Central executive training for ADHD: Impact on organizational skills at home and school. A randomized controlled trial

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Abstract

Objective: The current randomized controlled trial (RCT) was the first to examine benefits of central executive training (CET, which trains the *working* components of working memory) for reducing organizational skills difficulties relative to a carefully-matched neurocognitive training intervention (inhibitory control training/ICT).

Method: A carefully-phenotyped sample of 73 children with ADHD (ages 8–13, M=10.15, SD=1.43; 20 girls; 73% White/Non-Hispanic) participated in a preregistered RCT of CET or ICT (both 10-week treatments). Parent-rated task planning, organized actions, and memory/materials management data were collected at pre-treatment, post-treatment, and 2–4 month follow-up; teacher ratings were obtained at pre-treatment and 1–2 month follow-up.

Results: CET was superior to ICT for improving organizational skills based on teacher report (treatment x time interaction: d=0.61, p=.01, BF_{10}=31.61). The CET group also improved significantly based on parent report, but this improvement was equivalent in both groups (main effect of time: d=0.48, p<.001, $BF_{10}= 3.13 \times 10^7$; treatment x time interaction: d=0.29, p=.25, BF_{01}=3.73). Post-hocs/preregistered planned contrasts indicated that CET produced significant and clinically meaningful (Number Needed to Treat/NNT=3–8) pre/post gains on all 3 parent (d=0.50–0.62) and all 3 teacher (d=0.46–0.95) subscales, with gains that were maintained at 1–2 month (teacher-report) and 2–4 month follow-up (parent-report) for 5 of 6 outcomes.

Conclusions: Results provide strong initial evidence CET produces robust and lasting downstream improvements in school-based organizational skills for children with ADHD based on teacher report. These findings are generally consistent with model-driven predictions ADHD-related organizational problems are secondary outcomes caused, at least in part, by underdeveloped working memory abilities.

Keywords

Central Executive Training; Inhibitory Control Training; Organizational Skills; ADHD; Working Memory; Inhibition

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Conflict of Interest:
The principal investigator Michael Kofler/Florida State University (FSU) was awarded U.S. Patent 11,210,967 for the neurocognitive interventions described in the present study. Central Executive Training was recently licensed to Sky Therapeutics, where Michael Kofler is in negotiations to serve as consultant. There are no other financial or other conflicts to report.

Attention-deficit/hyperactivity-impulsivity disorder (ADHD) is a neurodevelopmental disorder that affects 5% of the population (Polanczyk et al., 2014). Organizational skills impairments are well-established in ADHD, and if untreated predict myriad adverse outcomes including academic underachievement longitudinally into high school (Langberg, Molina et al., 2011; Kent et al., 2011) and adverse occupational outcomes in adulthood (Bikic et al., 2017). To date, the most effective evidence-based approaches to treating organizational impairments in ADHD are behavioral interventions that teach, cue, and reinforce organizational skill behaviors (i.e., organizational skills training; Abikoff et al., 2013). Meta-analytic evidence indicates that these behavioral interventions yield moderate-sized gains in organizational skills at post-treatment for children with ADHD (g=0.54–0.83; for review, see Bikic et al., 2017). Some organizational skills-based behavioral interventions even demonstrate significant maintenance of gains at 2-month to 1-year follow-up (Evans et al., 2016; Abikoff et al., 2013; Langberg et al., 2008; Pfiffner et. al., 2007). However, the extent to which this maintenance is due to continued implementation of behavioral strategies/contingencies after the end of active study participation – a critical ingredient for maintenance of most other behavioral-based interventions for ADHD (Chacko et al., 2014; Chronis et al., 2004) – remains unclear.

Conceptually, a limitation that may place a ceiling on the potential gains from behaviorally-based interventions for ADHD may be that such interventions target observable behaviors (outcomes/clinical endpoints) rather than the (presumed) causes that underlie the development of organizational deficits in ADHD. Stated differently, influential models of ADHD propose that ADHD-related behavioral and functional difficulties may reflect, in large part, inconsistent performance of known skills as opposed to knowledge gaps (Chacko et al., 2014). For example, it is possible that children with ADHD may possess age-expected knowledge of organizational skills, though struggle to consistently implement these skills (Abikoff et al., 2013) – potentially due to interfering factors such as underdeveloped executive functioning (Kofler et al., 2018).

Aligned with this alternate conceptualization, ‘glitches’ in executive functioning have been widely hypothesized to interfere with the effective practice and application of organizational skills among children with ADHD (Abikoff et al., 2013; Kofler et al., 2018). Executive functions represent interrelated, higher-order cognitive processes that facilitate decision making, goal-directed behaviors, and self-regulation (Miyake et al., 2000; Baddeley, 2007). Meta-analytic evidence suggests two primary executive functions are present and separable in school-aged children (Karr et al., 2018): *working memory* (i.e., the top down, active processing/manipulation of temporary information via dual-processing, continuous updating, and temporal/serial reordering; Baddeley, 2007; Wager & Smith, 2003) and *inhibitory control* (i.e., the ability to withhold or suppress a pre-potent behavioral response; Alderson et al., 2007). A sizeable 62%−85% of children with ADHD exhibit working memory deficits and 21%−46% of children exhibit inhibitory control deficits (Fosco et al., 2020; Kofler et al., 2019).

Interestingly, despite influential conceptual models attributing organizational skill difficulties, at least in part, to underdeveloped executive functions (Abikoff et al., 2013), very few studies have examined this hypothesis empirically. In one study, working memory difficulties explained approximately 20% of the variance in teacher- and parent-reported organizational problems, with associations that were robust to control for ADHD symptoms (Kofler et al., 2018). These results are consistent with studies demonstrating that working memory is also involved in organizational skills-adjacent behaviors such as notetaking (McIntyre, 1992) and following directions (Jaroslawska et al., 2016). In contrast, the evidence linking inhibitory control and organizational skills is less direct, but a recent meta-analytic review found that children with ADHD exhibited significantly more impulsive responses and worse task planning than non-ADHD peers (Patros et al., 2019). From these findings, it could be speculated that difficulty withholding prepotent responses (i.e., inhibiting) may be related to the difficulties with task planning associated with ADHD. This is a hypothesis that needs further study but is aligned with prior work documenting that inhibition deficits in young children are associated with difficulties in task planning performance (Bull et al., 2004).

Taken together, mitigating neurocognitive deficits that prevent children with ADHD from demonstrating known organizational skills (Kofler et al., 2018) could offer an alternate and potentially more efficient means than targeting the behavioral end-products of these deficits. Notably, it is also possible there are both acquisition deficits (knowledge gaps in age-expected organizational skills) *and* performance gaps (difficulties implementing the organizational skills they do know; Abikoff et al., 2013). This latter hypothesis is consistent with the Chacko et al. (2014) model, which outlined a framework for combined neurocognitive + skills-based interventions for ADHD that involves (a) identifying neurocognitive vulnerabilities that are functionally related to specific, observable symptoms/ impairments, and then (b) augmenting skills-based training with targeted neurocognitive training aimed at remediating/reducing the interfering effects caused by the underdeveloped neurocognitive system(s). However, a critical first step towards a combined neurocognitive + skills-based approach requires evaluating the extent to which targeting suspected underlying neurocognitive vulnerabilities results in improvements in organizational skills performance, independent of direct attempts to teach organizational skills.

Unfortunately, while neurocognitive training has strong theoretical promise for improving functional outcomes, to date most attempts have failed to produce meaningful improvements in their target neurocognitive mechanism(s) (for review, see Rapport et al., 2013; Simons et al., 2016). For example, meta-analytic and clinical trial evidence indicates that first-generation ‘working memory’ training protocols were successful in producing small/ medium improvements in *short-term* memory (i.e., the temporary storage/rehearsal of information held in mind) but generally unsuccessful in improving the *working* components of working memory such as the updating/dual-processing/reordering of internally held information (e.g., Chacko et al., 2014; Rapport et al., 2013; Gibson et al., 2011; van Dongen-Boomsma et al., 2014). This distinction is important given that only the latter appears to be predictive of ADHD symptoms and functional impairments such as organizational skills difficulties (Kofler et al., 2018). Thus, it is potentially unsurprising that these first-generation protocols failed to find significant treatment gains in improving organizational problems (Passarotti et al., 2020; Bikic et al., 2017).

In contrast, recent clinical trials of next generation neurocognitive training protocols such as central executive training (CET) have shown more consistent success at improving the ADHD-related neurocognitive, behavioral, and functional outcomes that have been studied to date, with most results replicating across two carefully-controlled clinical trials (Kofler et al., 2018, 2020). Importantly, CET has shown replicated success in producing large magnitude improvements in its target neurocognitive mechanism (the *working* components of working memory; Fosco et al., 2020; Wager & Smith, 2003), thus positioning CET as an ideal candidate for assessing whether links between working memory and outcomes such as organizational skills are causal (Kofler et al., 2018) vs. epiphenomenal (van Lieshout et al., 2013). Specifically, across two clinical trials CET was superior to both behavioral parent training (BPT) as well as a competing neurocognitive training protocol (Inhibitory Control Training/ICT) for improving working memory (d=0.70–0.91 across studies; Kofler et al., 2018, 2020). In terms of clinical/behavioral outcomes, CET was equivalent to BPT in terms of parent-reported ADHD symptom reductions at post-treatment, and superior to BPT in terms of reductions in objectively-assessed ADHD symptoms at post-treatment and improvements in masked teacher-reported impulse control and academic success/productivity at 1–2 month post-treatment. CET was also superior to ICT in terms of teacher-reported ADHD symptom reductions at 1–2 month post-treatment, as well as parent-reported ADHD symptoms at 2–4 month follow-up (Kofler et al., 2018, 2020). However, the potential for further downstream effects to organizational skills among children with ADHD remains unknown.

Current Study

The current randomized controlled trial of CET vs. ICT examined the extent to which a next-generation neurocognitive training protocol that targets the central executive (i.e., *working* components of working memory) produces superior far-transfer improvements in parent- and teacher-reported organizational skills as compared to an active, credible, and carefully matched control intervention targeting inhibitory control. We hypothesized that CET would be superior to ICT in yielding significant effects on organizational skills for school-aged children with ADHD based on both parent and teacher report. We also hypothesized that these gains would be evident across all three assessed organizational skills components (task planning, organized actions, memory/materials management) and maintained 2–4 months after the end of treatment. These hypotheses were based on evidence that (a) working memory has an established link with all three of the organizational skills domains investigated in the current study in children with and without ADHD (e.g., Kofler et al., 2018; Jaroslawska et al., 2016), whereas we were unable to locate direct evidence linking inhibitory control with organizational skills in children with ADHD; and (b) CET has, in most cases, produced greater benefits than ICT in terms of the primary clinical outcomes that have been studied to date (i.e., ADHD behavioral symptoms, academic productivity/success/achievement; Kofler et al., 2018, 2020; Singh et al., 2022).

Method

Study Design and Timeline

The current study reports on secondary outcomes from the randomized controlled trial of central executive training (CET) vs. inhibitory control training (ICT; Kofler et al., 2020). Families recruited between March 2017 and March 2020 were randomized with allocation concealment to CET or ICT. Data from a subset of the current sample were included in the primary outcomes manuscript (Kofler et al., 2020). Recruitment to this study was closed in March 2020 due to the COVID-19 pandemic. Please see Table 1 and Kofler et al., 2020 for details on randomization, allocation concealment, and masking maintenance.

Transparency and Openness Statement

Primary and secondary outcomes and detailed data analytic plans were preregistered at https://osf.io/abwms. The current study used the preregistered organizational skills outcome measures *and followed the preregistered analytic plan for the primary outcomes with one clearly marked exception*. The de-identified raw data (.jasp) and results output (including analysis scripts and test statistics) are available for peer review as recommended (Redick, 2015): https://osf.io/jcmhk/. We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study. Data screening, cleaning, and analyses were conducted masked to treatment allocation.

Participants

The CONSORT study flow diagram is shown in Figure 1. As shown in Table 2, the treated sample comprised 73 children ages 8–13 (*M*=10.15, *SD*=1.43; 20 girls), consecutively referred to a university-based research clinic through community resources. IRB approval was obtained/maintained; all parents/children gave informed consent/assent. Psychoeducational evaluation reports were provided to caregivers. Child race/ethnicity was 73% White/Non-Hispanic, 8% Hispanic, 15% Black, and 4% multiracial race/ethnicity. All participants spoke English.

Inclusion/Exclusion Criteria

All families completed a comprehensive evaluation that included detailed semi-structured clinical interviewing (K-SADS; Kaufman et al., 1997) and age/sex norm-referenced parent and teacher ADHD ratings (ADHD-RS-4/5 and BASC-2/3; DuPaul et al., 1998, 2016; Reynolds & Kamphaus, 2004, 2015). Additional details regarding the psychoeducational evaluation and differential diagnosis process can be found on our preregistration website. Study eligibility required: (1) DSM-5 diagnosis of ADHD (any presentation) by the directing clinical psychologist and multidisciplinary treatment team based on K-SADS (2013 update for DSM-5) and differential diagnosis considering all available clinical information indicating onset, course, duration, and severity of ADHD symptoms consistent with the ADHD neurodevelopmental syndrome; (2) clinical/borderline elevations on at least one parent and one teacher ADHD rating scale (i.e., >90th percentile), or previous psychoeducational evaluation documenting cross-informant symptoms (e.g., for children prescribed medication that reduces ADHD symptoms at school); and (3) current impairment based on parent report.

Several children with ADHD also met criteria for common comorbidities based on the comprehensive psychoeducational evaluation, including anxiety (23%), autism spectrum (15%), oppositional defiant (12%)[1], SLD reading (12%), and SLD math (15%). To improve generalizability/external validity, these children were not excluded. The CET and ICT groups did not differ significantly in terms of comorbidities overall or within each diagnostic category (all p>.12, BF_{01}>1.44), or on any demographic characteristic, the number of children prescribed psychostimulants, or medication changes during the study (all p>.08, BF_{01}>1.03; Table 2). A 24-hour washout procedure was used before child pre/mid/post testing sessions (for testing not included in the current report); however, families were not required to withhold psychostimulants prior to child treatment visits. Children were excluded for gross neurological, sensory, or motor impairment; seizure disorder, psychosis, or intellectual disability; or non-stimulant medications that could not be withheld for testing. As an additional exclusionary criteria, n=2 children with scores in the average range or higher on all pretreatment working memory tests were excluded; no inhibitory control thresholds were set as specified in our NIMH grant.

Bayesian Analyses

Traditional null hypothesis significance tests (p-values) were supplemented with Bayes Factors as recommended (Redick, 2015). Bayes Factors were added because they allow stronger conclusions by estimating the magnitude of support for both the alternative and null hypotheses (Rouder & Morey, 2012). BF_{10} is the Bayes Factor (BF) indicating how much more likely the alternative hypothesis (H_1) is relative to the null hypothesis (H_0). BF_{01} is the inverse of BF_{10} (i.e., $BF_{01}=1/BF_{10}$), and is reported when the evidence favors the null hypothesis. BF_{01} is interpreted identically to BF_{10} (>3=moderate, >10=strong, >100=decisive evidence that the treatment groups are *equivalent* on an outcome). Both p-values and Bayes Factors are reported. We refer to findings of $BF_{10} > 3$ as significant evidence for an effect (i.e., support for the alternative hypothesis of an effect at/above pre-specified evidentiary thresholds; Wagenmakers et al., 2018), and findings of $BF_{01} > 3$ as significant evidence *against* an effect (i.e., support for the null hypothesis of no effect at/above pre-specified evidentiary thresholds).

Procedures

Parent and teacher pre-treatment ratings were obtained as part of the pre-treatment evaluation described above. Parent post-treatment ratings were obtained at immediate post-treatment (M=9.57 days, SD=7.82; the treatments were equivalent in the time between treatment completion and parent post-treatment ratings, p=.93, BF_{01}=4.02). Teacher questionnaires were sent during the post-treatment session and were completed by teachers approximately 1–2 months post-treatment (M=41.00 days, SD=40.81; the treatments were equivalent in the time between treatment completion and teacher behavioral ratings, p=.91,

[1]As recommended in the K-SADS, oppositional-defiant disorder (ODD) was diagnosed only with evidence of multi-informant/multi-setting symptoms. ODD comorbidity is 32.9% based on parent-reported symptom counts, and 39.7% based on meeting parent *or* teacher-reported symptom counts.

BF_{01}=3.25). Longer-term parent follow-up ratings were obtained approximately 2–4 months post-treatment (M=82.77 days, SD=28.77; the treatments were equivalent in the time between treatment completion and teacher behavioral ratings, p=.84, BF_{01}=3.38).2 Parents and teachers were asked to rate child behaviors off medication if applicable. Teachers were masked to the fact that the child was participating in a treatment intervention. Parents were masked to treatment condition but are considered unmasked to the fact that their child was participating in a treatment intervention because they were active participants (e.g., bringing their child to treatment, facilitating athome training). Data analyses were conducted masked to treatment group allocation.

Treatments

As detailed in Kofler et al., 2020, identical procedures were used for both treatment groups. Both CET and ICT are 10-week digital therapeutic treatments accessed via computer or mobile device. Once a week, children were monitored by study staff for a 1-hour session while they completed their training exercises in-office according to identical, manualized procedures. Additional weekly training sessions were parent-supervised, in-home training (goal: 15-min/day, 2–3 days/week). Weekly parent check-ins were also included. These check-ins were intended to promote adherence and troubleshoot difficulties with the at-home training (e.g., demonstrating login procedures, brainstorming feasible days/times for the child to complete training). No active treatment components are included in the parent check-ins, which were identical across groups and conducted by staff masked to treatment allocation. As reported in Kofler et al., 2020, the interventions did not differ in terms of parent satisfaction, feasibility, acceptability, or barriers to treatment.

Central Executive Training (CET).—CET is a software-based digital therapeutic treatment protocol with gaming elements that was developed to train the ‘working’ components of working memory (dual-processing, continuous updating, serial/temporal reordering; Kofler 2018, 2020) via repeated practice and feedback using a suite of 9 computer ‘games’ developed based on the Baddeley (2013) and Wager & Smith (2003) models of working memory. That is, CET emphasizes training of children’s capacity to mentally manipulate/update items rather than merely increasing the number of items children can hold in short-term memory (Fosco et al., 2019). CET also emphasizes children’s ability to recall instead of just recognize stimuli based on compelling evidence that recognition-based tasks share minimal variance (r=.20) with criterion working memory recall tasks (Redick & Lindsey, 2013). In each CET training game, a unique combination of central executive process (dual-processing, continuous updating, serial reordering) and stimulus modality (phonological, visual, spatial) were targeted. As noted above, CET has

[2]Of note, our preregistration called for parent and teacher ratings to be completed at immediate post-treatment and additional parent ratings to be completed at 2-month follow-up; however, in running the trial we elected to allow more flexibility to facilitate retention by maximally accommodating families’ schedules. As such, the relatively wide teacher post-treatment and parent follow-up SDs were to maximize retention through follow-up (e.g., children unavailable during the summer due to travel or out-of-town custody arrangements); teacher post-treatment ratings are therefore described as 1–2 months post-treatment, and parent follow-up ratings are therefore described as a 2–4 month follow-up to better characterize the obtained range. For children completing treatment during their summer holiday, teacher questionnaires were sent 1 month after the start of the school year to allow teachers sufficient time to observe the child.

been shown to be superior to both behavioral parent training and a competing neurocognitive training protocol (ICT) for improving working memory (Kofler et al., 2018, 2020).

Inhibitory Control Training (ICT).—ICT trains the action restraint and action cancellation components of inhibitory control (Alderson et al., 2007). ICT is identical to CET in all aspects except for the active ingredient (targeting inhibitory control instead of central executive working memory). For example, each of the 9 matched pairs of ICT/CET training games were identical in terms of website address, name, art, animations, storylines, layouts, interfaces, and use of adaptive training algorithms to maximize internal/ construct validity. More generally, best practice guidelines for cognitive training studies were closely followed (Table 1), allowing strong conclusions regarding emerging treatment group differences as a function of training target (Redick, 2015). ICT has been shown to be superior to CET for improving stop-signal inhibitory control (d=1.12), despite not improving go/no-go inhibition (Kofler et al., 2020).

Measures

Intellectual Functioning (IQ) and Socioeconomic Status (SES) at Pre-Treatment—IQ was estimated using the WISC-V Verbal Comprehension Index (Wechsler, 2014). Hollingshead SES was estimated based on caregiver(s)' education and occupation (Cirino et al., 2002).

Organizational Problems—The Children's Organization Skills Scale (COSS; Abikoff & Gallagher, 2009) contains 66 (parent) and 42 (teacher) items that assess organizational problems in children ages 8–13 (2–3-week test-retest = .88-.99; α=.89-.98). Factor analytic evidence indicates 3 factors (Abikoff & Gallagher, 2009; Molitor et al., 2017): Task Planning (e.g., skill at meeting deadlines, organizing tasks into steps), Organized Actions (e.g., use of organizational aids and routines like planners, lists), and Memory/Materials Management (e.g., skill at tracking assignments, recalling due dates, and managing related supplies). In the current sample, the COSS subscales correlated r=.45-.51 (teacher) and r=.26-.47 (parent) at pre-treatment (all p<.001), consistent with the factor analytic evidence that they are measuring correlated but distinguishable components of organizational skills. Following prior studies using the COSS to assess treatment-related changes in organizational skills (Abikoff et al., 2009, 2013), raw scores were selected *a priori* as recommended for research purposes (Achenbach, 1991; Farmer et al., 2020). Higher scores reflect more difficulties with organizational skills.

Data Analysis Overview—Data analyses were conducted using JASP 0.16 (JASP Team, 2022) according to the preregistered plan. We organized our analyses into five analytic Tiers. Tier 1 compared the CET and ICT treatment groups on pre-treatment characteristics. In Tier 2, the CET and ICT treatment groups were compared for changes in organizational skills between pre-and post-treatment. Separate analyses were conducted for parent-reported improvements at immediate post-treatment and for masked teacher-reported improvements at 1–2 months post-treatment. These analyses involved Treatment (between-subjects factor: CET/ICT) x Subscale (within-subjects factor: Task Planning, Organized Actions, Memory/ Materials Management) x Time (within-subjects factor: Pre/Post) repeated-measures/mixed-model ANOVAs, with post-hocs following significant interactions and preregistered planned contrasts to characterize the pattern of change over time separately for each group. In Tier 3, exploratory analyses were added to probe for maintenance of gains, and involved repeating the parent model, this time adding the 2–4 month follow-up as a third time point. Teacher reports were not collected beyond the 1–2 month post-treatment time point described above. In Tier 4, we conducted sensitivity analyses to explore alternative explanations for the pattern of obtained results, including medication status, medication changes during treatment, and maturation. Finally, Tier 5 investigated clinical significance by estimating the proportion of children in each treatment group who demonstrated reliable change on each outcome measure and using these data to compute the Number Needed to Treat (NNT).

Results

Power Analysis

Our sample size includes all participants whose study participation was completed prior to the COVID-19 shutdown, and exceeds the per-group sample size recommendations for best practices in cognitive training studies (Simons et al., 2016). Power analysis using G*Power 3.1 (Faul et al., 2007) indicated that for α=.05, β=.80, and 2 groups (CET, ICT), our N=73 is powered to detect within-subject effects of time at d>0.34, treatment x time interactions of d>0.34, and between-group effects of d>0.58. Thus, the study is sufficiently powered to address its primary aims. In contrast, power to detect 3-way interactions (treatment x time x subscale) was low, with our sample size able to detect at β=.80 only very large magnitude effects of d>1.36 because the N required to detect a 3-way interaction is fourfold that required to detect the same effect size in a 2-way interaction (Heo & Leon, 2010).

Study Retention, Outliers, and Missing Data Handling

Study retention was high for both CET (90% completers, 66% of teachers completing post-treatment questionnaires, 74% of parents completing follow-up questionnaires) and ICT (79%, 70%, 78%, respectively) treatment groups. The groups did not differ significantly on these completion/return rates (all p > .22, all BF_{01} > 2.17). In addition, the evidence indicated that missing data were missing completely at random (i.e., not systematically related to any child demographic characteristics or outcome measures; Little’s MCAR test, p = .99). Thus, there was no evidence for differential attrition by treatment group. Missing data were therefore imputed using the preregistered plan (expectation-maximization based on all available data). This maximum likelihood-based approach has been shown to produce unbiased results for missingness rates at/above the current levels when data are missing at random (Kristman et al., 2004) as was the case in the current study. Exploratory analyses added during the peer review process, with teacher/parent missingness added as a covariate, indicated that missingness did not have a significant main effect (both p>.43), missingness did not interact with any of the main or interaction effects (all p>.23), and the pattern, significance, and interpretation of all results were unchanged with missingness included. Finally, all independent and dependent variables were screened for univariate outliers, defined as values greater than 3 SD above or below the within-group mean. Two datapoints were identified as outliers and corrected to the most extreme value 3 SD above or below the within-group mean.

Tier 1: Pre-Treatment Characteristics

As shown in Table 2, the CET and ICT groups were equivalent or did not differ significantly on any demographic variable at pre-treatment (all p>.08, all BF_{01}>1.03). The two treatment groups additionally did not differ significantly at pre-treatment on any of the COSS organizational skills subscales of primary interest in the current study (p>.15, BF_{01} >1.70).

Tier 2: Parent-Reported Organizational Skills at Immediate Post-Treatment

The Treatment (between-subjects factor: CET, ICT) x Subscale (within-subject factor: Task Planning, Organized Actions, Memory/Materials Management) x Time (within-subject factor: Pre, Post) mixed-model/repeated measures ANOVA was significant for main effects of Time (d=0.48; p <.001, BF_{10}= 3.13×10^7), Subscale (p <.001, BF_{10}= 6.30×10^{164}), and Subscale x Time interaction (p=.004, BF_{10}=6.34). The Treatment (p=.89, BF_{01}=4.58), Treatment x Time (d=0.29, p=.25, BF_{01}=3.73), Subscale x Treatment (p=.58, BF_{01}=9.51), and three-way interaction (p=.41, BF_{01}= 6.94) were not significant.

A priori planned comparisons indicated that CET portended significant pre-post improvements on all three COSS subscales: Task Planning (d=0.50, p<.001, BF_{10}=1268.51), Organized Actions (d=0.58, p=.003, BF_{10}=15.21), and Memory/Materials Management (d=0.62, p<.001, BF_{10}=548.33). In contrast, the ICT group improved on Memory/Materials Management (d=0.67, p<.001, BF_{10}=147.04) but not Task Planning (d=0.33, p=.10, BF_{01}=1.15) or Organized Actions (d=0.17, p=.11, BF_{01}=1.37).

Tier 2: Teacher-Reported Organizational Skills at 1–2 Months Post-Treatment

The Treatment (between-subjects factor: CET, ICT) x Subscale (within-subject factor: Task Planning, Organized Actions, Memory/Materials Management) x Time (within-subject factor: Pre, 1–2 Month Follow-Up) mixed-model/repeated measures ANOVA was significant for main effects of Time (p<.001, BF_{10}=1.95×10^6), and Subscale (p <.001, BF_{10}= 6.04×10^{120}), as well as the Treatment x Time (d = 0.61, p=.01, BF_{10}=31.61) and Subscale x Time (p=.002, BF_{01}=1.26) interactions.[3] No significant effects were found for Treatment (p=.75, BF_{10}=.20), Subscale x Treatment (p = .76, BF_{10}=0.07), or the 3-way interaction (p=.23, BF_{10}=0.15).

As noted above, the significant Treatment x Time interaction indicated that CET was superior to ICT for improving teacher-reported organizational skills overall (d=0.61, p=.01, BF_{10}=31.61). Preregistered planned contrasts indicated that CET also portended significant pre-post improvements on all three teacher COSS subscales: Task Planning (d=0.68, p<.001, BF_{10}=88.94), Organized Action (d=0.46, p=.02, BF_{10}=3.86), and Memory/Materials Management (d=0.95, p<.001, BF_{10}=7951.37). In contrast, ICT was not associated with significant pre-post improvements on any of the teacher COSS subscales: Task Planning

[3]Given the different number of items across COSS subscales, these analyses were repeated using the percentage of the total possible score for each subscale for each child (i.e., obtained subscale score divided by the maximum possible subscale score) to equalize the scaling across subscales. These exploratory analyses were not preregistered but were added given questions raised by the study team during data processing. The critical Treatment x Time interaction remained significant (p=.01, BF_{10}=28.26) for the teacher report. The pattern and significance of results in the parent models were also unchanged when re-run using these percentage scores to equate the scaling across subscales.

(d=0.21, p=.27, BF_{01}=2.38), Organized Action (d=.04, p=.84, BF_{01}=3.95), and Memory/Materials Management (d=0.22, p=.27, BF_{01}=2.33).

Tier 3. Parent-Reported Organizational Skills at 2–4 Month Follow-Up

Additional analyses were conducted to probe for maintenance of effects based on parent report. The follow-up timepoint was included in our preregistration but the analytic plan for this time point was omitted; thus, these analyses are considered exploratory and are necessarily reported separately from the preregistered analyses above. These analyses involved repeating the parent Pre/Post-treatment model above, this time adding Follow-Up as a third time point. Consistent with the immediate post-treatment results above, there were main effects of Time (d=1.09, p<.001, BF_{10}= 3.13×10^7) and Subscale (p <.001, BF_{10}= 6.30×10^{164}), whereas there was no evidence to support Subscale x Time (p=.94, BF_{01}=2.15), Treatment (p=.93, BF_{01}= 4.31), Treatment x Time (d = 0.03, p=.10, BF_{01}= 4.64), Subscale x Treatment (p=.44, BF_{01}= 4.71), or three-way interaction effects (p=.48, BF_{01}=8.63). Of primary interest were planned contrasts assessing (a) whether organizational skills problems in each domain remained significantly below pre-treatment levels at follow-up (pre vs. follow-up), and (b) whether post-treatment gains were lost across the no-contact follow-up duration (post vs. follow-up). Reporting is truncated for readability.

Central executive training.—As reported above, the CET group showed significant pre/post improvements on all three parent COSS subscales. *A priori* planned contrasts indicated that these gains were maintained at 2–4 months follow-up as evidenced by non-significant post/follow-up changes overall (p>.99, BF_{01}=3.77) as well as for the Task Planning (d=−0.12, p=.45, BF_{01}=4.42) and Memory/Materials Management subscales (d=0.06, p=.69, BF_{01}=5.19). Follow-up scores remained significantly improved relative to pre-treatment overall (d=0.80, p=.01, BF_{10}=4756.2) as well as for the Task Planning (d=0.42, p <.03, BF_{10}=6.45) and Memory/Materials Management subscales (d=0.74, p<.001, BF_{10}=42.06). In contrast, the CET group no longer demonstrated significant improvements on Organized Actions relative to pre-treatment (d=0.32, p =.23, BF_{10}=1.59), despite no significant loss of gains between post and follow-up for this scale (d = −0.20, p=.23, BF_{01}=3.25).

Inhibitory control training.—As reported above, the ICT group showed significant pre/post improvements only for parent-reported Memory/Materials Management. The ICT group demonstrated additional improvements between post/follow-up overall (d=0.57, p=.03, BF_{10}=4.79), with *a priori* planned contrasts suggesting that this change was due to additional improvements on the Memory/Materials Management between post-treatment and follow-up (d=0.45, p=.01, BF_{10}=7.71). Their Memory/Materials Management follow-up scores remained significantly improved relative to pre-treatment (d=1.14, p<.001, BF_{10}=7879.97). In contrast, the ICT group did not show post/follow-up changes for the Task Planning (d=0.11, p=.51, BF_{01}=4.31) or Organized Actions subscales (d=0.06, p=0.74, BF_{10}=5.26). Consistent with ICT's post-treatment pattern, their follow-up Task Planning (d=0.42, p=.05, BF_{10} =2.34)[4] and Organized Actions (d=0.28, p=.34, BF_{01}=1.36) scores did not differ significantly from their pre-treatment scores.

Tier 4. Sensitivity Analyses: Medication Status, Medication Changes, and Maturation

Next, we conducted sensitivity analyses. These analyses are exploratory because they were not preregistered and were added after inspecting the data to probe for alternate explanations for the pattern of results. Despite the groups not differing in terms of pre-treatment medication status, medication changes during the course of treatment, age, or time between completing treatment and post teacher/follow-up parent report (Table 2), it was possible that the significant main effects of time were attributable to one or more of these potential confounds rather than the tested treatments. This hypothesis was predominantly unsupported: The pattern, significance, and interpretation of all results were unchanged when medication status, medication changes, age, time between treatment completion and teachers completing the post-treatment ratings, or time between treatment completion and parents completing the follow-up ratings were added to the models, with one minor exception: the significant main effects of Time and Subscale effects were no longer significant in the teacher model when child age or time between treatment completion and teachers completing the post-treatment ratings were added to the models (p>.07, BF_{01}>1.26). In both cases, the critical teacher Treatment x Time interaction remained significant (p<.01, BF_{10}>31.51), consistent with the primary analyses above that central executive training produced superior improvements in school-based organizational skill behaviors relative to inhibitory control training. None of the included covariates showed significant main effects or interacted with Time or the critical Treatment x Time interaction.

Tier 5. Exploratory Analyses: Reliable Change and Number Needed to Treat

A final set of analyses were added to estimate the proportion of children in each treatment who exhibited reliable change on each outcome measure, and then compute the Number Needed to Treat (NNT). These analyses were not preregistered but were added based on peer review feedback from a previous paper (Singh et al., 2022). Briefly, NNT refers to the number of patients who need to be treated to get one more patient better than would have improved without the treatment; 1/NNT estimates the probability any given patient will benefit from the treatment (Wang et al., 2000). Smaller positive NNT values suggest more effective treatments; NNT values are rounded to the nearest whole number. Biederman et al. (2019) considered NNTs < 10 to be indicative of effective treatment for ADHD given the high cost of illness and associated functional impairments; a more general rule-of-thumb based on Chong et al. (2006) suggests that NNTs < 5 indicates an effective treatment that should be 'ruled in' by clinicians whereas NNTs > 15 suggests small/minimal treatment benefits that should be 'ruled out' by clinicians. Reliable change was computed using the Zakzanis (2001) 'percent non-overlap' method, which estimates the percentage of participants in each treatment group whose post-treatment/follow-up scores fell outside of the pre-treatment range of scores (based on the pre-post/follow-up Cohen's d main effects of time for each treatment).

Focusing on the task planning and organized action outcomes, results showed that 33%−36% (parent report) and 30%−41% (teacher report) of children treated with CET

[4]Of note, the Inhibitory control group's non-significant (p=.05) pre-treatment to follow-up change in task planning remained non-significant in the sensitivity analyses described below (all p>.06, BF_{10}<1.00).

demonstrated reliable improvements in organizational skills relative to 11%−21% (parent) and 0%−15% (teacher) of ICT cases. In addition, 54% of CET cases showed reliable improvement in teacher-reported memory/materials management relative to 15% of ICT cases. In contrast, rates for parent-reported memory/materials management were more comparable for CET (38%) and ICT (41%). Collectively, these improvement rates corresponded to NNTs favoring CET of 2.6 to 7.8 for all outcomes except parent-reported memory/materials management (Table 3).

Discussion

The current randomized controlled trial (RCT) was the first to examine the benefits of central executive training (CET) for improving organizational skills difficulties relative to a carefully matched neurocognitive training intervention (inhibitory control training/ICT) in a well characterized ADHD sample. Additional strengths include the relatively large sample size (for a clinical child RCT), detailed preregistration of study outcomes and analytic plans, use of masked informants and data analysts, and careful adherence to best practices for clinical trials of cognitive training protocols (Simons et al., 2016). Overall, we found that CET produced significant gains on all 6 outcomes, with gains that were superior to ICT based on teacher report, but not parent report, and in 5 of 6 cases were evident several months after treatment termination based on both parent and teacher report. These findings have implications for the treatment of ADHD-related organizational skills difficulties and are generally consistent with conceptual models linking executive functions with organizational skills as described below.

Our hypothesis that CET would produce superior far-transfer improvements in organizational skills for school-aged children with ADHD was generally supported. The most rigorous test – masked ratings from teachers who were not involved in the intervention – showed a significant treatment x time interaction favoring CET (d=0.61), with post-hocs indicating that the CET group improved on all three organizational skills components (task planning, memory/materials management, organized action; d=0.46–0.95) whereas the ICT group did not improve in any assessed domain (d=0.04–0.22, *ns*). In contrast, the omnibus treatment x time interaction did not reach significance based on ratings from parents who were masked to treatment allocation but were active participants, with both groups improving significantly but equivalently based on parent report (d=0.48). These improvements were generally maintained at 2–4 month follow-up and were robust to changes in medication status/changes, age, as well as time between treatment and informant ratings at post/follow-up. These results were generally consistent with cross-sectional work demonstrating that working memory difficulties predict organizational problems even when controlling for ADHD symptoms (Kofler et al., 2018). Collectively, these findings contribute to the quickly growing evidence base linking working memory with ADHD behavioral symptoms (e.g., Kofler et al., 2011; Raiker et al., 2012; Rapport et al., 2009), functional impairments (e.g., Singh et al., 2022; Kofler et al., 2011), and genetic risk for ADHD (Moses et al., 2022).

To that end, the robust far-transfer effects of CET for improving school-based organizational skills are consistent with conceptual models suggesting that organizational problems in

ADHD likely reflect, to a significant extent, a *performance* deficit wherein working memory impairments interfere with these children's ability to select, implement, and carry through the organizational skills that they have learned (Kofler et al., 2018). Clinically, these results suggest that directly training working memory may prove to be an efficient means for reducing the oft-observed organizational difficulties such as misplaced materials, disorganized desks/backpacks, and mismanaged/missed deadlines and homework submissions among children with ADHD (Abikoff et al., 2013; Langberg et al., 2011; Power et al., 2006).

Interestingly, as noted above, ICT was inferior to CET in terms of effects on school-based organizational skills behaviors, with post-hocs/preregistered planned contrasts indicating improvements on only 1 of 6 assessed outcomes (parent-reported memory materials/management). Together, these results may suggest that the under-inhibited response style characteristic of many children with ADHD (Patros et al., 2019) may be implicated in a circumscribed subset of daily tasks of organization (Bull et al., 2004). Alternatively, given ICT was inferior to CET based on teacher report, and parents were involved in treatment (e.g., bringing their child to sessions), it may be that the parent memory/materials management subscale is particularly sensitive to expectancy effects (i.e., that the ICT gains on this subscale are spurious). More generally, the lack of superiority for either treatment based on parent report introduces the possibility that the significant parent-reported gains for both groups are statistical/methodological artifacts (e.g., expectancies, regression to the mean). While this may be unlikely given that most detected gains were maintained 2–4 months after treatment ended, it speaks to the importance of active, credible control conditions when evaluating psychosocial and digital therapeutic interventions (Simons et al., 2016). It will also be important to replicate these results, particularly in light of the highly limited work examining links between inhibitory control and organizational skills in ADHD.

Finally, across both CET and ICT, improvements that were evident at immediate post-treatment were generally maintained across the 2–4 month no-contact follow-up period per parent report. This initial evidence for durability is notable given a critical component of sustained treatment gains among extant evidence-based behavioral interventions is continued implementation of labor-intensive strategies/contingencies (Chronis et al., 2004; Chacko et al., 2014). As such, neurocognitive training may prove to be a more efficient and sustainable course of treatment for improving organizational problems in ADHD, as compared to both behavioral treatments and psychostimulant treatments whose benefits dissipate within minutes to hours following treatment discontinuation (Chronis et al., 2004). This hypothesis is of course highly speculative given that the current trial did not directly compare CET with behavioral/pharmacological treatment. To that end, future research may benefit from examining whether sequencing neurocognitive and then skills-based approaches may yield greater and more sustained gains in organizational skills in pediatric ADHD without the need for costly continued implementation of strategies/contingencies (Chacko et al., 2014).

Limitations

Despite several study strengths as noted above, results should be interpreted in context of the following limitations. First, despite the study's relatively large sample and successful randomization that matched the treatment groups on all Table 1 demographics, the majority of our sample identified as White/Non-Hispanic and reported relatively high maternal education (i.e., a Bachelor's degree or higher). Thus, generalizability of findings may be limited for families from historically marginalized and lower socioeconomic households. Second, while parents were explicitly asked about changes in medication and other treatments or services, none reported new or modified behavioral, academic, or organizational skills interventions; and thus, we were unable to probe for potential additive treatment effects. Similarly, organizational problems were not part of the study inclusion criteria; thus, we were unable to examine whether CET/ICT would have greater efficacy for children with more severe organizational difficulties. Third, though the use of multiple informants across home and school settings was a strength, subjective reports can introduce biases (e.g., halo effects, retrospective recall) that may obscure detection of treatment-related changes. As such, future research may benefit from replicating our findings with objective, task-based measures of organizational skills.

Clinical, Educational, and Research Implications—Taken together, our findings provide strong initial evidence based on teacher report supporting the potential for CET to produce robust and lasting downstream improvements in school-based organizational skills – a key area of functional impairment for children with ADHD (Abikoff et al., 2013; Kofler et al., 2018). These findings are also consistent with basic science research identifying working memory as a mechanism underlying, at least in part, ADHD-related organizational skills difficulties. Thus, the current findings suggest potential benefits of using CET in clinical and school settings to target school-based organizational skills difficulties in children with ADHD, either as a monotherapy or potentially to augment existing behaviorally-based organizational skills interventions (Chacko et al., 2014).

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Key Points

Question:

Central executive training (CET) is a ‘Level 2’ evidence-based treatment for improving working memory, ADHD-related behavioral symptoms, and academic success/achievement for children with ADHD, but does it produce downstream effects on the disorder’s prominent organizational skills difficulties?

Findings:

In a preregistered, randomized controlled trial, CET produced significant and clinically meaningful pre/post gains in school-based organizational skills that were superior to a matched neurocognitive intervention (inhibitory control training, ICT) based on teacher report.

Importance:

Results provide strong initial evidence that CET produces robust and lasting downstream improvements in school-based organizational skills for children with ADHD.

Next steps:

Future research would benefit from replicating these findings in more diverse samples and determining the extent to which CET can complement/augment evidence-based psychosocial interventions that teach and reinforce organizational behaviors.

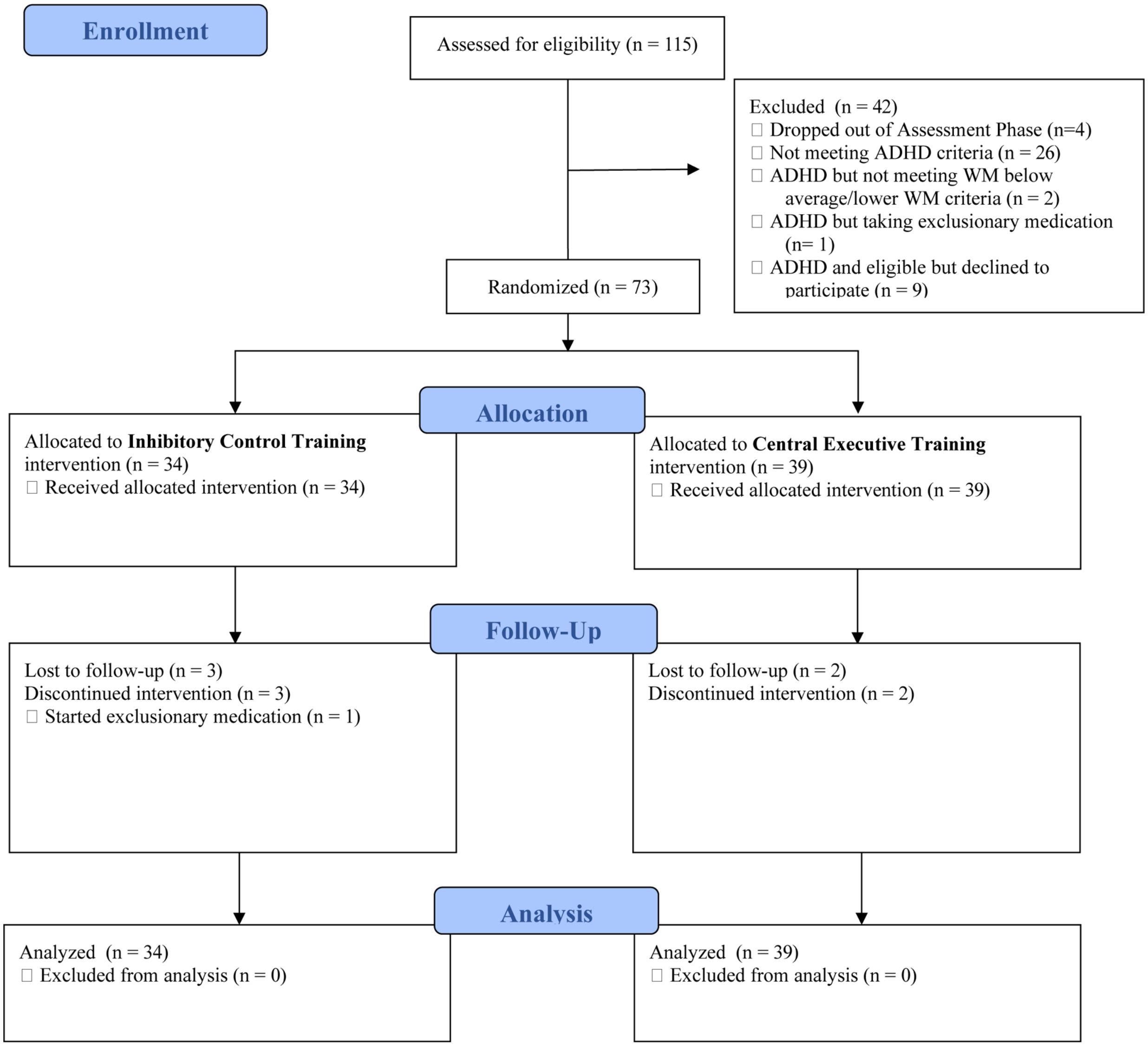

Figure 1.

CONSORT diagram. The 115 children assessed for eligibility include all children recruited for evaluation in our research clinic during the study timespan, regardless of recruitment reason (because families would have been offered the intervention trial if their child was diagnosed with ADHD and otherwise eligible). The number of confirmed ADHD cases who were considered for eligibility is 85, of which 73 (85.9%) were randomized and treated/analyzed.

Table 1.

Critical evaluation of the current study relative to best practice guidelines for cognitive training methodology and reporting standards (adapted from Simons et al., 2016 and Redick, 2015)

Criterion / *Commentary*
Best practice recommendations from Simons et al. (2016)
✓ Assess pre-treatment baseline performance for all groupsz
The current secondary outcomes study used a pre/post test design in which the outcome of interest was assessed at two (teacher report) or three (parent report) time points. Pre-treatment performance was assessed and included in all models probing for between-treatment differences at post-treatment/follow-up.
✓ Include an active, credible control group matched for expectancies
*Working memory and inhibitory control are both putative core mechanisms implicated in ADHD and featured in prominent conceptual models of the disorder's etiology and psychopathology. The two versions are identical in all aspects except the target mechanisms, and served as active, credible controls for each other. As reported in*Kofler et al., 2020, *the two treatments produced identical expectancy effects and did not differ in caregiver feasibility or acceptability.*
✓ Include at least 20 participants in each treatment arm
All analyses include CET = 39 and ICT = 34.
✓ Randomly assign children to condition
Children were randomly assigned using unpredictable allocation concealment.
✓ Pre-register the trial, and explicitly acknowledge departures from the pre-registered plan
The current study's outcome measures and detailed data analytic plans were pre-registered. Preregistration occurred during data collection and prior to accessing the data. Data screening, cleaning, and analyses were conducted masked to treatment allocation.
✓ Mask raters for all subjective outcome measures
Parent and teacher ratings served as the clinical endpoints for assessing organizational skills changes. Teachers and parents were masked to condition and remained masked based on a post-treatment parent questionnaire (Kofler et al., 2020). *However, parents were not masked to the fact that their child was receiving an intervention because they were active participants in both treatments* (Simons et al., 2016). *Thus, parent ratings are considered unmasked and may be conceptualized under the feasibility/acceptability umbrella of "perceived efficacy" rather than primary evidence of efficacy (Sonuga-Barke et al., 2013). Meta-analytic evidence indicates that estimates of treatment effects on ADHD symptoms are inflated for unmasked raters vs. masked raters by* d = *0.36–0.40 for neurocognitive training studies* (Rapport et al., 2013).
✓ Label any analyses conducted after inspecting the data as 'exploratory'
The analyses reported herein did not depart from the preregistered plan, with one clearly marked exception.
✓ Avoid subgroup analyses unless preregistered
No subgroup analyses were preregistered; therefore, none were conducted. Within-treatment analyses were limited to planned contrasts to characterize the pattern of change over time for each treatment.
✓ Identify all outcome data collected, including outcomes not reported herein
A complete list of data collected for secondary research questions can be found on the study's OSF preregistration website.
Additional recommendations from Redick (2015)
✓ Report full pre-test and post-test means and SDs for all groups
Pre-treatment and post-treatment means and SDs *are shown in*Tables 2 and 3.
✓ Provide full, subject-level data as supplementary material
JASP (.jasp) raw data files and results output are posted for peer review on the study's OSF website.
✓ Use likelihood ratios, in particular Bayes Factors
Traditional p-values are supplemented with Bayes Factors to allow stronger conclusions regarding both between-treatment equivalence and emerging between-treatment differences.
✓ Examine outcomes graphically to ensure that the pattern of pre- to post-test change is theoretically consistent with the expected pattern of results
Data were visually inspected to ensure the pattern of change was consistent with our descriptions in the text.

Table 2.

Pre-treatment sample and demographic variables

Variable	CET (*n*=39)		ICT (*n*=34)		BF_{01}	*p*
	M	*SD*	*M*	*SD*		
Sex (Girls/Boys)	11/28		9/25		4.08	.87, *ns*
Age	10.09	1.39	10.22	1.50	3.90	.72, *ns*
SES	46.35	10.79	49.15	9.15	2.26	.24, *ns*
VCI	102.08	13.59	105.77	12.57	2.23	.24, *ns*
Medication (No/Yes)	24/15		23/11		3.65	.59, *ns*
Med. Changes During Study (Stop/No/Start)	1/33/5		2/25/7		3.82	.67, *ns*
Race/ethnicity (W/B/H/M)	29/6/3/1		24/5/3/2		3.77	.65, *ns*
Maternal Education Level (HS/A/B/G)	1/2/7/18/11		0/3/6/16/9		14.28	.87, *ns*
BASC Attention Problems (T-score)						
Parent	69.59	6.06	66.77	7.30	1.03	.08, *ns*
Teacher	65.77	7.30	65.85	7.33	4.13	.96, *ns*
BASC Hyperactivity (T-score)						
Parent	71.08	12.50	66.41	13.03	1.46	.12, *ns*
Teacher	64.00	14.31	62.68	11.65	3.82	.67, *ns*
COSS (Parent Raw Scores)						
Task Planning	16.05	5.12	15.00	3.95	2.80	.34, *ns*
Organized Action	34.72	2.68	33.91	4.18	2.70	.32, *ns*
Memory/Materials Management	22.59	5.41	23.12	5.17	3.82	.67, *ns*
COSS (Teacher Raw Scores)						
Task Planning	15.56	5.01	14.06	3.72	1.70	.15, *ns*
Organized Action	36.39	5.86	35.62	5.41	3.58	.57, *ns*
Memory/Materials Management	24.90	8.12	23.15	7.74	2.83	.35, *ns*

Note. Raw *p*-values are presented (uncorrected for multiple comparisons). BASC = Behavior Assessment System for Children (T-scores); BF = Bayes Factor, BF_{01} is the odds ratio of the evidence favoring the null to the evidence favoring the alternative hypothesis. A value of 1 indicates that the data are equally likely under the null and alternative hypotheses, values >1 favor the null hypothesis that the groups are equivalent, and values >3 are considered statistically significant evidence of equivalence. CET = Central Executive Training; ICT = Inhibitory Control Training; VCI = Verbal Comprehension Index (Wechsler IQ; standard scores); Medication (No/Yes): indicates the number of children taking psychostimulant medication for ADHD symptoms at pre-treatment; (Stop = Discontinued medication during study, No = No changes reported, Add = Started medication during study); Maternal Education Level (HS = High School diploma or equivalent, A = at least 1 year of college, Associate's degree or specialized training, B = Bachelor's/4-year college degree, G = Graduate degree); Race/ethnicity (W = White/Non-Hispanic, B = Black/African American, H = Hispanic/Latino, M = Multiracial);

Table 3.

Organizational skills at 1–2 month follow-up (parent/teacher reports) and 2–4 month follow-up (parent report)

Variable	**CET (*n*=39)**		**ICT (*n*=34)**		**Pre- to Post-Treatment (Cohen's *d* Effect Sizes)**		**Pre- to Follow-up (Cohen's *d* Effect Sizes)**		**CET Number Needed to Treat**
	Post-treatment		**Post-treatment**						
	M	***SD***	***M***	***SD***	**CET**	**ICT**	**CET**	**ICT**	
Parent-Reported Organizational Skills (COSS Raw Scores)									
Task Planning	13.82	3.64	13.89	2.71	0.50 *	0.33, *ns*	0.42 *	0.11, *ns*	7.8
Organized Actions	32.82	3.76	33.09	5.16	0.58 *	0.17, *ns*	0.32, *ns*	0.06, *ns*	**4.1**
Memory/Materials Management	19.62	4.05	20.03	3.93	0.62 *	0.67 *	0.74 *	1.14 *	−36.8
	1–2 Mo. Post		**1–2 Mo. Post**		**Pre- to 1–2 Month Follow-Up (Cohen's *d*)**				
	M	***SD***	***M***	***SD***					
Teacher-Reported Organizational Skills (COSS Raw Scores)									
Task Planning	12.03	5.34	13.09	5.42	0.68 *	0.21, *ns*	-	-	**3.8**
Organized Actions	33.77	5.43	35.35	6.11	0.46 *	0.04, *ns*	-	-	**3.6**
Memory/Materials Management	18.18	5.89	21.35	8.49	0.95 *	0.22, *ns*	-	-	**2.6**

Note: Effect sizes and statistical tests reflect paired-sample T-tests (pre/post or pre/follow-up). Cohen's d effect sizes are interpreted as small = .20; medium = .50;large = .80.

*= statistically significant change ($p < .05$ and $BF_{10} > 3.0$). CET = Central Executive Training; ICT = Inhibitory Control Training; COSS = Children's Organizational Skills Scale. 1–2 Mo. Post = 1–2 month follow-up timepoint. Lower scores = better functioning on all subscales. Number needed to treat (NNT) was computed for central executive training, based on the proportion of children in the CET treatment group who demonstrated reliable change from CET relative to the proportion of children who demonstrated reliable change in the active, credible control condition (ICT). NNT refers to the number of patients who need to be treated to get one more patient better than would have improved without the treatment; 1/NNT estimates the probability that any given patient will benefit from the treatment (Wang, 2000). Smaller positive values suggest more effective treatments; the negative NNT value for parent-reported memory/materials management indicates that fewer children reliably improved in the CET relative to ICT treatment group. NNTs ≤ 5 are bolded.