demographics and group assignment is presented in Table 2.

Intervention Protocol

The CPAT includes separate training games targeting sustained, selective and executive attention (see Shalev et al., 2007, Spaniol et al., 2018 for more details) with gradually increased level of difficulty as participants progress in each game (Figure 1). Participants in the CPAT group trained on all three games in every training session. For the active control group, three readily available computer games were used: Plants versus Zombies, Snoopy Snails, and Pacman. These games also feature increased levels of difficulty. All children were told they were playing games that could help them in school and were not aware of the two groups or the grouping assignment (more details in Data S1).

Measures

Participants in both groups were assessed across a range of performance and behavioral measures (see Table 1 and Data S1). The main outcome measures of interest were tests of academic attainment (though attention and fluid-intelligence were also measured). We assessed participants in three time points: before (baseline), immediately after and 3 months following the end of the intervention, to assess whether improvements gained following the intervention are maintained long-term. We also assessed behavior in the three time points using parents' reports. Importantly, we employed a double-blind design with experimenters, participants and parents all being blind to group affiliation.

Data Analysis

Outcome measures (academic, cognitive and attention tasks) were analyzed using an ANOVA with time (pre, post and follow-up) as within-subjects factor and group (CPAT vs. active control) as between-subjects factor. For the sake of brevity, for each outcome measure we only report results in details if the group by time interaction from the ANOVA was significant, in which case planned pairwise comparisons of the change in performance between the different time points for each group separately is also reported (using t-test for normal distribution and Wilcoxon test for non-normal data). For a full report of the analysis see Data S1. The level of significance was set at $p < 0.05$. Effect sizes are reported as partial eta squared (n_p^2) for ANOVAs, Cohen's d (same group size) and Hedges g (different group size) for simple-effects. All data are reported as mean ± standard error of the mean (across subjects) (SEM). Individual changes were explored using the reliable change index (RCI; Guhn et al., 2014) and are reported in Data S1.

TABLE 1 Description of all measures used in the assessments to evaluate intervention effects, showing tests (main outcome measures) and questionnaires (for parents) and its measurements

Tests	Description
Main outcome measures	
Standardized academic test (TDE: Teste de Desempenho Escolar)	To measure school performance in math, reading and writing (Stein, 1994).
Raven's - educational: Colored progressive matrices (CPM)	To measure non-verbal cognition and fluid intelligence (Raven, 2008).
Attention cancellation task (Teste de atenção por cancelamento - TAC)	To measure sustained, selective and switching of attention (Montiel & Seabra, 2012).
Behavioral questionnaires for parents	
Autism behavior checklist (ABC autism)	Measuring ASD symptomatology and severity (Krug et al., 1980).
The behavior problems inventory (BPI-01)	To measure aggression, self-aggression, and stereotypic behaviors (Rojahn et al., 2001).
Brief problem monitor (parent version- BPM-P)	To briefly measure problem behavior (Achenbach & Rescorla, 2001).
Aberrant behavior checklist (ABC behavior)	To measure atypical behavior (Aman et al., 1985).
SNAP-IV rating scale	To measure inattention and hyperactivity (Swanson, 1992).
Semi-structured interview	To evaluate perceived changes in behavior, attention and school performance (as in Spaniol et al., 2018).

Note: More details in Data S1.

RESULTS

Baseline

The groups did not significantly differ in academic performance, cognitive performance or ASD severity prior to the intervention (reading: $T = 94.5$, $z = 0.541$, $p = 0.595$, $gs = 0.26$; writing: $t(24) = 0.199$, $p = 0.844$, $gs = 0.08$; math: $T = 76.5$, $z = -0.388$, $p = 0.705$, $gs = 0.1$; CPM: $t(24) = 2.37$, $p = 0.905$, $gs = 0.15$; ABC autism scores: $t(24) = 1.59$, $p = 0.125$ $gs = 0.6$; Table 2).

Academic and cognitive performance

Reading

Reading scores were calculated as the number of correctly read words (maximum of 70). There was a significant interaction between time and group ($F_{(2.48)} = 5.71$, $p = 0.006$, $n_p^2 = 0.192$) with the CPAT group showing significant improvement in reading scores from pre (44.2 ± 5.25) to post (52.6 ± 3.7) assessment ($T = 105$, $z = 3.312$, $p = 0.01$, $d = 0.5$), which was maintained at follow-up (54.7 ± 3.6, $T = 58.5$, $z = 0.377$, $p = 0.706$, $d = 0.15$, Figure 2(a)). In contrast, there were no improvements in performance for the active control group (pre = 38.4 ± 7.3; post = 36.6 ± 6.9, $T = 4$,

TABLE 2 Baseline measures and group comparison for gender, age, CPM, academic performance (Reading, Writing and Math) and autism severity in the pre-training phase.

	All ($n = 26$)	Active control ($n = 12$)	CPAT ($n = 14$)	Difference (p value)
Gender	6F, 20 M	3F, 9 M	3F, 11 M	0.829
Mean age, (Stdv) range	11.3, (1.7) 8–14	11.2, (1.7) 9–14	11.4, (1.7) 8–14	0.710
CPM age equivalent (Stdv)	8.02 (2.3)	8.06 (2.3)	7.98 (2.4)	0.933
CPM – Standard score (Stdv) range	81.8 (20.9) <60–125	83.7 (20.8) <60–125	80.3 (21.7) <60–115	0.689
CPM raw score	25.8 ± 1.2	26 ± 1.7	25.7 ± 1.6	0.905
Reading	41.5 ± 4.3	38.4 ± 7.3	44.2 ± 5.2	0.52
Writing	18.2 ± 1.8	18.6 ± 2.8	17.8 ± 2.4	0.844
Math	6.9 ± 0.9	7.2 ± 1.3	6.7 ± 1.2	0.80
ABC autism	54.3 ± 4.6	62.1 ± 7.9	47.5 ± 5.2	0.125

Note: Mean, standard deviation and range are shown for each measure across all participants and seperately for the active control and CPAT groups. The difference between the groups is represented with p (significance) value.
Abbreviations: CPAT, computerized progressive attentional training; CPM, colored progressive matrices.

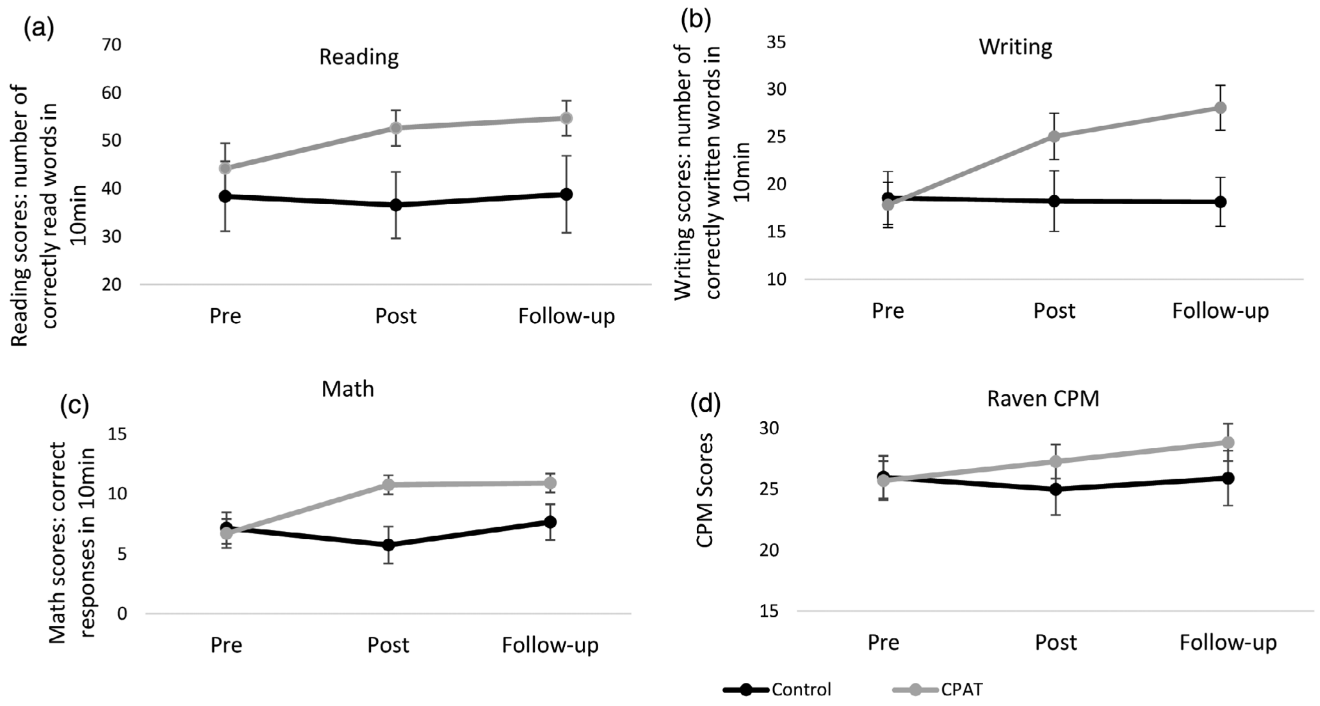

FIGURE 2 Performance (mean ± SEM) in the three time points (baseline, immediately following the intervention and at 3-month follow-up) in the CPAT (gray) and active control (black) groups on (a) reading scores; (b) writing scores; (c) math scores; and (d) cognitive - Raven's CPM scores. CPAT, computerized progressive attentional training; CPM, colored progressive matrices

$z = -1.693$, $p = 0.09$, $d = 0.07$; post to follow-up $= 38.8 \pm 8$; $T = 47$, $z = 1.247$, $p = 0.213$, $d = 0.08$).

Writing – Copying of words

Writing scores were computed as the number of words that were correctly written (maximum of 34). A significant interaction between time and group was found ($F_{(2.48)} = 8.06$, $p = 0.001$, $n_p^2 = 0.251$). Again, the CPAT group showed significant improvement from pre (17.8 ± 2.4) to post (25.1 ± 2.4) scores ($T = 101$, $z = 3.054$, $p = 0.002$, $d = 0.8$), which was maintained at follow-up (26.3 ± 2.4; $T = 42$, $z = 1.489$, $p = 0.137$, $d = 0.13$; Figure 2(b)). Once again, in the active control group there was no evidence for improvement in performance (pre $= 18.6 \pm 2.8$; post $= 18.2 \pm 3.2$; follow-up $= 18.2 \pm 2.6$; $T = 37.5$, $z = 0.401$, $p = 0.688$, $d = 0.03$; $T = 29.5$, $z = 0.204$, $p = 0.838$, $d = 0.008$).

Math

Math scores were analyzed using the number of correct responses (maximum of 35). There was a significant interaction of group and time ($F_{(2.48)} = 12.00$, $p < 0.001$, $n_p^2 = 0.333$), with the CPAT group showing significant improvement in the math scores from pre (6.7 ± 1.2) to post (10.8 ± 0.8, $T = 89.5$, $z = 3.097$, $p = 0.002$, $d = 1.07$), which was maintained at follow-up (10.9 ± 0.8; $t(13) = -0.241$, $p = 0.813$, $d = 0.05$; Figure 2(c)). In contrast the active control group showed no improvement from pre (7.1 ± 1.3) to post (5.7 ± 1.5, $T = 11.5$, $z = -1.644$, $p = 0.10$, $d = 0.28$). However, there was an indication of improvement from post-test to follow-up (7.6 ± 1.5; $t(11) = -2.82$, $p = 0.017$, $d = 0.36$) in this group, which is likely attributed to the drop in performance at post-test.

Attention cancellation task - TAC

The TAC provides two measures of interest in three levels of difficulty (sets 1–3): correct responses (hits) and commission errors (false alarms) – see complete results from TAC in Data S1. In set 2 the ANOVA on commission errors showed a significant interaction of time and group ($F_{(2.48)} = 4.63$, $p = 0.014$, $n_p^2 = 0.162$). In the CPAT group, the number of errors committed was significantly smaller post-intervention (pre $= 4.4 \pm 0.9$; post $= 0.8 \pm 0.4$; $T = 0.000$, $z = -2.93$, $p = 0.003$, $d = 1.3$) and was maintained at follow-up (1.1 ± 0.5; $T = 7.5$, $z = 0.921$, $p = 0.357$, $d = 0.2$). In contrast, the active control group showed no significant change in performance from pre to post (pre $= 4.7 \pm 2.1$; post $= 5.6 \pm 3.2$; $T = 17$, $z = -0.654$, $p = 0.513$, $d = 0.09$) and possibly worse performance (increased errors) at follow-up, albeit not-significant (9.75 ± 5; $T = 31.5$, $z = 1.893$, $p = 0.058$, $d = 0.3$; Figure 3).

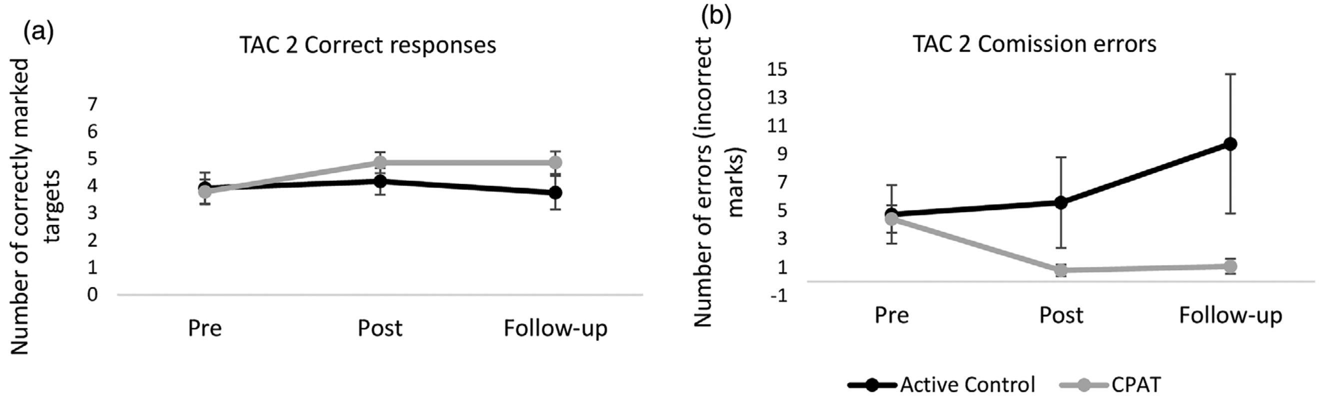

FIGURE 3 Attention performance (mean ± SEM) in TAC set 2 in the three time points (baseline, immediately following the intervention and at 3-month follow-up) in the CPAT (gray) and active control (black) groups. a) Number of correct responses (hits). b) Number of Commissions errors. CPAT, computerized progressive attentional training

Cognition – CPM

Colored progressive matrices (CPM) change was analyzed using raw scores. There was no significant effect of time or interaction with group. Here for the CPAT group there was a trend of improvement in CPM scores (albeit not significant – see Data S1).

Behavioral measures

There were no significant differences between the groups for parent's evaluations, and for most measures, there was a main effect of time showing that post-intervention scores were generally higher than baseline scores for both CPAT and active control groups (see Data S1).

DISCUSSION

Overall, we found considerable performance improvements in the CPAT group over and above performance recorded in the active control group. Attention performance in the CPAT group improved not only in the trained games (evidenced by the increased level of difficulty achieved by participants in this group) but also showed near-transfer effects to a non-trained pencil and paper attention task. More importantly, we report unique improvements in the CPAT group throughout the primary outcome measures. Across measures of academic performance (reading, writing, and math) children with ASD in the CPAT group showed statistically significant improved performance immediately after the intervention, in contrast with the active control group and these improvements were also echoed in the individual RCI reported in the Data S1 (albeit with RCI for math and writing showing more robust changes compared to reading). Moreover, our results are the first to show that performance gains following the CPAT intervention are maintained at least 3 months after the end of the intervention. It is important to note that the active control group in our study represents a rigorous test for the benefits of CPAT – not only the activity and format in the two groups was highly similar, the games used for the control group also involve cognitive processes such as problem solving skills (Shute et al., 2016) and visual search (Oei & Patterson, 2013). The current findings support our initial pilot study (Spaniol et al., 2018) providing encouraging further evidence of the efficacy of the CPAT as a viable intervention program in ASD with the potential of bringing lasting far transfer effects to non-trained academic tests. These findings are important, especially on the background of attention intervention studies that mostly target joint attention in ASD (Murza et al., 2016) which typically do not train core attention functions. It is also important given the lack of consistent transfer effects reported in intervention studies using technology in ASD (Golan & Baron-Cohen, 2006).

The far transfer effects we report here echo similar findings of the use of CPAT with other groups, including Stroke patients (Sampanis et al., 2015) and Foetal Alcohol Syndrome (Kerns et al., 2010) which documented transfer effects to non-trained cognitive performance. Similarly, far transfer effects were found using digital intervention to train multitasking in children with ASD and ADHD symptoms, showing improvements in cognitive control (Yerys et al., 2019). de Vries et al. (2015) also shows transfer effects with cognitive training in working memory improving attention for children with ASD.

While clear differential improvements were recorded for the two groups using objective measures of academic performance, parents' subjective evaluations did not differentiate between the two groups. Parents in both groups reported reduced levels of inattention and hyperactivity, self-aggression, stereotypy, atypical behaviors including lethargy, irritability, inappropriate speech and severity of autism, motivation, and autonomy (see Data S1). It is most likely that these results, as well as similar subjectively assessed behavioral improvements across both groups reported in Spaniol et al. (2018) represent a placebo effect, as parents were not aware of group assignment and generally parental reports may diverge from their child's test performance (Hong et al., 2016; Johnson et al., 2009; Miller et al., 1991). Parental reports also tend to be overly positive about therapies for their children with ASD (Goin-Kochel et al., 2009). Nevertheless, it is also possible that the intervention protocol itself was beneficial across both groups. Specifically, the interaction with the experimenter, learning and following rules for the training session and the cognitive and motor effort associated with performing computer games in both groups may all have some beneficial effects.

It is worth noting the Brazilian context of the current study, as previous research using the CPAT was performed in developed countries (UK, Canada, and Israel). Within the Brazilian Unified Health System, there are noticeable issues related to lack of units and unequal distribution of financial and human resources (Paula et al., 2012). Considering these aspects, the CPAT program was successfully applied in a busy health care unit, using existing facilities and materials as reward and to increase motivation. Participation in the study fitted within parents' schedule at the unit. Thus, our modest pilot study also demonstrates the feasibility of the CPAT program in the health care system of a middle-income country.

This pilot study has limitations primarily due to the small sample size, which may have led to the study being underpowered (seen in some small effect sizes in our results), but which could also lead to overestimated effect sizes (Kraemer et al., 2006). Nevertheless, the findings we report here provide a replication to our earlier (and smaller) pilot study (Spaniol et al., 2018) in a larger sample, and are therefore encouraging. Consequently, it is acknowledged that future research should now focus on expanding the sample size to test the efficacy of CPAT, and attention training more broadly, in ASD.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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