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Parent and child neurocognitive functioning predict response to behavioral parent training for youth with ADHD

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Abstract

Parental cognitive functioning is thought to play a key role in parenting behavior and may inform response to behavioral intervention. This open-label pilot study examined the extent to which parent and child cognition impacted response to behavioral parent training for children with ADHD. Fifty-four participants (27 parent–child dyads; M_{ages} = 10.6 and 45.2 for children and parents, respectively) completed tasks assessing visuospatial and phonological working memory, inhibitory control, and choice-reaction speed at pre-treatment. Drift diffusion modeling decomposed choice-reaction time data into indicators of processing speed (drift rate) and response caution (boundary separation). Parents completed a 10-week manualized behavioral parent training program. Primary outcomes were pre- and post-treatment child ADHD and conduct problem severity, and parent-reported relational frustration and parenting confidence. Bayesian multiple regressions assessed parent and child cognitive processes as predictors of post-treatment outcomes, controlling for pre-treatment behavior. Better child visuospatial and phonological WM and higher parental response caution were associated with greater reductions in inattention. For conduct problems, better parental self-regulation (stronger inhibitory control and greater response caution) predicted fewer post-treatment conduct problems. Higher parental response caution also predicted lower post-treatment relational frustration and higher parental confidence. Bayesian

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Human and animal rights This study was approved by the institution's IRB. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed/assent was obtained from all individual participants included in the study.

evidence supported no relation between parent and child cognitive functions and treatment-related changes in hyperactivity. This pilot study demonstrates that cognitive processes central to etiologic theories of ADHD and models of parenting behavior can be successfully integrated into treatment outcome research to inform which families are most likely to benefit from behavioral interventions. This study demonstrates the feasibility of bridging the translational research gap between basic and applied clinical science and facilitates research on the role of cognition in psychosocial interventions.

Keywords

ADHD; Behavior therapy; Working memory; Processing speed; Inhibitory control

Introduction

Behavioral parent training (BPT) is a frontline evidence-based psychosocial intervention for attention-deficit/hyper-activity disorder (ADHD; Evans et al. 2018). Decades of research document its effectiveness in reducing ADHD symptoms, co-occurring conduct problems, and related impairments. For parents, participating in BPT often decreases parental stress and reduces negative parenting behaviors (Chronis-Tuscano et al. 2011; Chacko et al. 2009). Despite its overall effectiveness, BPT is not effective for every family (Evans et al. 2018; Owens et al. 2003). An important step toward enhancing the effectiveness of existing treatments and improving patient care requires understanding who is most likely to benefit from particular treatments (e.g., Kraemer et al. 2002).

Identifying treatment moderators has the potential to maximize clinical outcomes while reducing burden and cost (Hinshaw 2007; Kraemer et al. 2002). Yet, relatively little work in the BPT literature has sought to elucidate ADHD treatment moderators. Existing research has focused primarily on how limited demographic (e.g., sex, SES) and psychological (e.g., symptom severity, comorbidity profile) characteristics of children/families impact treatment response (e.g., Chronis-Tuscano et al. 2017; Hinshaw 2007; Sonuga-Barke et al. 2002). Investigations of parent characteristics aside from parental psychopathology are surprisingly scarce (see Johnston et al. 2012).

Though an important starting point, selection of extant moderators to date has been largely divorced from theory, which limits the translation of basic mechanisms involved in ADHD to clinical application (Johnston et al. 2012). The current study addresses this gap in the BPT literature by examining the moderating role of candidate cognitive processes (working memory [WM], inhibitory control, processing speed) that are steeped in both theories of ADHD etiology (e.g., Barkley 1997a, b; Castellanos and Tannock 2002; Rapport et al. 2008) and models of parenting behavior (see Crandall et al. 2015; Johnston et al. 2012).

ADHD is associated with multiple neurocognitive weaknesses suspected to possibly underlie its development (Nigg et al. 2018). As a group, individuals with ADHD across the lifespan demonstrate prominent deficits on tasks of WM (Kasper et al. 2012) and inhibitory control (Alderson et al. 2007; Lipszyc and Schachar 2010), and show medium-sized processing speed differences (Fosco et al. 2017; Karalunas et al. 2012), though substantial within-disorder heterogeneity exists (Fair et al. 2012). Given the strong heritability of ADHD (Faraone et al. 2005) and ADHD-related cognitive functions (Crosbie et al. 2013), parent and child neurocognitive abilities are strong candidate moderators of treatment response. Indeed, child cognitive function has been shown to predict response to stimulant medication (Molitor and Langberg 2017), and stimulant effects on inhibitory control and working memory partially mediate stimulant effects on classroom behavior (Hawk et al. in press); yet, a recent review summarizing the use of cognitive task performance as a tool for treatment planning highlighted that there is a dearth of research examining the extent to which cognitive function also informs response to psychosocial interventions (Molitor and Langberg 2017).

Within the broader parenting literature, several studies have shown that stronger parental WM predicts more positive parenting behaviors (Mazursky-Horowitz et al. 2017) and less harsh parenting in the context of challenging child behaviors (Deater-Deckard et al. 2010). Responsive parenting also correlates with stronger parental inhibitory control (Shaffer and Obradović 2017). To date, investigations studying parental neurocognitive function have focused exclusively on relating individual differences in cognition to parenting behavior. The current study is the first to assess whether parental cognitive function impacts the effectiveness of interventions specifically designed to improve parenting behavior.

Parenting is a transactional process between caregivers and children, and children's own cognitive functioning may impact responsiveness to BPT intervention strategies. The only study to test whether specific child cognitive processes, beyond global intelligence (Owens et al. 2003), moderated behavioral treatment response showed that better processing speed, but not WM, predicted greater symptom reduction among children with ADHD-inattentive type during a multimodal psychosocial intervention (Adalio et al. 2018). However, both constructs were measured with the WISC-V index scores, which lack measurement specificity in isolating neurocognitive processes compared to laboratory-based tasks (Tarle et al. 2017), and show poor correspondence with criterion WM tests (Wells et al. 2018).

The present open-label pilot study extends this important initial work by examining the extent to which both parents' *and* children's WM, inhibitory control, and multiple components of processing speed impact BPT effectiveness. The primary aims were to (1) demonstrate the feasibility of collecting both parent and child cognitive data within the context of a treatment study and (2) provide initial evidence for associations between cognitive function and improvement in children's symptoms, as well as in secondary outcomes of parent's stress and parenting confidence. We predicted that poorer pre-treatment cognitive functioning in children and parents would be associated with attenuated BPT benefits. Given the established role of WM in parenting behavior (Deater-Deckard et al. 2010), WM was hypothesized to show stronger effects than inhibitory control or processing speed. Given prior findings (Adalio et al. 2018), we anticipated that children's processing speed would most strongly predict BPT treatment response.

Methods

Participants

The modified CONSORT study flow diagram is shown in Fig. 1. Parents of children aged 8–13 years were consecutively referred to a university-based children's learning clinic through community resources. Caregivers were provided with psychoeducational evaluations. Informed consent/assent was obtained from all individual participants included in this study; IRB approval was obtained. The final sample included 27 parent–child dyads (Total $N = 54$; see Table 1).

Inclusion/exclusion criteria

All children and caregivers completed an identical evaluation that included a semi-structured clinical interview (K-SADS; Kaufman et al. 1997). Pre-treatment parent and teacher ADHD ratings were obtained from the Behavior Assessment System for Children (BASC-2; Reynolds and Kamphaus 2004) and Child Symptom Inventory (CSI-IV; Gadow and Sprafkin 2002).

Study eligibility required: (1) DSM-5 diagnosis of ADHD (Combined Presentation $n = 18$; Inattentive $n = 7$; Hyperactive/impulsive $n = 2$) on the K-SADS; and (2) Borderline/clinical elevations on at least one parent and one teacher ADHD rating scale, or previous psychoeducational evaluation documenting cross-informant symptoms (e.g., for children prescribed medication that reduced ADHD symptoms at school).

Comorbidities reflect clinical consensus best estimates, and included oppositional defiant (37.0%), anxiety (18.5%), and depressive (11.1%) disorders. Fifteen children (55.6%) were currently prescribed psychostimulants that were withheld ≥ 24 h prior to pre-treatment cognitive testing. Continued medication was allowed during BPT treatment (Table 2).

Children were excluded for gross neurological, sensory, or motor impairment, seizure disorder, psychosis, autism spectrum disorder, or intellectual disability, or non-stimulant medications that could not be withheld for testing.

Procedures

Children first attended an intake assessment to determine eligibility. Pre-treatment cognitive testing occurred during a larger battery of two, 3-h sessions (child) or one, 90-m session (parent). All tests were counterbalanced within/across sessions. Children and caregivers received brief breaks after each task, and preset longer breaks every 2–3 tasks. Pre-treatment symptom ratings were collected as part of the child's initial assessment prior to the first treatment session. The median duration between the completion of the child assessment and the first treatment session was 31 days ($M = 46.15$, $SD = 35.69$), and the duration between parent pre-treatment testing and the first treatment session was 10.52 days ($SD = 13.91$).

Behavioral parent training

BPT was delivered according to manualized procedures in small group format ($n = 23$) or individually ($n = 4$) as needed to accommodate families' schedules. Evidence-based BPT

(Evans et al. 2018) was provided using the 10-session manualized Barkley (1997a, b) Defiant Children protocol. BPT was delivered by behaviorally trained, PhD-level clinicians (two licensed psychologists and one postdoctoral fellow). In all BPT sessions, clinicians covered the intervention content by conducting sessions with the treatment manual open as the session guide. Parent-reported treatment feasibility and acceptability were excellent (see Kofler et al. in press). As reported below, parent-reported ADHD symptom reductions in this group were consistent with recent reviews of BPT for ADHD (Evans et al. 2018). Four families discontinued treatment after approximately half of sessions. For these families, mid-treatment scores were used in place of post-treatment scores. All other families attended at least 8 out of 10 sessions.

Measures

Intellectual Functioning (IQ)—Child IQ was estimated using the WASI-II (Wechsler 2011). Parent IQ was estimated with the WASI-II Matrix Reasoning subscale.

Child Symptoms—Parent-reported ADHD and ODD symptoms were assessed using T-scores (age and gender norms) from the Behavior Assessment Scale for Children (BASC-2; Reynolds and Kamphaus 2004) attention problems, hyperactivity, and conduct problems subscales. Psychometric support for these subscales includes high internal consistency (attention problems α = .79–.90, hyperactivity α = .84–.88, conduct problems α = .87–.88), test–retest reliability (attention problems = .90, hyperactivity = .91, conduct problems = .87–.88), and expected correspondence with other broadband and narrowband indices of ADHD and ODD symptoms (e.g., Achenbach and Rescorla 2001; DuPaul et al. 2016). Higher scores indicate higher quantity/severity of ADHD/ODD symptoms.

Parental stress and confidence—The Parenting Relationship Questionnaire (PRQ; Kamphaus and Reynolds 2006) assesses the quality of the parent–child relationship. The current study utilized T-scores (age and gender norms) from the Relational Frustration and Parenting Confidence sub-scales of the PRQ. Relational frustration assesses a parent's stress in relating to their child and managing their child's behavior. Higher scores reflect greater stress/frustration. Parenting confidence involves the degree of perceived confidence in making parenting decisions and implementing parenting practices. Higher scores reflect more confidence. Psychometric support includes good internal consistency (frustration α = .86–.89, confidence α = .78–.80) and test–retest reliability (frustration = .82, confidence = .77).

Candidate neurocognitive moderators

Working memory—Children and parents completed a visuospatial (VS) and phonological (PH) WM task (Rapport et al. 2009). Twelve trials per set size were administered in ascending order at a rate of 1 stimuli per second. Brief breaks were given between blocks. Children completed set sizes of 3–6 stimuli per trial; caregivers completed set sizes of 3–7 stimuli to avoid ceiling effects. Five practice trials were administered before test trials (80% correct required).

Task outcome variables—Number of stimuli correct per trial were summed at each set size; total stimuli correct were then averaged across set sizes, within modality (phonological vs. visuospatial). Higher scores reflect better WM.

Inhibitory control—The stop-signal task (SST) assessed inhibitory control. Go stimuli were the letters "X" and "O" (equal probability) displayed in the center of a computer screen for 1000 ms. A 1000-Hz auditory tone (i.e., stop signal) was presented randomly on 25% of trials. Stop-signal delay (SSD)—the latency between presentation of go stimuli and stop stimuli—was initially set at 250 ms, and dynamically adjusted in 50-ms increments, contingent on participant performance. The algorithm is designed to approximate successful inhibition on 50% of the stop trials. After two practice blocks, participants completed four consecutive experimental blocks of 32 trials per block (24 go trials, 8 stop trials).

Task outcome variables—Data for one child were lost due to technical issues. The speed of the stop process (stop-signal reaction time; SSRT) was the primary SST outcome variable.[1] To ensure that differentially skewed "go" reaction times (RT) did not impact SSRT estimates, SSRT was computed as median RT—mean SSD (Verbruggen et al. 2013). SSRT was computed for each block and then averaged across blocks. Smaller values reflect better inhibitory control.

Processing speed and response caution—A two-choice RT task required participants to press one of two keys to indicate whether a "Y" or "N" appeared on the screen on each trial. Stimuli were presented randomly, with equal probability. Max stimulus duration was 2500 ms (jittered ISI 800–2400 ms). Participants' response terminated the trial. After a 10-trial practice block (100% correct required), participants completed 60 test trials.

Task outcome variables—Anticipatory responses (RTs < 150 ms) and outlying RTs (> 2500 ms) were screened and excluded. A three-parameter (boundary separation, drift rate, nondecision time) drift diffusion model (DDM) using Fast-DM and the Kolmogorov–Smirnov criterion (Voss et al. 2015) was fit to the data. The three-parameter model can provide robust parameter estimation even for small trial numbers (Lerche et al. 2017). In the current sample, model fit was acceptable for all participants (all *p*s > .20, with $p < .05$ representing poor fit).

The DDM separates RT data into psychologically-distinct processing components. *Drift rate* (v) represents the speed of information accumulation and was selected to indicate processing speed in the current study. Drift rate is advantageous over mean RT because it provides a purer assessment of processing speed that separates processing speed from overall accuracy, level of response caution and speed of motor output, all of which affect overall RT estimates (Lerche et al. 2017). Higher values indicate faster processing speed. *Boundary separation* (a) reflects response caution, such that higher values indicate a response style that emphasizes accuracy over speed, and lower values indicate an emphasis on speed over accuracy. *Nondecision time* (t_{err}) reflects time for processes outside of the decision-making process,

[1]SSD was also computed due to the current debate in the literature regarding the optimal metric for estimating inhibitory control (Alder-son et al. 2007). The pattern of results was the same for SSD and SSRT.

including stimulus encoding and motor response execution (Voss et al. 2015). Nondecision time was excluded from analysis because it is comprised of several non-cognitive processes that are unrelated to decision-making (e.g., stimulus encoding, skeletomotor response speed).

Data analytic plan

Data screening indicated no outliers (> 3 *SD*s) or problematic skewness/kurtosis for any variable used in primary analyses.

Bayesian analyses—The primary data analytic strategy included Bayesian analyses conducted in JASP 0.8.2 (JASP Team 2017), rather than traditional null hypothesis significance testing. The benefits of Bayesian methods over *p*-values are well documented (e.g., Wagenmakers et al. 2016); for our purposes, Bayesian analyses allow stronger conclusions by estimating the magnitude of support for both the alternative and null hypotheses (Rouder and Morey 2012), and because they are appropriate for smaller samples sizes (Miočević et al. 2017).

Default JZS noninformative priors were selected because informative priors were not available for any parent and most child predictors. Instead of a *p* value, these analyses provide BF_{10}, which is the Bayes Factor of the alternative hypothesis against the null hypothesis. BF_{10} is an odds ratio, where values above 3.0 are considered significant evidence supporting the alternative hypothesis (i.e., statistically significant evidence for the alternative hypothesis). BF_{10} values above 10.0 are considered strong (> 30 = very strong, > 100 = decisive/extreme support; Wagenmakers et al. 2016). Conversely, BF_{01} is the Bayes Factor of the null hypothesis against the alternative hypothesis and is reported when the evidence indicates a lack of an effect (i.e., favors the null hypothesis). BF_{01} values are interpreted identically to $BF_{10,}$ but in support of the null hypothesis that a predictor does *not* affect an outcome (Rouder and Morey 2012).

Analyses were conducted in a manner similar to those reported by Adalio et al. (2018). Bayes factor linear multiple regressions were conducted with the inattention, hyperactivity, and conduct problems scales from the BASC-2 as outcomes. Each model included pre-treatment symptom severity for that domain as a nuisance variable (covariate) and all five cognitive predictors (VSWM, PHWM, inhibitory control, drift rate, boundary separation). Child and parent cognitive function were examined in separate models. For each Bayesian regression, the best-fitting model was selected (criteria: individual main effects or combination of main effects with highest $BF_{10} \geq 3$), with the contribution of individual predictors tested relative to this best-fitting model (Rouder and Morey 2012).

Exploratory analyses were conducted by repeating the analyses above with the addition of child age, parent age, and child medication status as potential covariates. Generally, the pattern of evidence for the alternative hypothesis (BF_{10}) remained the same regardless of whether these covariates were included, but the evidence *against* the alternative hypothesis (BF_{01}) was weaker. For ease of interpretation and because this is the first study to examine both child and parent cognition in relation to behavioral treatment response, we present analyses without age and medication status but report footnotes where inclusion of covariates significantly impacted results.

Results

Preliminary analyses

Treatment led to significant improvements in parent-rated attention problems (BF_{10} = 20.74, d = 0.61), hyper-activity (BF_{10} = 6.86 × 10^5, d = 1.47), conduct problems (BF_{10} = 135.11, d = 0.85), and relational frustration (BF_{10} = 5.29, d = 0.54). Treatment did not significantly impact parents' self-reported parenting confidence (BF_{01} = 2.20, d = 0.17). Correlations between BASC/PRQ scores at pre/post and each parent and child cognitive variable are presented as supplemental online resources (see Supplemental Tables 1–5). The remaining analyses were conducted controlling for pre-treatment scores.

Child cognitive function

Inattention—Stronger VSWM (BF_{10} = 5.44, β = −0.23) and PHWM (BF_{10} = 4.79, β = −0.35) were associated with greater treatment-related reductions in attention problems. There was moderate evidence *against* effects of child inhibitory control (BF_{01} = 3.44, β = −0.10), drift rate (BF_{01} = 3.48, β = 0.17), and boundary separation (BF_{01} = 3.07, β = 0.04) on changes in attention.

Hyperactivity—There was moderate evidence *against* effects of all five child neurocognitive abilities on treatment-related improvements in hyperactivity (BF_{01} = 3.25–5.08).

Conduct problems—There was significant evidence *against* effects of most child neurocognitive abilities on treatment-related changes in conduct problems (BF_{01} = 3.55–4.72) but inconclusive evidence regarding PHWM effects on treatment outcomes (BF_{01} = 2.68).

Parental stress and confidence—Evidence regarding the relation between children's cognitive functioning and parent-reported changes in relational frustration was inconclusive, but leaned toward the absence of an association for all cognitive variables (BF_{01} = 2.46–2.66). Parental confidence followed a similar pattern, such that evidence was inconclusive but leaned toward the absence of an association (BF_{01} = 1.64–2.43).

Parent cognitive function

Inattention—Bayesian evidence provided moderate support that higher parental boundary separation predicted greater treatment-related reductions in inattention (BF_{10} = 4.27, β = −0.43). Contrary to hypotheses, there was significant evidence *against* effects of parental WM on treatment-related changes in child attention (VSWM: BF_{01} = 3.91, β = 0.01; PHWM: BF_{01} = 3.85, β = −0.14). Bayesian evidence regarding inhibitory control (BF_{01} = 2.19, β = −0.20) and drift rate (BF_{01} = 1.71, β = 0.09) were inconclusive.

Hyperactivity—Consistent with the results of child cognitive function and hyperactivity, Bayesian analyses provided significant evidence against effects of PHWM, SSRT, drift rate, and boundary separation (BF_{01} = 3.00–5.46) on child outcomes. Evidence against VSWM was inconclusive (BF_{01} = 1.44).

Conduct problems—The best-fitting Bayesian model provided strong support that the combination of inhibitory control, drift rate, and boundary separation predicted treatment-related reductions in conduct problems, (BF_{10} = 17.34).[2] Specifically, better inhibitory control on the stop-signal task (BF_{10} = 15.32, β = 0.34), and higher boundary separation (i.e., response caution) on the choice RT task (BF_{10} = 17.21, β = −0.66), predicted lower post-treatment conduct problems. Surprisingly, higher drift rate, reflective of faster processing speed, was associated with *less* treatment-related improvement in conduct problems (BF_{10} = 17.18, β = 0.63). Parental WM did not predict post-treatment conduct problems (VSWM: BF_{01} = 3.91, β = 0.01; PHWM: BF_{01} = 4.75, β = 0.14).

Parental stress and confidence—The best-fitting model provided very strong support for the combination of boundary separation and drift rate predicting decreased relational frustration with treatment (BF_{10} = 30.75).[3] Similar to the pattern observed for conduct problems, higher boundary separation predicted greater treatment improvements in parent-reported relational frustration (BF_{10} = 29.77, β = −0.89), but faster drift rate was associated with less change in relational frustration (BF_{10} = 29.77, β = 1.0). Neither working memory (VSWM: BF_{01} = 3.02, β = −0.15; PHWM: BF_{01} = 2.91, β = 0.04) nor inhibitory control (BF_{01} = 3.03, β = 0.21) predicted treatment changes in relational frustration. For parental confidence, the model with the strongest evidentiary support included the combination of PHWM, inhibitory control, drift rate, and boundary separation (BF_{10} = 4.87). However, examination of the relative contribution of individual predictors indicated that the effect was carried primarily by drift rate (BF_{10} = 4.61, β = −0.90) and boundary separation (BF_{10} = 4.64, β = 0.93; PHWM: BF_{10} = 2.43, β = −0.50; inhibitory control: BF_{10} = 1.72, β = −0.40).[4] Evidence regarding VSWM was inconclusive (BF_{01} = 2.62, β = 0.22).

Discussion

Enhancing treatment outcomes for children with ADHD requires identifying moderators that impact treatment effectiveness (Hinshaw 2007; Kraemer et al. 2002). The present pilot study integrated etiologic theories of ADHD (Bark-ley 1997a, b; Castellanos and Tannock 2002; Rapport et al. 2008) and models of parenting behavior (Crandall et al. 2015) to evaluate the extent to which core parent and child cognitive functions central to both domains (working memory, inhibitory control, processing speed) predicted response to ADHD behavioral parent training (BPT).

[2]When child and parent age and child medication status are included as covariates, the best-fitting model includes PHWM, inhibitory control, drift rate, and boundary separation (BF_{10} = 51.08).
[3]When child and parent age and child medication status are included as covariates, the best-fitting model includes VSWM, inhibitory control, drift rate, and boundary separation (BF_{10} = 9.47).
[4]When child and parent age and child medication status are included as covariates, the best-fitting model includes drift rate and boundary separation (BF_{10} = 14.70).

For children, a clear pattern emerged in which better WM predicted greater treatment-related attention improvements. Children with poor WM may benefit less from treatment because they have a harder time maintaining in mind the changing environmental contingencies that occur as a result of BPT. In contrast, there was significant evidence against effects of inhibitory control and processing speed on attention. Our use of Bayesian statistics allowed stronger conclusions by providing significant support for the null (instead of just failing to reject it). To that end, our findings are consistent with prior experimental and longitudinal work linking WM deficits with attention problems in ADHD (Karalunas et al. 2017; Kofler et al. 2010); however, they directly contradict the only other study to date to investigate effects of child neurocognitive abilities on behavioral treatment-related improvements in attention (Adalio et al. 2018), which reported significant effects of processing speed but no significant evidence for effects of WM. This discrepancy likely reflects the large differences in construct measurement between the two studies, as the current study employed laboratory-based tasks and computational modeling to derive construct estimates, whereas Adalio and colleagues measured global processing speed and WM with the construct-insensitive WISC-IV subscales (Canivez et al. 2016; Snyder et al. 2015). They also included two active treatments—a traditional parent training similar to that utilized in the current study, and a multimodal intervention that involved parent, child, and teacher components. This difference may suggest that processing speed is more important for benefitting from non-parenting components of multimodal psychosocial treatment.

For parents, greater levels of response caution (higher boundary separation) predicted greater reduction in child inattention. A similar pattern was found for conduct problems, with stronger parental inhibitory control, higher response caution, and slower information accumulation leading to greater improvement in children’s conduct problems. Parents with higher response caution and slower information accumulation also experienced greater reduction in their level of relational frustration with their child and improved confidence in their parenting abilities. Taken together, this pattern indicates that BPT produces greater benefit when parental self-regulation is stronger, reflected by strong inhibition and response styles emphasizing accuracy over speed. It may reflect that parents with better cognitive self-regulation abilities were better able to learn to withhold reactive, dominant responses to child misbehavior, which would be consistent with the literature showing that reductions in negative parenting behaviors (as opposed to increases in positive parenting) primarily drive treatment-related improvement in child behavior (Chronis-Tuscano et al. 2011). This pattern may also suggest that when child behavior/compliance is unclear in the moment, parents with greater inhibition and response caution may grant extra time to evaluate contextual factors to determine whether children comply, follow instructions, or adhere to rules, which in turn may relate to lower levels of perceived stress and frustration. These hypothesized relations between cognitive function and actual parenting behavior are an important avenue for future research, as the current study was not designed to examine associations between cognitive function and parental behavior.

Limitations

The current open-label pilot study was limited by a small sample size and a lack of follow-up after post-treatment. Due to the timing of parent and child assessments, children experienced a greater gap between cognitive assessment and treatment, which may have contributed to the general lack of association between child cognitive function and treatment outcomes. Completing child and parent assessments in closer temporal proximity in future work will help determine the extent to which results for children's cognitive functioning in the current study were influenced by timing of assessments.

Given our reliance on parent ratings to assess change in child symptoms and parenting stress and confidence, we could not assess which parental behaviors changed throughout treatment. The use of parent ratings, rather than observations of parenting or child behavior, may explain why we found significant evidence *against* parental WM predicting outcomes in any symptom domain,[5] even though WM has been previously linked to parenting behavior (e.g., Deater-Deckard et al. 2010). The lack of an association between cognitive functioning and parental confidence may also be a function of the normative pre-treatment levels of parenting confidence of the sample (i.e., overall, parents remained confident in their parenting while experiencing significantly reduced parenting stress).

Finally, we included several relevant covariates, including child medication status and child and parent age, and demonstrated that results were largely unaffected. It will be important for future studies to consider additional variables that may impact the observed relations, such as caregiver sex, generation status (i.e., grandparent/parent), and caregiver relationship status (Chacko et al. 2009).

Future directions

The current pilot investigation focused on the influence of parent and child cognitive processes in treatment response, as this is an important direction for psychosocial research (Molitor and Langberg 2017). Contemporary parenting models also emphasize emotion regulation in addition to cognitive function (Crandall et al. 2015) because parents must first be able to modulate their own emotional reactions to a situation before implementing adaptive parenting strategies. ADHD-specific parenting work also highlights parent motivational factors (Johnston et al. 2012). Motivational dysfunction in ADHD primarily involves the need for consistent extrinsic reinforcement to motivate behavior and the preference for immediate rewards (Luman et al. 2005). Most parenting involves reinforcement that is delayed (e.g., ignoring a child's crying in the moment to work toward a longer-term goal of extinguishing tantrum behaviors), or inconsistent (a child thanks the parents only infrequently), and involves consequences that may not be particularly rewarding to the parent; this makes many aspects of successful parenting particularly challenging for individuals with ADHD-related motivation difficulties. Moving forward, emotion regulation, motivational processes, and cognition should be examined concurrently in studies of parenting in ADHD to assess their individual and collective impact on parenting behavior and treatment outcome, given their interplay (Deater-Deckard et al. 2010;

[5]Parent working memory was included in the best-fitting model for predicting treatment-related improvements in parenting confidence but failed to provide sufficient evidence as an individual predictor (i.e., its BF_{10} of 2.4 fell below the accepted threshold of 3.0). Similarly, parent working memory improved model fit for predicting treatment-related improvements in child conduct problems and parent relational frustration, but only when demographic covariates were included, suggesting that these findings may not be particularly robust. We thus emphasize findings from our a priori rather than exploratory models, while noting this inconsistency as an important area for future research.

Mazursky-Horowitz et al. 2017). Future work will also need to include parental ADHD symptoms, along with these basic processes, to examine their unique and interactive effects on parent and child behavior.

Finally, it is important to keep in mind that medication was a concurrent intervention for many children in this study. Progress toward the long-term goal of person-centered treatment matching and tailored interventions (e.g., based on cognitive profiles) will require evaluation of which parent and child variables predict response to single treatments (behavior therapy or medication) versus their combination, as well as better understanding treatment mechanisms (Hawk et al. in press).

Conclusion

This open-label pilot study was the first to integrate both parent and child cognitive processes that are central to etiologic theories of ADHD and models of parenting behavior into a treatment outcome study. We provided initial evidence that children's and parents' performance on brief computerized tasks can inform children's symptom improvement in treatment—across methods and across a several month interval. We hope that this initial study demonstrates the feasibility of bridging the translational research gap between basic and applied clinical science and facilitates research on the role of cognitive function in psychosocial interventions.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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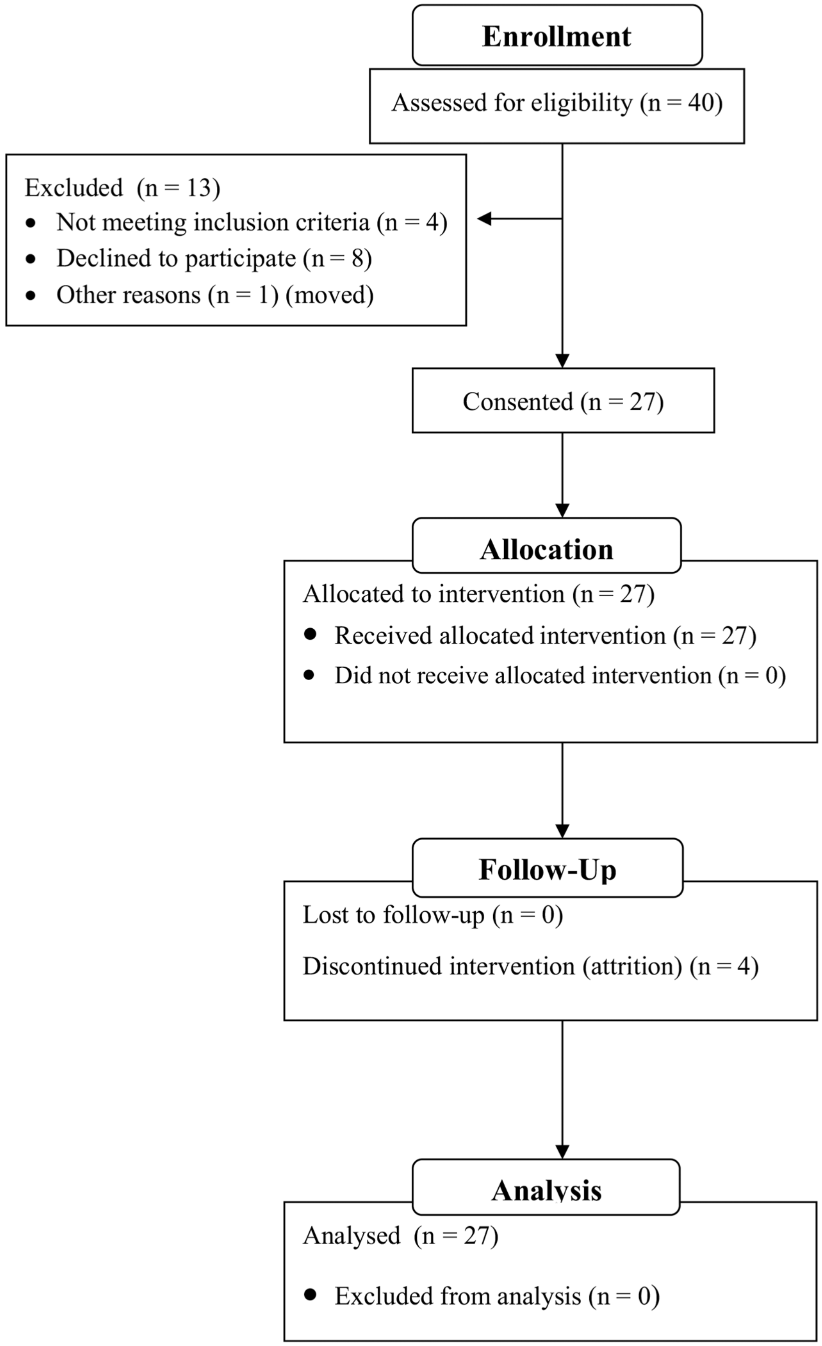

Fig. 1.

Behavioral parent training modified CONSORT diagram (modified to emphasize open-label design)

Table 1

Participant characteristics

	Children	Parents
Age	10.6 (1.5)	45.2 (6.9)
Sex (% male:% female)	63%:37%	15%:85%
IQ		
VCI	109.4 (13.2)	
PRI	111.48 (13.0)	11.8 (1.8)[a]
Ethnicity		
n (%) caucasian, non-hispanic	21 (78%)	
n (%) hispanic	3 (11%)	
n (%) multiracial	3 (11%)	
Baseline measures		
Inattention	67.0 (7.3)	N/A
Hyperactivity	71.7 (13.5)	N/A
Conduct problems	59.6 (13.4)	N/A
Relational frustration	N/A	60.9 (10.2)
Parenting confidence	N/A	43.8 (9.2)

Unless otherwise stated, values represent the mean (*SD*)

VCI verbal comprehension index and *PRI* perceptual reasoning index from the WASI-II. Baseline symptoms (T-scores) were measured with the BASC-2 and baseline relational frustration and parenting confidence were measured with the PRQ

[a]Parents were administered the Matrix Reasoning subscale from the WASI-II. Values represent the standard score

Table 2

Descriptive statistics for parent and child cognitive function

	Children	Parents
VSWM	2.69 (0.79)	3.57 (0.75)
PHWM	3.11 (0.82)	4.19 (0.36)
SSRT	330.74 (78.90)	281.71 (80.43)
SSD	269.10 (58.49)	314.80 (68.20)
Drift rate (*v*)	1.94 (0.93)	4.22 (1.73)
Boundary separation *(a)*	1.78 (1.04)	2.06 (1.27)

Values represent the mean (*SD*)

VSWM visuospatial working memory, *PHWM* phonological working memory, *WM* values are the average number of stimuli correct across trials, *SSRT* stop-signal reaction time, lower values reflect better inhibitory control, *SSD* stop-signal delay, higher values represent stronger inhibitory control