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RESEARCH ARTICLE

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Targeting cognitive control to reduce anxiety in very young children: A proof of concept study

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Abstract

Objective: Underdeveloped cognitive control (CC)—the capacity to flexibly adjust to changing environments—may predispose some children to early onset anxiety disorders and represents a promising intervention target. The current study established and pilot-tested "Camp Kidpower"—a novel group-based, interactive CC training intervention—and assessed its impacts on behavioral and neurophysiological indices of CC among preschool children with elevated anxiety symptoms.

Methods: Forty-four anxious children (4–6 years) were enrolled in Camp Kidpower, delivered in four sessions over 10 days. Before and after camp, children's capacity for CC was measured using well-validated, non-trained behavioral tasks and error-related negativity (ERN). Child anxiety symptoms were measured by parent report on the Spence Preschool Anxiety Scale.

Results: Thirty-two children completed the study, as defined by completion of pre- and follow-up assessments and at least three camp sessions. From baseline to after camp, performance on behavioral tests of CC improved, ERN amplitude increased, and anxiety symptoms decreased.

Conclusion: Results provide initial evidence that play-based cognitive training targeted to behavioral and brain markers of CC reduces anxiety in preschoolers.

KEYWORDS

anxiety, cognitive control, ERN, intervention, preschool

1 | INTRODUCTION

Early childhood anxiety disorders affect up to 20% of preschoolers (Bufferd et al., 2012) and, if not effectively treated, increase risk for persistent anxiety, depression, substance abuse, school drop-out, and even suicide (Beesdo et al., 2007; Bittner et al., 2007). The gold standard treatment for anxiety in children is cognitive-behavioral therapy (CBT), but among the very young, only half of those treated experience remission of clinically significant symptoms (Hirshfeld-Becker et al., 2010; Monga et al., 2015). Novel treatment strategies for early onset anxiety are clearly needed. Thus, building from evidence that deficits of cognitive control (CC) may underlie anxiety at young ages (Fitzgerald et al., 2021), we piloted a play-based, CC training intervention, targeted to behavioral and neural markers of CC, to reduce anxiety in preschoolers.

https://clinicaltrials.gov/ct2/show/NCT03093376; NCT03093376.

Hans S. Schroder and Ka I. Ip contributed equally to this manuscript and are co-first authors.

1.1 | CC as an intervention target

The maturation of CC—the capacity to flexibly and volitionally coordinate behavior—is critical for healthy self-regulation, and takes place throughout childhood and adolescence (Luna et al., 2015). Underdeveloped CC has been linked to the expression of clinical anxiety, with low levels of CC in early childhood, assessed through both parent-report (Kertz et al., 2016) and behavioral measures (Ip, Jester, et al., 2019) found to predict later anxiety, even beyond other psychopathology (e.g., attention deficit hyperactivity disorder, ADHD; Kertz et al., 2016). In theory, low levels of CC may lead to problems coping with difficult emotions and promote avoidance behaviors (Fitzgerald et al., 2021). Indeed, low levels of CC have also been shown to be concurrently related to higher levels of anxiety problems (Han et al., 2016; Hopkins et al., 2013; Kavanaugh et al., 2020; Meyer & Klein, 2018; Muris et al., 2008), although CC-anxiety associations remain understudied in children and some studies have produced negative results (McTeague et al., 2016).

Longitudinal work points to nuanced relationships between childhood temperament, facets of CC, and the development of later anxiety (Henderson et al., 2015). For instance, prior research has shown that early behavioral inhibition—a temperament style characterized by shyness and heightened reactivity to and avoidance of novel situations—predicts later social anxiety. Of particular relevance to the current investigation, this link appears moderated by parent report of greater inhibitory control, but less set-shifting behaviors in real-world situations in 7-year-old children (e.g., Buzzell et al., 2021; Troller-Renfree et al., 2019). There is also evidence that greater behavioral inhibition in early childhood is more likely to predict later anxiety from middle childhood into adolescence in those who rely more on reactive control, whereas higher levels of proactive control may protect against anxiety despite behaviorally inhibited temperament (Valadez et al., 2021). Although connections between specific elements of CC and later development of anxiety are complex, it is quite clear that increasing CC promotes adaptive behaviors in children (Diamond, 2013) and therefore may have relevance for helping children overcome anxiety (Fitzgerald et al., 2021). Yet, whether increasing CC impacts the severity of anxiety in childhood remains largely unexplored.

Indeed, CC training is linked with several positive outcomes in children, including in those with heightened anxiety. In healthy children, it improved performance on non-trained behavioral tests of CC and facilitated better academic outcomes (Diamond, 2011). In children with ADHD, CC training has been found to improve symptoms (Veloso et al., 2020). Preliminary support for CC training as a potential treatment for pediatric anxiety disorders comes from findings that working memory training improved anxiety symptoms and inhibitory control among 11–14 years old (Hadwin & Richards, 2016). However, no study has examined the effects of CC training on anxiety in younger children, when brain-behavioral substrates for CC may be most malleable.

1.2 | Neural correlates of CC and anxiety

CC is instantiated by a neural network comprising dorsal anterior cingulate cortex (dACC) and lateral prefrontal cortex (Niendam et al., 2012). Within this CC network, dACC is widely held to monitor performance, particularly the detection of errors (Luna et al., 2015; Shackman et al., 2011), to heighten CC and optimize performance toward task goals. This dACC-based monitoring process can be observed through the error-related negativity (ERN), a negative deflection in the event-related potential (ERP) that occurs within 100 ms following an erroneous response (Gehring et al., 1993). ERN amplitude has been found to increase with development (Ip, Liu, et al., 2019; Lo, 2018) and is associated with better behavioral performance on CC-demanding tasks, including in young children, suggesting it is linked with CC (Checa et al., 2014; Lawler et al., 2020; Torpey et al., 2012). In adults, anxiety disorders are correlated with greater ERN amplitude (Hajcak, 2012; Moser et al., 2013; see Moser, 2017 for review). Increased ERN has also been documented among older children and adolescents with anxiety and OCD disorders (e.g., Carrasco et al., 2013; Hajcak et al., 2008). However, in very young children (ages 4–6), the relationship is reversed such that higher anxiety correlates with *smaller* ERN (Ip, Liu, et al., 2019; Lo et al., 2016; see also Meyer et al., 2012; but see Meyer et al., 2012). A smaller ERN among anxious children may index underdeveloped CC, leading to reduced capacity for adaptive emotion regulation (Fitzgerald et al., 2021), and is a potentially promising target for CC training. However, no study thus far has examined whether CC training could increase the ERN or reduce anxiety in preschoolers.

1.3 | The current study

Leveraging the experimental therapeutics approach (Insel, 2015), we tested a novel, neurally targeted cognitive training intervention to increase CC and reduce anxiety in preschoolers in this proof-of-concept study. Camp Kidpower incorporated short game-like exercises targeting multiple elements of CC (selective attention, inhibitory control, working memory, and set shifting) and included titration of game difficulty, physical activity, and social bonding to optimize the likelihood that CC training effects would transfer to non-trained behaviors (Diamond & Lee, 2011). We hypothesized that, after the intervention, anxious preschoolers would exhibit improved performance on CC-demanding behavioral tasks, increased ERN, and decreased anxiety.

2 | METHODS

2.1 | Participants

Forty-four 4- to 6-year-old children (25 females; Mean = 5.50 ± 0.85, range = 4.00–6.99) were recruited from clinical settings and the

community. Eligible children had (a) heightened anxiety (i.e. *t*-scores ≥ 60 on the DSM-oriented anxiety subscale of the Child Behavior Checklist (CBCL 6-18 or CBCL 1.5-5; Achenbach & Rescorla, 2001) or parental concern about child anxiety interfering with daily function, (b) no major medical or neurological problems, (c) no history of head injuries, (d) no use of medications that affect the central nervous system, (e) no history of aggression toward peers, and (f) no previous diagnosis and/or expressed concerns for neurodevelopmental delay, autism spectrum disorder, or intellectual disability.

Parents reported on their child's anxiety symptoms using the Spence Preschool Anxiety Scale (PAS; Spence et al., 2001). Average pre-camp PAS scores were 62.93 ± 12.10 (range = 41.00–87.00), indicating heightened anxiety severity (Spence et al., 2001). Parents also completed the age-specific CBCL (Achenbach & Rescorla, 2001), the Social Communication Questionnaire (SCQ; Rutter et al., 2003), and the Behavioral Inhibition Questionnaire (BIQ; Bishop et al., 2003). Sample characteristics are reported in Table 1. Of the 44 enrolled, 32 were considered study completers, defined as attendance for at least 3 days of the 4-day camp (considered the minimal sufficient "dose") and participation in both pre-camp and follow-up assessments (Figure 1). This sample consisted of 18 females; M_{age} = 5.66 ± 0.73 years, range = 4.25–6.99; 68.8% Caucasian, 12.5% African American, 2% Asian, and 6.3% Multiracial children; 46.9% with household income above $75,000, 37.5% between $25,000 and $75,000, and 5.6% less than $25,000. Compared to study completers, excluded children were marginally younger (p = .09), but with no difference in other demographic characteristics, pre-intervention ERN, behavioral measures of CC, PAS anxiety scores, or other symptom measures during initial assessment (see Table 1).

2.2 | Procedure overview

Parents and children provided informed consent and verbal assent, respectively. Parents completed questionnaires while children completed behavioral and EEG tasks. Several weeks after baseline assessment (17.35 ± 13.49 days), children began Camp Kidpower. A follow-up behavioral and EEG assessment visit occurred ~4–6 weeks after the last day of camp (32.53 ± 17.04 days, Min. = 1, Max. = 77). None of the CC behavioral tasks used during baseline and follow-up assessments were taught during the intervention, thus enabling the measurement of CC skill transfer to non-trained tasks. We considered children to have completed the camp if they attended at least 3 out of the 4 days of camp (75% of the intervention).

2.3 | Intervention: Camp Kidpower

The group intervention was styled as an interactive, child-friendly camp delivered as four half-day sessions over 10 days. During each camp, camp counselors (graduate students in clinical psychology and social work and trained research staff) taught 12 game-like exercises to small groups of children (3–6 children/camp). Games were designed to enhance CC skills (see Supporting Information: Table S1) and were adapted from prior work (Halperin et al., 2013). Counselor-to-child ratio was approximately 1:1, allowing for child-specific supervision, encouragement, and coaching. Each session began with a 30-min warm-up period including parents, children, and counselors.

After separation from parents, children learned and practiced games tapping different elements of CC, including inhibitory control (e.g., "Red

TABLE 1 Sample characteristics of participants who did and did not complete the full study

Measures	Study completers (n = 32) Mean ± SD (min–max)	Study non-completers (n = 12) Mean ± SD (min–max)	Study completers versus non-completers Statistical test
Gender	18F (56%)	7F (58%)	X^2 = .015, df = 1, p = 1.00
Age	5.66 ± 0.73 (4.25–6.99)	5.08 ± 1.02 (4.00–6.75)	t(15.44) = 1.81, p = .09
Spence PAS total T	62.69 ± 10.90 (41.00–87.00)	63.64 ± 15.69 (44.00–85.00)	t(13.47) = 0.19, p = .86
CBCL anxiety DSM-5 subscale	67.50 ± 9.14 (50.00–90.00)	62.45 ± 9.73 (50.00–76.00)	t(41) = 1.56, p = .13
CBCL depression DSM-5 subscale	60.38 ± 8.53 (50.00–79.00)	60.73 ± 11.18 (50.00–82.00)	t(41) = 0.11, p = .91
CBCL ADHD DSM-5 subscale	55.56 ± 5.66 (50.00–73.00)	56.00 ± 6.72 (50.00–71.00)	t(41) = 0.21, p = .83
CBCL Oppositional-defiant DSM-5 subscale	58.00 ± 7.15 (50.00–73.00)	58.64 ± 9.25 (50.00–73.00)	t(41) = 0.24, p = .82
SCQ total	4.91 ± 3.80 (1.00–14.00)	7.18 ± 4.09 (0.00–14.00)	t(41) = 1.68, p = .10
BIQ total	112.50 ± 31.82 (41.00–179.00)	106.91 ± 32.06 (51.00–156.00)	t(41) = 0.50, p = .62

Note: Of the 32 camp completers, behavioral data were successfully acquired in 31 and ERN data in 22 children at pre- and post-intervention time points. Of the 12 participants without usable ERN data, 8 attended fewer than 3 days of intervention (camp completers) and 4 completed camp but did not return for a post-assessment visit. There were no differences in demographic or clinical characteristics between completers with usable pre- and post-intervention ERN data (n = 22) and those without (n = 10), ps > .12. PAS = Preschool Anxiety Scale; CBCL = Child Behavioral Checklist, SCQ = Social Communication Questionnaire; BIQ = Behavioral Inhibition Questionnaire. Note that for Age and Spence PAS scores, the Levene's Test for equality of variances was significant, so we report corrected degrees of freedom.

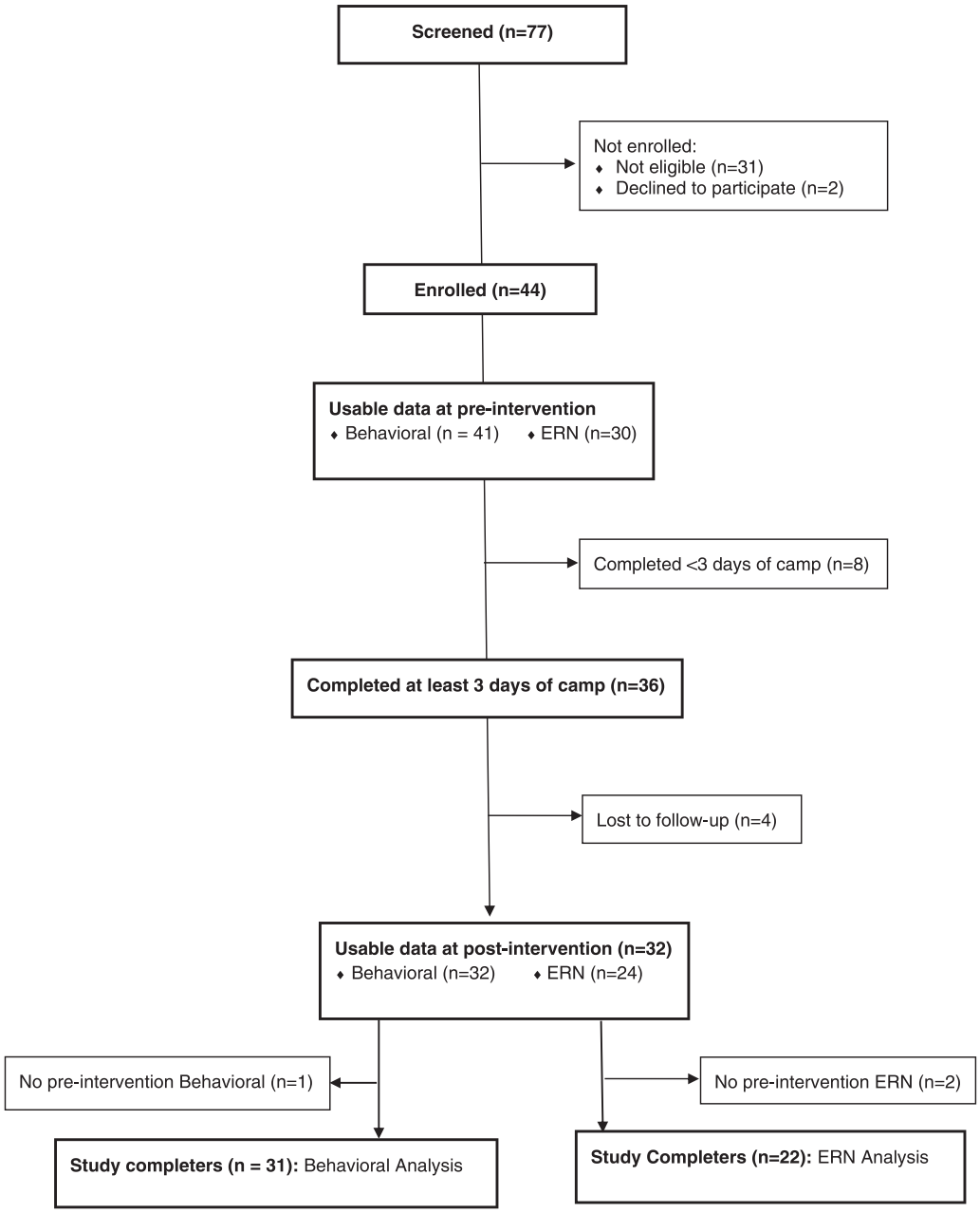


FIGURE 1 Kidpower CONSORT diagram

Light/Green Light"), attention control (e.g., "Track It"), working memory (e.g., "Copy Me"), fine motor, and visuospatial skills (e.g., "Block Building"). Each game was designed to be progressively more challenging. Difficulty level was calibrated based on performance to allow children to build success and learn from their mistakes. The final 30 min of each session included a parent–child interaction period where children taught parents (with counselor supervision) games that they had learned. Families were encouraged to play the games at home.

Throughout the camp, children engaged in one-on-one reflection training in which their camp counselor asked them to reflect on the rules and how to adapt behavior to succeed in the games. In addition, children were invited to "group-think" strategies to help one another get better at the games. This approach was adapted from prior work showing that reflection can improve CC training outcomes (Espinet et al., 2013). Children were also incentivized with "Power Stars," earned collectively by participation in games and group reflection, and redeemable for a group prize (e.g., group parachute activity and individual bubbles container) to be enjoyed at the end of each session.

2.4 | Behavioral capacity for CC

2.4.1 | Dinky Toys task

Children are asked to view a plastic box filled with toys and tell the experimenter which toy he or she wants while holding their hands

immobile in their lap for up to 2 min (Kochanska et al.,1996). Scores for the Dinky Toys task range from 0 (hands never left lap) to 5 (grabbed toy(s)), with lower scores reflecting greater inhibitory control. The Dinky Toys task was administered three times at each visit (pre-visit and follow-up), and scores were averaged to compute a total score. We computed internal reliability of the Dinky toys by treating each administration as an "item" and computed Cronbach's alpha, which indicated acceptable reliability (pre-camp $\alpha = .67$, follow-up $\alpha = .80$).

2.4.2 | Head-Toes-Knees-Shoulders

Children are given prompts such as "touch your head" and, depending on instruction context, must either follow the command or substitute a different body part (e.g., shoulder instead of head) (McClelland et al., 2014). The Head-Toes-Knees-Shoulders (HTKS) includes 20 trials, each scored as 0 = incorrect response, 1 = self-corrected error, or 2 = correct response. Total HTKS scores were calculated by averaging all trials together, with higher scores reflecting greater inhibitory control, working memory, and attentional focusing. Reliability was computed by treating each trial as an item and alpha coefficients indicated satisfactory reliability (pre-camp $\alpha = .90$, follow-up $\alpha = .84$).

2.4.3 | Dimensional Change Card Sort

The Dimensional Change Card Sort (DCCS) is a measure of cognitive flexibility, implemented using the NIH toolbox paradigm via iPad (Zelazo et al., 2013). Age-corrected standardized scores are calculated using the toolbox, such that higher scores reflect greater flexibility. Item-level data were unavailable as we used the toolbox to score the DCCS, but prior research has found this to be reliable (see Zelazo et al., 2013).

2.4.4 | Flanker Inhibitory Control and Attention task

The NIH toolbox flanker task—also administered on an iPad—instructs children to respond to a target (fish or arrow) stimulus in an array of fish/arrows that are either facing the same direction (congruent) or in the opposite direction as the central target (incongruent) (Zelazo et al., 2013). Item-level data were unavailable as we used the toolbox software to score the flanker task (see Zelazo et al., 2013).

2.4.5 | Zoo task

The Zoo task is a go/no-go paradigm used to elicit the ERN (see below) (Grammer et al., 2014). For the behavioral assessment, we computed the number of false alarms, number of correct hits, and average response time on Go (hit) trials (split-half reliability with Spearman–Brown correction: .97 at pre, .94 at post).

2.5 | The ERN

Continuous electroencephalogram (EEG) data were collected during the Zoo task (Grammer et al., 2014). Children were asked to put loose animals back in their cages by pressing a button every time an animal picture was presented (Go Trials), but to withhold their response each time they saw an orangutan (No-go trials). Accuracy and speed were equally emphasized.

EEG was recorded from 16 Ag/AgCl scalp electrodes and two mastoid electrodes, using the BioSemi ActiveTwo recording system. Electro-oculogram (EOG) data were recorded from electrodes placed above and below the right eye and at the outer canthi of both eyes to capture vertical EOG and horizontal EOG, respectively. Data were referenced to a ground formed from a common mode sense active electrode and driven right leg passive electrode (see http://www.biosemi.com/faq/cms%26drl) and sampled at 1024 Hz. For analysis, EEG data were referenced to averaged mastoid electrodes, and band-pass filtered 0.1–30 Hz using zero-phase shift Butterworth filters. EEG data were screened using automated algorithms that rejected epochs in which the absolute voltage range exceeded 500 μV for midline channels (Fz, FCz, and Cz), consistent with prior work (Grammer et al., 2014). Ocular movement artifacts were then corrected using a regression-based algorithm (Gratton et al., 1983). After ocular correction, individual trials were rejected if any amplitudes were greater than 150 μV, differed by more than 50 μV from the previous time point, or were less than 0.5 μV in magnitude in any midline electrode.

The ERN was defined as the average ERP amplitude in the 0–50 ms post-response window on false alarm trials; the correct-response negativity (CRN) was defined in the same window on correct Go trials. Response-locked data were baseline-corrected using a pre-response baseline of −200 to −100 ms (Grammer et al., 2014). ERN amplitude was measured at electrode sites Fz, FCz, and Cz. Trial counts and reliability information for ERPs are listed in Supporting Information: Table S2. Although previous recommendations suggest at least six trials are needed for reliable ERN (Pontifex et al., 2010), one child had five usable error trials in their post-assessment. However, excluding this participant from analyses did not change any results, so their data were included to increase statistical power. The number of usable ERP trials did not differ between pre- and post-camp visits for either ERN ($t(21) = 1.62$, $p = .12$) or the CRN ($t(21) = 0.83$, $p = .42$).

2.6 | Child anxiety

Child anxiety symptoms were measured by parent report on the Spence PAS (Spence et al., 2001); $\alpha_{pre} = .88$ and $\alpha_{post} = .84$), a

validated 28-item questionnaire for the assessment of anxiety symptoms in 2.5–6.5 years old. Higher scores indicate higher levels of child anxiety.

2.7 | Analytical plan

Paired-samples *t*-tests were used to assess pre- to post-intervention changes in the behavioral measures of CC. Changes in ERN amplitude were assessed with a 2 Time (pre- vs. post-intervention) × 3 Site (Fz, FCz, Cz) × 2 Trial type (Error vs. Correct) ANOVA. The Supporting Information presents analyses using multilevel modeling to control for variation in measurement timing, specific camp attended, and missing data in the intent-to-treat sample (not presented here for space constraints). Notably, these analyses replicate the results reported here. Paired-sample *t*-tests were used to assess change in anxiety symptom scores on the Spence PAS. Finally, Pearson correlations were computed to assess relations between change scores (post minus pre); given the number of variables, a more conservative cutoff of $p < .01$ was used.

3 | RESULTS

3.1 | Increased behavioral capacity for CC

Results of the behavioral tasks are presented in Table 2. Significant improvements in performance from pre-camp to follow-up were apparent on the Dinky Toys task and the HTKS. Improvement on the DCCS approached significance ($p = .059$). Responses were significantly faster after camp on the Zoo task, but there were no differences in accuracy (number of false alarms or correct hits). As ERN is sensitive to the number of errors (Torpey et al., 2012), this finding indicates that any differences detected in ERN amplitude (reported below) cannot be due to differences in accuracy across the pre- and post-camp visits. Thus, in line with hypotheses, behavioral performance improved on several CC-demanding tasks.

3.2 | Increased error-related negativity

Figure 2 presents response-locked ERP waveforms, and Table 3 displays average amplitudes for ERN, CRN, and the difference ERN. A 2 Time (Pre- vs. Post-Camp) × 3 Site (Fz, FCz, Cz) × 2 Trial Type (Error vs. Correct) ANOVA revealed a significant main effect of Trial Type ($F(1, 21) = 131.55$, $p < .001$, $\eta^2_p = .86$), consistent with a robust ERN effect (ERN was more negative than CRN at all sites) in the 0–50 ms post-response time window. A Site × Trial Type interaction ($F(2, 42) = 8.41$, $p = .004$, $\eta^2_p = .29$) indicated the difference in amplitude between error and correct was larger at Cz and FCz compared to Fz. There was also a significant main effect of Time ($F(1, 21) = 11.15$, $p = .003$, $\eta^2_p = .35$) which indicated that post-response amplitudes (ERN, CRN) increased from pre- to post-camp. Most importantly, there was a significant Time × Site × Trial Type interaction ($F(2, 42) = 6.91$, $p = .007$, $\eta^2_p = .25$). Decomposition of this interaction revealed that the ERN difference (ERN minus CRN) was significantly increased from Pre- to Post-Camp at Cz ($p = .029$) and marginally so at FCz ($p = .051$), but not at Fz ($p = .75$). Thus, in line with hypotheses, the ERN was significantly increased after the camp and, further, this increase was most pronounced at Cz.

Given the lack of a waitlist control group, we cannot rule out that the increase in ERN amplitude was due to natural developmental maturation (Lo, 2018). To address this, we computed estimated ERN amplitudes based on a recent developmental meta-analysis (see Supporting Information) and found that the follow-up ERN was significantly larger than the developmentally estimated ERN amplitude at FCz ($t(21) = 3.45$, $p = .002$, $d = .74$) and Cz ($t(21) = 3.00$, $p = .007$, $d = .64$), but not at Fz ($t(21) = 1.39$, $p = .18$, $d = .30$). Additional correlations between ERN and CC measures from pre-visit to follow-up are presented in Supporting Information: Table S3.

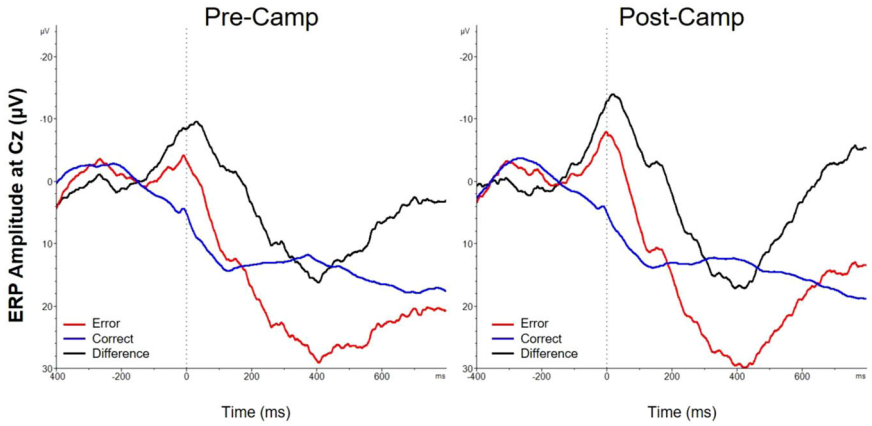
TABLE 2 Behavioral indicators of cognitive control before and after Camp Kidpower

		Pre-camp		Follow-up		Statistical analysis			
Measure name	*N*	*M*	*SD*	*M*	*SD*	*t*	*df*	*p*	*d*
Dinky Toys*	28	3.44	1.08	3.87	1.11	2.14	27	.042	.39
HTKS**	31	1.08	0.50	1.33	0.47	3.75	30	.001	.51
DCCS	31	99.84	10.69	103.52	11.56	1.96	30	.059	.33
Flanker	30	101.20	10.55	101.83	9.41	0.29	29	.77	.06
# Go Correct	24	223.58	15.07	216.00	34.54	1.16	23	.26	.28
Go RT (ms)**	24	580.51	70.32	537.81	61.52	4.04	23	.001	.65
# NoGo errors	24	27.58	13.11	23.46	10.44	1.55	23	.14	.35

Note: Values for *t* and *d* are absolute values.

Abbreviations: DCCS, Dimensional Change Card Sort; HTKS, Head-Toes-Knees-Shoulders task.

*$p < .05$.; **$p < .01$.



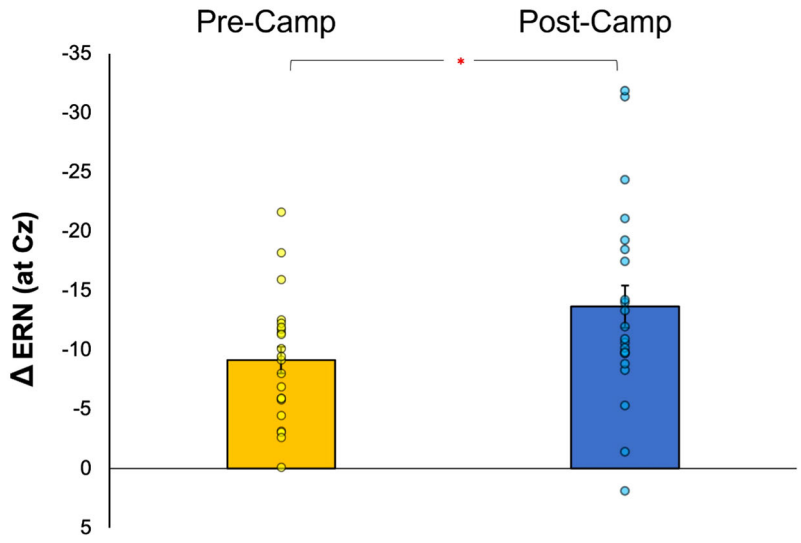


FIGURE 2 Top panel: Grand average response-locked ERP waveforms ($N = 22$) at electrode Cz from before camp (left panel) and after camp (right panel). Negative amplitude on the *y*-axis is plotted up and dashed vertical line at Time 0 signifies response onset. Bottom panel: Bar graphs (error bars are ±1 SEM) depicting the ΔERN change from pre- to post-camp at channel Cz. Each data point represents an individual participant. ERN, error-related negativity; ERP, event-related potential.

TABLE 3 Event-related potential results

Measure	Pre-camp		Post-camp	
	M	*SD*	*M*	*SD*
ERN				
Fz	−3.26	5.98	−5.56	7.65
FCz	−2.29	6.03	−7.85	8.86
Cz	−1.07	5.99	−6.53	9.60
CRN				
Fz	6.06	4.83	4.39	5.25
FCz	8.45	5.85	6.92	5.79
Cz	8.09	6.80	7.14	5.74
ΔERN				
Fz	−9.32	5.91	−9.95	6.92
FCz	−10.74	5.74	−14.77	7.92
Cz	−9.16	5.30	−13.66	8.38

Note: All values presented in microvolts, μV. All amplitudes are calculated as the average voltage within the 0–50 ms post-response time window.

Abbreviations: CRN, correct-response negativity; ERN, error-related negativity; ΔERN, ERN minus CRN.

3.3 | Decreased anxiety symptoms

Consistent with our hypothesis, children's anxiety, as indexed by the PAS *T*-score, decreased significantly from pre- ($M = 64.05$, $SD = 11.19$) to post-intervention ($M = 59.14$, $SD = 11.80$, $t(21) = 3.08$, $p = .006$, $d = .66$). Again, because we do not have a control group, attenuation of scores due to time cannot be completely ruled out. However, this effect size is notably larger than a previous test–retest estimate of interview-based parent-reported anxiety changes across an average period of 11 days ($d = .12$; Egger et al., 2006).

3.4 | Correlations

Correlations of change variables are presented in Table 4. None of the hypothesized correlations were significant at the $p < .01$ level, although change in ERN at Cz and change in anxiety symptoms were in the hypothesized direction ($r = -.30$, $p = .18$), such that larger increase in ERN correlated with fewer anxiety symptoms. Moreover, there were medium-sized correlations between ERN change and change in Dinky scores (none reached statistical significance) that were consistent with a larger ERN correlating with better inhibitory control.

TABLE 4 Correlations of change in CC measures, ERN, and anxiety symptoms

	1.	2.	3.	4.	5.	6.	7.
1. Change in DCCS	–						
2. Change in flanker	.03	–					
3. Change in Dinky Toys	−.11	.21	–				
4. Change in HTKS	.005	.001	.29	–			
5. Change in ΔERN at Fz	.25	−.18	−.49	−.13	–		
6. Change in ΔERN at FCz	.20	−.16	−.42	.08	.86**	–	
7. Change in ΔERN at Cz	.21	−.13	−.37	.04	.72**	.90**	–
8. Change in anxiety	.007	.07	−.18	.02	−.06	−.15	−.30

Note: Anxiety measured with Spence Preschool Anxiety Scale(Spence et al., 2001). All change variables calculated as follow-up minus pre. *$p < .01$.

Abbreviations: CC, cognitive control; DCCS, Dimensional Change Card Sort; ΔERN, Difference wave error-related negativity (ERN minus CRN); HTKS, Head Toes Knee Shoulders Task.

**$p < .001$.

4 | DISCUSSION

This pilot, proof-of-concept study tested a novel CC intervention among preschool children with elevated anxiety symptoms. The intervention was styled as a child-friendly camp during which several facets of CC were trained through exposure to progressively more difficult games requiring flexibility, self-monitoring, and inhibitory control. At the follow-up visit, behavioral markers of CC were improved, the ERN was increased, and anxiety symptoms were decreased.

4.1 | Impact on behavior

Several indicators of CC significantly improved after CC training in our sample of young, anxious preschoolers. Improved performance on the Dinky Toys and HTKS tests of inhibitory control suggest that cognitive training delivered during camp improved CC function on non-trained tasks. On the Zoo task, RTs were significantly faster, whereas accuracy rates remained consistent across the two time points. Faster RT in the presence of maintained accuracy is indicative of improved performance *efficiency*—a cognitive deficit of anxiety (Eysenck et al., 2007).

4.2 | Increased ERN

Based on the relationship of smaller ERN with greater anxiety at young ages (Ip, Liu, et al., 2019; Lo et al., 2016; Meyer et al., 2012), an increase in ERN in young anxious preschoolers supports the notion that training to increase CC may help to reduce anxiety in early life (Fitzgerald et al., 2021). Moreover, given developmental increases in ERN amplitude with the maturation of CC performance in healthy children (Lo, 2018; Tamnes et al., 2013), it is possible that training facilitated the maturation of CC neural substrates. In contrast, studies employing standard treatments (CBT or SSRI) find no ERN differences before vs after treatment (Kujawa et al., 2016; Ladouceur et al., 2018; Riesel et al., 2015). Thus, it is likely that interventions designed to modulate ERN (and, hence anxiety) must be targeted to underlying neurocognitive mechanisms, rather than interventions that exclusively target symptoms. This hypothesis is supported by recent work with targeted cognitive training interventions in older youth and adults that find the ERN can be modulated (Klawohn et al., 2020; Meyer et al., 2020; Nelson et al., 2017).

The likelihood that ERN increase after camp reflects the increased engagement of neural mechanisms for CC is strengthened by three rule-outs. First, it is unlikely that development alone could explain findings, as our developmentally informed analysis of estimated ERNs found post-camp ERNs to be larger than would be expected from development. Second, increased ERN could not be explained by fewer number of errors in post-camp assessment, as error rates in the Zoo game did not differ between pre- and post-camp. Third, practice effects are unlikely to fully explain ERN results, given that only minor deviations in ERN amplitude have been observed in children tested several weeks apart (Lin et al., 2020).

4.3 | Impact on anxiety symptoms

Children's anxiety symptoms also decreased after the intervention, a result with several explanations. We hypothesized that increased CC—indexed by improved performance on non-trained behavioral tests and the ERN—may help children resolve interference between feared and and more contextually realistic outcomes, identify fears "thinking errors," and resist avoidance behaviors (Fitzgerald et al., 2021). Contrary to prediction, changes in behavioral markers and ERN were not correlated with changes in anxiety symptoms, although there was some evidence that ERN non-significantly correlated with behavioral markers and anxiety in the predicted direction. It is possible that these mechanisms operate in parallel, or that improved CC "sets the stage" for a wider behavioral repertoire for dealing with anxiety, that might then lead to reduced anxiety. It is also possible that aspects of camp (e.g., separation from parents, social contact with other children) functioned as an exposure. Alternatively, some combination of the cognitive training delivered during camp along with the natural exposures that occurred may have led to anxiety reduction. A change in the cognitive process underlying the ERN may represent a unique "hotspot" for introducing exposure-based CBT which, in theory, requires CC for patients to engage with feared stimuli. To be clear, relations between ERN, CC, and anxiety are complex, potentially dependent upon childhood temperament, and likely change across

time (e.g., Henderson et al., 2015). Future studies with larger samples, multiple follow-up assessments, and control groups (e.g., a playgroup without CC training) will be needed to parse the nuanced relations between ERN, CC, and anxiety across time.

5 | LIMITATIONS AND CONCLUSION

Primary limitations of this study are small sample size and lack of control group. Small sample sizes may have reduced statistical power to detect effects. Without a control group, we cannot rule out the role of development, practice effects, or exposure on pre-to-post-camp differences in ERN, anxiety, or behavior. However, our supplemental analyses suggest follow-up ERNs were still larger than what would have been expected developmentally. Another caveat is that ERN amplitudes exhibited low internal reliability in the pre-camp visit, which can increase Type II error and mask significant findings. Camps were conducted throughout the school year, although our small sample size precluded statistical evaluation of seasonal effects; future studies with larger samples would benefit from examining the effects of timing of the intervention. Finally, the consent page indicated the camp was designed to reduce anxiety, so there is potential for demand characteristics for parents to rate lower anxiety at the follow-up visit. Despite these important limitations, the current findings point to promising targets for future interventions aimed at improving CC capacity to help mitigate anxiety in young children.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data are available upon reasonable request to the last author.

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SUPPORTING INFORMATION

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

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