

Conducting EEG research in clinically anxious preschoolers: A pilot study and preliminary recommendations

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Abstract

Electroencephalography (EEG) data collection can be challenging in preschoolers with anxiety who are often debilitated by fear of the unknown. Thus, we iteratively refined techniques for EEG collection in three cohorts of children with anxiety enrolled in our study of a novel intervention. Techniques involved directing child attention away from the EEG setup (Cohort 1, $N = 18$), open discussion of equipment and processes during setup (Cohort 2, $N = 21$), and a preparatory EEG-exposure session prior to data collection (Cohort 3, $N = 6$). Children ($N = 45$, 4–7 years) attempted a Time 1 EEG before intervention, and those who completed intervention ($N = 28$) were invited to a Time 2 EEG. The percentages who provided analyzable EEGs were assessed by cohort. Cohort 3 provided more Time 1 EEGs (83.3%) than Cohorts 1 or 2 (66.7% each), suggesting that the preparatory session supported first-time EEG collection. More children provided Time 2 EEG data across successive cohorts (Cohort 1: 66.7%, Cohort 2: 82%, Cohort 3: 100%), suggesting that more open communication facilitated repeat EEG collection. Ultimately, increased EEG exposure and child-friendly communication about procedures improved data acquisition in this sample of clinically anxious preschoolers. Detailed study procedures are shared to support future EEG research in young children with anxiety.

KEYWORDS

anxiety, children, EEG techniques, ERN, preschoolers

1 | INTRODUCTION

To pave the way toward objective diagnostic tests and novel interventions for early life anxiety, better understanding of the underlying neurobiological systems is needed (Casey et al., 2014; Cuthbert, 2014). However, neuroimaging techniques often are difficult to conduct in young children, particularly those who exhibit symptoms of anxiety (e.g., avoidance of novel stimuli, heightened sensitivity to perceived threat, fearing the unknown) (Grupe & Nitschke, 2013; Williams et al., 2015). Such challenges are evidenced by various experimenters seeing low electroencephalography (EEG) data acquisition rates related to

anxiety symptoms. Canen and Brooker (2017) collected data from only 60.2% of their preschool sample of children across spectrum of risk for anxiety problems. Brooker et al. (2011) acquired analyzable data from only 45.5% of their community sample of young children (age 4–8 years), noting that the excluded children exhibited significantly more shyness and poorer effortful control (i.e., a risk factor for pediatric anxiety; Hopkins et al., 2013), and they often refused EEG data collection altogether. Notably, in other community samples, such low rates of data collection have not been reported (e.g., 94.4% [Torpey et al., 2009]; 95.7% [Lo et al., 2017]; 87.5% [Ip et al., 2019]), which may suggest an ability for less anxious youth to better tolerate EEG procedures.

1.1 | Purpose of the present study

With consideration of these challenges and other practical and ethical concerns, this paper summarizes our experience with EEG data collection in young children with anxiety. These strategies were developed through the collaboration of a child psychiatrist with expertise in childhood anxiety disorders (KDF), event-related potential (ERP) experts with experience testing young children (JSM, YL), a clinical developmental psychologist specializing in early childhood development (KR), and an occupational therapist with over 20 years of practice with anxious preschoolers (RS).

The initial protocol was designed primarily from experimenters' prior EEG collection in a community sample of children age 4–9 years old (Ip et al., 2019; Lo et al., 2017), where the protocol attempted to minimize child awareness of unfamiliar (and potentially threatening) EEG materials and to focus their attention toward more engaging activities (e.g., talking about the stuffed monkey who lived in the EEG room, playing games). In addition, many widely utilized practices were implemented into the initial protocol design, including prolonged experimenter training, themed room and equipment decoration, children–experimenter conversation about child-friendly topics during EEG hookup, limitation of number of EEG electrodes, EEG task-practice immediately prior to data collection, and rewards for participation in EEG tasks through verbal praise and prizes (Brooker et al., 2020; Kyllianen et al., 2014). However, as the study progressed, experimenters noted that preschoolers with clinical anxiety were not as amenable to techniques developed for the older and less anxious participants in prior work. In fact, attempts to direct child focus away from EEG setup procedures through conversation and/or watching a favorite movie felt forced and often seemed to increase anxiety and cap refusal.

Thus, the study team worked to improve EEG data collection in three successive cohorts of anxious preschoolers over several years of data collection. Utilizing principles from previous research in children with other forms of psychopathology in addition to exposure-based and occupational therapies for young children with anxiety, the EEG protocol was adapted to incorporate more direct explanation of the EEG procedures and ultimately to include a preparatory visit. First, many modifications were adopted from Kylläinen et al. (2014), who explained the value of desensitizing EEG materials for successful data collection in their sample of children with autism spectrum disorder (e.g., suggesting an additional visit for practicing setup, feeling materials, and establishing familiarity with the lab). Additionally, we incorporated well-known exposure techniques to prepare anxious children for EEG data collection, while recognizing that traditional exposure therapy can take significant time to reduce anxiety toward any given stimuli and that young children may be resistant to this approach (Bouchard et al., 2004). Thus, the study's multidisciplinary team worked collectively to brainstorm new techniques. In particular, the contribution of an occupational therapist (RS) was critical for developing play-based strategies that could be efficiently delivered to reduce sensory-related anxiety related to the unfamiliar sights, sounds, and touch of EEG study participation.

Preliminary data showing the outcome of the three versions of the protocol in three separate cohorts of children are presented. Detailed description of techniques related to EEG lab personnel, equipment, setting, and EEG application is shared to serve as information to help other laboratories seeking to collect EEG data in children with anxiety.

2 | METHOD

2.1 | Study overview

Success rates for analyzable EEG data collection in children with subclinical-to-clinical anxiety, ages 4–7 years, are presented in the context of a novel cognitive control training intervention, a play-based cognitive training intervention, Camp Kidpower (hereafter referred to as “camp”), designed to reduce early childhood anxiety. EEG data collection was attempted at two time points, before and after camp, with nine total camps held over approximately 2.5 years. EEG protocol modifications occurred twice, after the fourth and eighth camp, yielding three cohorts of participants who experienced three different EEG data collection protocols, that is, Cohort 1 (camps 1–4), Cohort 2 (camps 5–8), and Cohort 3 (camp 9). Between-cohort differences in EEG data collection techniques are detailed below and in Table 1, whereas study procedures that were held constant across the cohorts are summarized in the Supporting Information. The research was conducted with U-M Institutional Review Board (IRB) approval and was designated as no more than minimal risk.

2.2 | Participants

Participants were recruited from the UM Psychiatry Child OCD & Anxiety Disorders Clinic, UM Early Childhood Clinic, and community advertising (e.g., fliers). Child participants were selected for high levels of anxiety by telephone prescreening via parent report on the DSM Anxiety subscale of the Child Behavior Checklist (CBCL/6–18 or CBCL/1.5–5; Achenbach & Rescorla, 2001); *t*-scores of 60 or greater were required for inclusion. Children with major medical or neurological problems, previous diagnosis and/or expressed concern for autism spectrum disorder, and those with a history of aggression toward peers were excluded. Participants recruited included 18 children in Cohort 1, 21 children in Cohort 2, and six children in Cohort 3 (Intent-to-treat [ITT] sample). Child race was reported as 73% “White or Caucasian,” 13% “Black or African American,” 7% “Multiracial,” and 4% “Asian,” and ethnicity was reported as 91% “Not Hispanic or Latino” and 7% “Hispanic or Latino” (noting race/ethnicity data were not completed for one child).

Parents completed the age-specific Child Behavior Checklist (Achenbach & Rescorla, 2001), Spence Preschool Anxiety Scale (PAS; Spence et al., 2001), Social Communication (SCQ; Rutter et al., 2003), and Behavioral Inhibition Questionnaires (BIQ; Bishop et al., 2003). Of note, child Spence PAS scores were 63.25 ± 12.15 (41–87), indicating anxiety severity in the clinical range (Spence et al., 2001). Parents

TABLE 1 Original and improved techniques for EEG data collection in clinically anxious preschoolers

Study phase	Original (Camp 1–4)	Initial modifications (Camp 5–8)	Later modifications (Camp 9)
Previsit contact (parent only)	Phone call: (1) Describe & schedule study	Phone call: (1) Describe, schedule study (2) Seek parent input on child personality, best interactional techniques Email: (1) Follow-up parent email to detail EEG visit (2) FAQ sheet attached to email (3) Email and/or telephone questions encouraged	Email: (1) Follow-up parent email to detail of EEG visit (2) FAQ sheet, social story, and video introducing lab personnel, space and EEG equipment (3) Email and/or telephone questions encouraged
EEG assent	(1) Assent script read (2) Child free-play with experimenters while parent consented	(1) EEG social story shared by child and experimenter at visit (2) Assent script discussed with child in context of social story, while parent consented	(1) EEG social story and video viewed ahead of visit by child and parent (2) EEG social story reread by child and parent with experimenter at visit (3) Assent script discussed with child in context of social story (4) Ongoing discussion of assent with child during EEG preparatory session (see next)
EEG preparatory session	None	None	(1) Child visit with EEG data collection personnel to EEG lab to sit in “captain’s chair” in front of computer, see EEG materials (caps, electrodes gel), and play with EEG dolls, gel, and pretend cap with EEG staff (2) Parent exploration/discussion in EEG lab (3) Child sent home with EEG “play kit” to practice using gel and pretend EEG cap on their own
Transition to EEG lab	Encourage and support separation from parent		
EEG lab setting	Child-friendly décor, equipment, and language		
EEG staffing/hookup	(1) Two technicians and behavioral experimenter (2) Avoid child attention to EEG hookup (3) Gel syringes covered/hidden (4) Direct child attention to movies, stories unrelated to EEG	(1) Two technicians (2) Explain EEG hookup steps to child (3) Gel syringes exhibited, discussed (4) Invite child curiosity about EEG, conversational references to EEG social story, request feedback from child about hookup process	
Resource and time investment (preparation and hookup/task with child)	Three experimenters 80–110 min over one visit	Two experimenters 90–120 min over one visit	Two experimenters 90–180 over two visits

provided self-report on the Beck Depression Inventory-II (BDI; Beck et al., 1996), Beck Anxiety Inventory (BAI; Beck & Steer, 1990), and annual household income.

2.3 | EEG overview

EEG data collection sessions were conducted at two time points per child—Time 1 (before participation in the intervention) and Time 2 (after participation in the intervention). Given that the primary aim of the larger study was to assess the effect of cognitive control training on an ERP index of cognitive control (i.e., the error-related negativity [ERN]; Gehring et al., 2012), EEG data were collected during the error-eliciting Zoo Task (i.e., a child-friendly Go/No-Go paradigm; Grammer et al., 2014). To participate in the Time 2 EEG session, children must have provided analyzable Time 1 EEG data and attended at least 3 days of the 4-day camp (chosen to maximize the likelihood that children had received a sufficient “dose” of the camp to observe effects on cognitive control). EEG data were considered analyzable if participants had five or more recorded errors on the task, no significant artifacts during data recording, and responses for at least half of the task (Ip et al., 2019). Thus, 12 children (of 18 recruited) in Cohort 1, 11 children (of 21) in Cohort 2, and five children (of 6) in Cohort 3 were eligible for a Time 2 EEG.

2.3.1 | Original techniques (Cohort #1, Camps 1–4)

Techniques focused on establishing a fun and trusting relationship with children and a study team member (“child support person”) who, during EEG hookup by lead and assist EEG technicians, would attempt to entertain and distract the child from procedures. Again, much of this original protocol was adopted from study team experience with data collection in a community sample of children (Ip et al., 2019; Lo et al., 2017). Techniques involved three experimenters and 80–110 min with the child at the EEG data collection visit (approximately 20 min during preparation and 60–90 min for hookup/task administration).

EEG consent and preparation

The parent was consented to their own and their child’s participation by the lead EEG technician, and concurrently, the child and the child-support person played freely nearby. During this time, a brief assent script was read to the child; however, the primary focus was for the child to build rapport with the child-support person and to be introduced to the EEG (via a stuffed animal monkey, “Mr. Bananas,” wearing an EEG cap), whereas parent and lead EEG technician engaged in more detailed conversation about the aspects of the study.

EEG hookup

During EEG hookup, the child-support person attempted to engage the child in conversation about the child’s day, family, or hobbies and occasionally played on an iPad as the EEG lead and an assistant endeavored to unobtrusively apply cap and electrodes. This approach was intended

to distract the child from the novel and potentially intimidating EEG equipment to fun and more familiar topics. If children asked a question about the EEG hookup, they were answered but quickly redirected to non-EEG topics of conversation with the support person. When not in use, EEG materials (e.g., electrode gel and applicator) were covered, with the intent to minimize child attention to the details of the EEG hookup.

2.3.2 | Initial modifications (Cohort #2: Camps 5–8)

Although the original approach had been intended to minimize distress, study participants often seemed curious and fearful of equipment when it was not acknowledged directly, and low rates of successful data acquisition with high levels of child sensitivity were noted. Thus, the initial modifications described below focused on more open discussion of EEG hookup procedures. These modifications involved collective efforts from the interdisciplinary team, with specific contributions from EEG experts (i.e., adjusting training and hookup steps for two technicians instead of three), psychologists (i.e., introducing a “social story” to this new setting and unfamiliar team members), and psychiatrists (i.e., utilizing clinical knowledge to recommend more open communication given that children with anxiety are often afraid of the unknown). On average, the EEG visits involved two experimenters and 90–120 min with the child (approximately 30 min during preparation and 60–90 min for hookup/task administration).

Previsit contact

The study team conducted more detailed phone conversations with and sent descriptive emails (see Supporting Information) to parents prior to their initial sessions. These communications described general information about EEGs, answered frequently asked questions, provided directions about how to prepare children for the visit physically (e.g., remove hair clips or braids), and gave child-friendly language to aid parents in discussing EEG procedures with their children (electrodes described as “stickers” that go on special EEG “hat”). Further, parents were consulted as the “expert” in their child’s likely response to various steps in the EEG hookup and data collection process, with experimenters asking parents to advise on likely child reactions and provide suggested approach to maximize child comfort and success during EEG data collection.

EEG consent and preparation

Again, the parent consented to their own and their child’s participation at the start of the visit. In addition, prior to data collection, an extended story-like assent was read to children by the lead experimenter. This was inspired by the idea of “social stories,” a tool used “to bring predictability to a situation that from the perspective of the [child...] is confusing, frightening, and/or difficult to ‘read’” (Gray, 1998, p. 170). This story (see Supporting Information) detailed each step of the visit with child-friendly words and images, made connections between unknown EEG materials to familiar objects, and directly emphasized

that the child may stop at any point in an effort to reinforce trust and safety.

EEG staffing and hookup

To form a more open dialogue with EEG personnel and reduce the number of adults in the EEG room, the child-support role was eliminated and taken on by the lead EEG technician who focused on engaging with the child while leading the EEG hookup. The lead EEG experimenter would announce the onset of a new procedure, demonstrate what the step would entail on their own bodies, and regularly ask for the child's experience of the EEG hookup (framing questions neutrally to maintain the safe nature of the experience; e.g., "how did that feel?" vs. "did that hurt?"). Importantly, experimenters were taught to modify technique (e.g., changing pressure on gel applicator or during electrode placement) in response to child preference.

2.3.3 | Later modifications (Cohort #3: Camp 9)

Despite experimenters and some children reporting greater levels of comfort with EEG data collection after initial modifications, low rates of successful data acquisition, particularly at Time 1, continued to concern the study team. Thus, based on prior work demonstrating that exposure and desensitization can facilitate successful research participation by children with anxiety (Raschle et al., 2012), and with conversation among of the interdisciplinary team, the child psychiatrist team member (KDF) suggested an "EEG preparatory visit" to habituate children to the EEG lab setting, personnel, equipment, and procedures approximately 1 week "prior" to attempting data collection. To implement this suggestion, an occupational therapist (RS) was recruited to guide the team in developing play-based, sensory-focused strategies to efficiently reduce anxiety during the preparatory visit and through at-home practice. On average, this approach involved two separate visits of 45–90 min each with the same two experimenters attending each visit. Notably, participant compensation was increased with this additional visit.

Previsit contact

A modified introductory email (see Supporting Information), edited social story (shortened and updated with lab-specific pictures; see Supporting Information), and an EEG lab video (3 min long, introducing study materials, personnel, and physical space) were sent following initial phone screens. These materials introduced study team personnel, laboratory space, and EEG equipment to children and introduced child-friendly EEG language prior to the first lab visit.

EEG consent and preparation

As in the previous cohorts, parents consented on behalf of themselves and their child. Then, an experimenter would reread the social story with the child and ask for the child's assent. Notably, the child was assented after the family received and reviewed the previsit contact (including the modified social story and video). In addition, this assent

discussion with the child continued into an EEG preparatory session (see next), which offered children the opportunity to become more familiar with the EEG environment and procedures. With these modifications, the study team sought to offer more transparency to the child, to establish trust between child and experimenters, and to make the child feel included in the decision-making process.

EEG preparatory visit

During this visit, child and parent acclimated to the experimenters, lab space, and EEG equipment "without" any attempt to collect EEG data. Children completed non-EEG behavioral tasks for approximately 1 h with the lead EEG experimenter, allowing time for child-experimenter bonding. At the same time, parents were toured through the EEG lab by the EEG assist for more discussion about EEG procedures, child-friendly EEG language, and strategies for helping their child to perform successfully. After completing study behavioral tasks, children were engaged in a sticker "scavenger hunt" that led to the EEG lab to "meet Mr. Bananas" and "play EEG." The lab space and equipment then were explored for approximately 30 min, without any data collection nor parents. During this visit to the EEG lab, children were directed to positive stimuli in the room (e.g., child-friendly stickers on the walls) and invited to sit in the "captain's chair" (i.e., data collection chair placed in front of a computer) and particular protocol steps were enacted for demonstration. Children had the opportunity for hands-on experience: feeling actual EEG materials compared to similar, familiar materials (e.g., electrode conductive gel and hair gel), wiping their own face with "cool" alcohol pads, squeezing gel from a child-safe "silly squirter," and placing stickers on their skin as electrode proxies. They practiced having their head touched by experimenters' hands and/or a head "tickler" (scalp massager used for sensory desensitization to the experience of hair being parted to place electrodes on scalp) and were measured for proper cap placement. EEG-related materials were identified, using the same child friendly descriptions previously introduced in the video and social story. The entire experience was presented as a game, with children earning stickers for each experience and with time granted for working through child-specific apprehensions. Children were sent home with an EEG "play kit" (including a practice cap, hair gel, favorite stickers, and a head tickler) and were encouraged to "play EEG" with these materials at home prior to returning for their data collection visit.

EEG staffing and hookup

In previous data collection cohorts, experimenters often communicated with one another inconspicuously by writing each other notes in attempt to minimize children becoming intimidated by confusing discussions. However, in camp 9, open communication between EEG technicians was favored over exchanging notes, using the consistent child-friendly language previously introduced. Through the EEG hookup, experimenters frequently referred back to the EEG preparatory visit and worked to engage children in the details of the processes (e.g., using the child's favorite stickers, as included in their sensory bag, atop facial electrodes). EEG hookup time ranged from 45 to 60 min, as opposed to the longer duration in previous cohorts.

TABLE 2 Reasons for lack of analyzable EEG data at Time 1 (ITT sample) and Time 2 (completer sample) by data acquisition cohort

	Time 1, ITT				Time 2, completer			
	Camps 1–4 (N = 18)	Camps 5–8 (N = 21)	Camp 9 (N = 6)	Total (N = 45)	Camps 1–4 (N = 12)	Camps 5–8 (N = 11)	Camp 9 (N = 5)	Total (N = 27)
Scheduling conflict	0	0	1	1	2	1	0	3
Refused separation	0	1	0	1	0	0	0	0
Refused face wiping	0	0	0	0	1	0	0	1
Refused cap	1	4	0	5	0	0	0	0
Refused electrodes	1	1	0	2	0	0	0	0
Refused Zoo Task	3	0	0	3	1	1	0	2
EEG data artifact	1	1	0	2	0	0	0	0

2.3.4 | EEG recording and analysis

EEG data were screened using automated algorithms that rejected epochs in which the absolute voltage range exceeded $500 \mu\text{V}$ for midline channels (Fz, FCz, Cz, and Pz), as with prior work (Grammer et al., 2014). After ocular correction (Gratton et al., 1983), individual trials were rejected if amplitudes were greater than $100 \mu\text{V}$, differed by more than $50 \mu\text{V}$ from the previous time point, or were less than $0.5 \mu\text{V}$ in magnitude in any midline electrode. Other details of EEG recording and analysis are included in the Supporting Information.

2.4 | Analysis

To assess whether modifications to EEG data collection techniques increased the acquisition of analyzable EEG data, primary analyses examined the success of data acquisition for the three data collection cohorts at Time 1 (first-time EEG data collection) and at Time 2 (second-time EEG data collection of eligible participants). In addition, demographic and clinical characteristics were compared for (1) children who failed to provide analyzable EEG data at Time 1, (2) children who provided analyzable EEG data at Time 1 “only,” and (3) children who provided analyzable EEG data at “both” Time 1 and Time 2. Finally, reasons for failure to provide analyzable data were assessed by cohort.

3 | RESULTS

Of children who presented for at least one visit to the EEG lab, the percentage providing analyzable Time 1 EEG data ($N = 45$) was similar between original collection methods and initial modifications but increased with later modifications: 66.7% (12 of 18, Camps 1–4), 66.7% (14 of 21, Camps 5–8), and 83.3% (5 of 6, Camp 9). Of the 28 children who were eligible for an EEG at Time 2, the percentage providing analyzable EEG data increased after both initial and later modifications: 66.7% (8 of 12, Camps 1–4), 82% (9 of 11, Camps 5–8), and 100% (5 of 5, Camp 9). Refusal of cap or electrode placement, face wiping, or Zoo task administration was more common in the first two data collection cohorts than in the final cohort (Table 2). Notably, only one subject in

the third data collection cohort failed to provide Time 1 EEG, and this was due to a scheduling conflict that prevented the family from returning for EEG data collection after a successful preparatory visit. Exclusion due to artifact was rare, occurring in only two subjects at Time 1.

When clinical and demographic characteristics, across cohorts, were studied by the degree of child success in contributing analyzable EEG data, two significant findings emerged. First, age was younger among children who were unable to provide analyzable data at Time 1 compared to those who contributed EEG data at Time 1, or Time 1 and Time 2 (Table 3). Interestingly, parents of children who provided EEG data at both Time 1 and Time 2 reported higher levels of anxiety than parents of children who successfully contributed EEG data only at Time 1 or no EEG data at all or (see Table 3). The remaining clinical and demographic characteristics, including parent-reported child anxiety, were statistically similar across cohorts.

4 | DISCUSSION

This study explored strategies to improve ability of preschoolers with clinical anxiety to provide analyzable EEG data before and after a novel effortful control training intervention. As specific child attributes impact EEG data collection, this paper provides suggestions for future studies to more effectively collect EEG data from young children with anxiety. Initially, literature review and team member ideas informed strategies for collecting EEG data from young children; strategies focused primarily on drawing little attention to EEG protocol. Low rates of successful data collection led the study team to improve iteratively upon strategies. Initial modifications of the protocol focused on the use of more open and direct discussion of EEG equipment and materials during the EEG data collection visit. Subsequently, a preparatory visit was introduced to acclimate child and parent to EEG personnel, equipment, and procedures before attempting EEG data collection. With protocol modifications, we hoped to observe an increase in successful data collection from preschool-aged children with clinical anxiety. Of all strategies attempted, the percentage of children providing analyzable Time 1 EEG in our sample increased only after the introduction of the preparatory visit, despite similar levels of anxiety relative to previous cohorts. Thus, it is probable that

TABLE 3 Descriptives by ability to provide EEG

	No Time 1 EEG (n = 14)	Time 1 EEG Only (n = 9)	Time 1 and 2 EEG (n = 22)	Test statistic (p)
	Mean ± SD (min-max)	Mean ± SD (min-max)	Mean ± SD (min-max)	
Child characteristics				
Gender	8 F (57%)	4 F (44%)	13 F (59%)	$\chi^2 = .58 (.75)$
Age (years)	4.88 ± 0.90 (4-7)	5.92 ± 0.51 (5.17-6.75)	5.71 ± 0.71 (4.33-7)	F = 7.28 (.002) ^a
Spence PAS	61.62 ± 13.41 (41-85)	63.67 ± 13.74 (44-79)	64.05 ± 11.19 (45-87)	F = .16 (.85)
CBCL DSM anxiety	67.23 ± 10.01 (51-90)	67.33 ± 14.12 (50-87)	66.09 ± 8.03 (50-85)	F = .08 (.93)
CBCL internalizing	58.15 ± 8.01 (49-76)	63.22 ± 9.86 (48-72)	62.00 ± 8.36 (37-74)	F = 1.16 (.32)
CBCL externalizing	53.08 ± 10.23 (32-70)	55.33 ± 10.57 (40-74)	58.05 ± 8.67 (40-70)	F = 1.14 (.33)
BIQ	110.15 ± 34.80 (41-162)	114.11 ± 41.92 (51-179)	111.82 ± 26.05 (66-154)	F = .04 (.96)
SCQ	6.46 ± 4.37 (2-14)	6.56 ± 3.94 (0-11)	4.59 ± 3.58 (1-13)	F = 1.32 (.28)
Parent characteristics				
BAI	5.85 ± 7.50 (0-26)	4.44 ± 4.72 (0-14)	12.27 ± 8.74 (0-43)	4.59 (.02) ^a
BDI	8.15 ± 6.72 (0-25)	7.44 ± 6.06 (0-18)	13.82 ± 10.62 (0-36)	2.51 (.09)
Household income ^a				$\chi^2 = .43 (.65)$
<\$24,999	2 (15%)	0 (0%)	3 (14%)	
\$24,999-74,999	5 (39%)	4 (44%)	9 (41%)	
>\$75,000	6 (46%)	5 (56%)	10 (46%)	

Note: The Spence Preschool Anxiety Scale (PAS) is reported as T-scores based on the summation of all items. The DSM Anxiety, Internalizing, and Externalizing subscales of the Child Behavior Checklist (CBCL) are also reported as T-scores. The Behavioral Inhibition Questionnaire (BIQ), Beck Anxiety Inventory (BAI), and Beck Depression Inventory (BDI) are reported as total raw scores (range BIQ: 30-210, BAI and BDI: 0-63). Note that Spence PAS, CBCL, BIQ, SCQ, BAI, BDI, and income data missing for one participant (i.e., data reported for "Not" analyzable pre-camp EEG sample N = 13).

^aHousehold income across three levels: (1) < \$24,999; (2) \$24,999-74,999; (3) > \$75,000.

Asterisk (*) indicates a statistically significant difference. Children with no Time 1 EEG group was significantly younger than those who provided an EEG data at Time 1 only ($p = .006$) or at Time 1 & 2 ($p = .006$). BAI scores were higher for parents of children who provided both Time 1 and 2 EEG data compared to those who provided EEG data at Time 1 only ($p = .043$) or no EEG data at all ($p = .067$).

as study staff clarified and prepared children for the EEG with both exposure and ample time, they became familiar with the sights, sounds, and feelings of EEG procedures prior to data collection. This effort required additional time but paid off in the child's willingness, comfort, and ability to participate in a new experience, the initial EEG. Although these results appear promising, these data were collected and interpreted in the context of the relatively sample size, and future research is required to expand on this protocol design and recommendations.

Secondary analyses assessed the effect of changes in the EEG protocol on data collection at a second time point (after the brief cognitive training intervention), across the three data collection cohorts. Children were only eligible for a Time 2 EEG if they had (1) successfully provided a Time 1 EEG "and" (2) attended at least 3 days of camp. At this second or "Time 2" visit, a larger percentage (82%) of Cohort 2 children were able to provide analyzable EEG data than Cohort 1 (only 66.7%). Thus, more direct communication about EEG procedures seemed to have impacted willingness of children in this population to return for a second EEG. However, as this effect was not noted at Time 1, it appears that Cohort 2 protocols were successful in improving data collection only among those already amenable to providing EEG data and who may have benefitted from the intervention. Critically, it was not until the preparatory visit was added in Cohort 3 that

greater success in acquiring analyzable EEG data was observed at Time 1 (i.e., in EEG-naïve children) and Time 2 (i.e., postintervention children).

To determine whether subject characteristics influenced the likelihood of acquiring analyzable data at Time 1, we collapsed across cohorts to test for differences in demographic and/or clinical measures in three categories of children: those who (1) failed to contribute EEG data at Time 1, (2) provided EEG data "only" at Time 1, or (3) contributed EEG data at "both" Time 1 and Time 2. Younger age was observed among children in the first group (no EEG data at Time 1). By contrast, there were no age differences among children who provided EEG at only Time 1 compared to both Time 1 and Time 2. Further, there were no differences in anxiety severity across the three categories of children, despite varying levels of success in providing analyzable data—an observation that should be interpreted cautiously given the small sample size. Notably, children who provided "both" Time 1 and Time 2 had highest parent self-report anxiety symptoms. It is plausible that parents with personal experience of anxiety symptoms may have more readily discussed the EEG with their children ahead of time, noted anxiety symptoms in their children, and/or better equipped their children with coping strategies; these hypotheses warrant additional assessment.

Specific barriers to acquisition of analyzable EEG data were assessed. Interestingly, the primary refusal of Time 1 EEG occurred during EEG hookup, whereas the primary reason for Time 2 refusal was due to scheduling conflict. The initial EEG session was particularly challenging for some children—whether fear of the novel situation or inability to tolerate procedures; however, after completing the first EEG, children were less likely to stop participation mid-way through the second hookup. This sense of familiarity seemed important for success and, given that no child in Cohort 3 refused Time 1 EEGs mid-way through hookup, the EEG preparatory visit likely provided children with that familiarity prior to the initial data collection. Further, it is important to note that only two EEGs at Time 1 were considered as unanalyzable due to artifact in EEG, as opposed to other studies where artifacts in EEG collection are the primary reason for lost data. It seems that when the protocols described above were successful, children were better able to sit still, maintain task engagement, and provide high-quality data than different or more rushed study methods; this was likely resultant from both children feeling more comfortable and adequate time for staff to perform hookup precisely.

Importantly, the study team consisted of members of interdisciplinary backgrounds (e.g., psychiatrists, psychologists, social workers, neuroimaging experts), as well as members at various points in training (e.g., medical students, undergraduate students, psychology PhD candidates). The nature of this work was iterative and creative, and the protocol's transformation benefited drastically from the unique knowledge bases of all team members. New ideas were brought to team meetings for discussion and approval; for example, when the study team determined the need for more EEG preparation, psychologists guided the development of materials to be shared with parents before the first visit, psychiatrists suggested the additional preparatory exposure visit, the occupational therapist developed EEG "play kits" to alleviate some anxiety of "the unknown," and EEG experts brainstormed of duplicate materials that were most akin to EEG equipment yet safe for home use. Again, this study aims to offer guidance for future data collection, but we also call for future research to continue refining these protocols. Given our experience, we recommend that future efforts utilize interdisciplinary teams to produce the most widely applicable and successful techniques.

4.1 | EEG technique comparison

EEG data collection in young children is nuanced in challenging populations and differs from that in the general population of youth. Kylliäinen et al. (2014) detailed guidelines for collecting psychophysiological data from young children with Autism Spectrum Disorder (ASD); recommendations mimicked the current study in numerous ways such as early parent consultation, a desensitization visit and video introducing the study environment, and provision of home materials mimicking study equipment. In contrast, data collection recommendations for the ASD population differed from our youth with anxiety through withholding room decorations to avoid distraction and overstimulation, utilizing belts and head support to minimize motion, and maintaining par-

ents within the testing room to support behavior challenges (where our protocol separated parent from child early to minimize parent accommodation of child anxiety or parental "pushing" beyond point of child comfort). Thus, it is necessary to test specific protocols that accommodate different clinical populations.

Although many studies do not contain detailed methods of conducting EEGs, young children have successfully provided EEG data in many community samples. Torpey et al. (2013) utilized a sample of 413 6-year-old children, drawn from a community sample initially assessed at age 3 years old for temperamental negative emotionality. Notably, of the 413 participants, 326 (78.9%) were retained for ERP analysis due to lack of usable artifact-free trials, technical error, or EEG-task responses beyond acceptable deviation from mean. This percentage of analyzable EEG data (78.9%) is slightly higher than the rate of analyzable Time 1 EEG data acquired in the present study's first two cohorts (i.e., 66.7% collected in Camps 1–4 and Camps 5–8) but slightly lower than the final cohort (83.3% collected in Camp 9). In the prior study, unanalyzable EEG data from participants primarily resulted from artifacts during actual data collection, unlike our study where children often refused to participate before task administration began. The initial non-EEG visit at age 3 in Torpey et al. (2013) may have provided beneficial exposure to experimenters and/or environment, enabling children 3 years later to feel more comfortable providing EEG data. Additionally, it is likely that lower levels of anxiety and slightly older average age in Torpey et al. (2013) associated positively with tolerance of EEG procedures, as anxiety symptoms may have coupled with young age in our sample to heighten sensitivity to unfamiliar materials and settings. Because study modifications targeted these symptoms of anxiety and improved participation, it is likely that in samples representing participants without such challenges, data collection would have improved.

4.2 | Limitations

Relatively small sample sizes across three data collection protocols may limit the findings presented. For example, although no families in the present study verbalized hesitancy to participate in more lab visits (i.e., Cohort 3 addition of "EEG preparatory visit"), it is possible that scheduling data collection over multiple sessions may be unfeasible for some families with parents/caregivers who work later hours or lack readily available transportation. Given that the current primary study is ongoing, with continued enrollment, we are encouraged to study EEG data collection in a larger, more diverse sample. In addition, it is possible that because of the logistics and timeline of the primary study, unmeasured factors may have affected results. Specifically, success of Time 2 data collection may have been impacted by the anxiety intervention, and staff changes might have confounded data collection in later cohorts (e.g., long-term experimenters became more comfortable performing EEG protocols over time; new experimenters onboarded during the study had subtle personality or technique differences that promoted data collection). In order to piece apart other potential confounding variables further, future research may serve to study these techniques in a more controlled environment, perhaps using

blinded coding to ensure consistency of behaviors and/or using the same experimenters throughout the study. Further, the present study assessed only ERN via the "Zoo Task," Go/No-Go paradigm; eliciting other ERPs (e.g., face stimuli to elicit late positive potential) may affect data retention in preschoolers with anxiety and may require nuanced data collection techniques. Future research efforts may inform applicability of the aforementioned techniques for the acquisition of other ERPs.

Though the present study did demonstrate strong potential for successful EEG data collection in preschool-aged children with anxiety, not all children were able to complete the EEG visit, even with refined EEG data collection strategies. Ethically, our team had high concern for our sensitive, young subjects and knowledge that some children may be unable to tolerate EEGs despite protocol adjustments (Kylliäinen et al., 2014). We utilized a relatively low threshold to terminate EEGs and did not collect data from children who may have been successful if pressed to continue, as staff were trained to notice child withdrawals of consent based on physical and verbal responses. Staff further avoided any coercive techniques (e.g., children never were bribed to continue to earn prize toys). Thus, for such practical and ethical reasons, data collection was determined impossible in particular cases.

5 | CONCLUSIONS

Although literature emphasizes the importance of EEG data for understanding pediatric psychopathology, little data exist on how best to collect such clinically valuable data among populations with unique challenges. The current study aimed to elucidate whether specific techniques could promote successful EEG data collection within three cohorts of preschool-aged children with anxiety. Through review of literature, trial and error of lab-specific techniques, and ultimate refinement of the protocol, we recommend the final strategies (Cohort 3) be considered for future ethical collection of analyzable data. We encourage a balance between utilizing clinical and technical skills and hope to continue fine-tuning processes to improve further participant tolerance for the EEG protocol.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

All authors have contributed sufficiently to this work through study conception/design, data acquisition, data interpretation, and/or manuscript writing. Authors have given approval of this work to be published and have agreed to be accountable for all aspects including integrity and accuracy of this manuscript.

DATA AVAILABILITY STATEMENT

Requests for reprints can be sent to Kate D. Fitzgerald, at krd@med.umich.edu. The data supporting these findings are available in NIMH Data Archive at <https://nda.nih.gov> and from the corresponding author upon reasonable request.

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