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SHORT REPORT

Early parenting intervention accelerates inhibitory control development among CPS-involved children in middle childhood: A randomized clinical trial

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Abstract

Children at risk for neglect or abuse are vulnerable to delays in inhibitory control development. Prior findings suggest that early parenting interventions that target parental sensitivity and responsiveness during infancy can improve executive function outcomes of high-risk children during preschool years; however, little is known about how persistent these gains are through middle childhood. Participants included 76 CPS-involved children who were randomly assigned to either the ABC intervention ($N = 32$) or the Developmental Education for Families (DEF) control intervention ($N = 44$), and 53 low-risk children. Children completed the Stop Signal Reaction Time (SSRT) paradigm at ages 8 and 10. Intervention group predicted performance on the SSRT at age 8 such that children who received the ABC intervention and children in the low-risk group performed significantly better than children who received the DEF intervention (ABC vs. DEF: *Cohen's d* = 0.92; low-risk group vs. DEF: $d = 0.56$). The performances of the ABC and the low-risk groups were not statistically different. There were no significant group differences in SSRT performance at age 10. These findings demonstrate that the ABC intervention has long-term beneficial effects on inhibitory control development in children with a history of early caregiving adversity.

KEYWORDS
caregiving, early adversity, early intervention, inhibitory control

1 | INTRODUCTION

Inhibitory control refers to the child's capacity to inhibit a dominant or prepotent response (Williams et al., 1999). Along with cognitive flexibility and working memory, inhibitory control is one of our executive functions that plays a key role in children's social, emotional, and cognitive functioning (Hitch, 2006; Jacques & Marcovitch, 2010; Rhoades et al., 2009). Behaviorally, inhibitory control may be seen in the child's ability to think before acting impulsively or in the ability to sustain attention despite distractions (Schachar et al., 2000). During the first years of primary education, opportunities and demands for adequate response inhibition arise at times when children manage conflicts with peers (Collins et al., 2002; Holmes et al., 2016), solve problems (Cassotti et al., 2016; Lengua, 2003; Skinner & Zimmer-Gembeck, 2016), make decisions (Van den Wildenberg & Crone, 2005ildenberg & Crone, 2005), think morally (Kochanska et al., 1997), set goals (Chevalier, 2015), and practice emotion regulation (Lengua, 2003; Skinner & Zimmer-Gembeck, 2016). Successful navigation of these tasks is dependent on the child's developing capability to monitor changing environmental demands and inhibit automatic responses that are incongruent with the environment's expectations or do not serve the child's needs (van der Molen et al., 2003).

Decades of research on socioemotional and cognitive development have demonstrated that children with histories of early life caregiving adversities such as neglect or abuse are more likely to experience difficulties or delays in inhibitory control than children from nurturing and sensitive family backgrounds (Dozier & Bernard, 2019; Lind et al., 2017; Masten et al., 2012; Noble et al., 2007; Pears et al., 2010; Pechtel & Pizzagalli, 2011). Given that good inhibitory control is a protective factor in the face of a range of negative life outcomes (Holmes et al., 2016; McLaughlin et al., 2017; Smith et al., 2014), intervening early to shape the caregiving environment may be important in promoting healthy inhibitory control development among high-risk children.

Inhibitory control begins to develop during infancy with its developmental trajectory affected by the quality of the early caregiving environment and the attachment relationship between the parent and the child (Roskam et al., 2014). Infants are dependent on their parents for emotional and physiological regulation, such that the parent's capacity to respond sensitively to the infant's needs differentially shapes the development of critical neural circuits implicated in self-regulation (Kolb et al., 2012; McLaughlin et al., 2012; Nelson et al., 2019; Pechtel & Pizzagalli, 2011).

The Attachment and Biobehavioral Catch-up (ABC) intervention was designed to promote parental sensitivity, to increase rates of secure, organized attachment, and to enhance physiological and behavioral regulation among vulnerable infants with early experiences of abuse or neglect (Dozier & Bernard, 2019). This 10-session parenting program promotes nurturing care when the child is distressed, fosters contingent responsiveness during parent–child interactions, and encourages non-frightening parental behavior when interacting with the child. Parent coaches trained in ABC help parents master these behaviors through manualized content and by making frequent comments that foster nurturing and responsive parental behavior. The ABC intervention has been found to increase maternal sensitivity (Bick & Dozier, 2013), promote secure, organized attachment (Dozier, Lindheim, Lewis, Bick, Bernard, & Peloso, 2009), enhance executive functioning (Lind et al., 2017, 2019), improve cognitive flexibility among preschool-aged children (Lewis-Morrarty et al., 2012), and promote cortical maturation during middle childhood (Bick et al., 2019).

Highlights

- Children with a history of neglect or abuse are vulnerable to delays in inhibitory control development.
- Improved parenting skills, such as sensitivity and responsiveness to children's needs, can enhance the inhibitory control development of adversity-exposed children.
- Attachment and Biobehavioral Catch-up—a 10-session parenting intervention implemented during infancy—improves CPS-involved children's inhibitory control outcomes during middle childhood.

1.1 | The current study

The ABC intervention has been found to improve children's executive functioning abilities among preschool-aged children, but sustained intervention effects on inhibitory control during middle childhood have not yet been tested. The aim of the present study was to assess the causal effect of the ABC intervention on the development of inhibitory control among 8- and 10-year-old CPS-involved children who were randomly assigned either to the ABC intervention or a control intervention, called Developmental Education for Families (DEF), in a randomized clinical trial as infants. Inhibitory control outcomes of CPS-involved children were compared to outcomes among a low-risk group of children without CPS involvement. Our key hypotheses were that children who received the ABC intervention would demonstrate better inhibitory control at ages 8 and 10 in middle childhood as measured by the SSRT paradigm (van der Molen et al., 2003; Verbruggen & Logan, 2009) than children who received the DEF intervention. We predicted that children in the ABC group would not perform significantly differently from the low-risk group on the SSRT paradigm, but that both would perform better than children who received the DEF intervention. Given that inhibitory control development continues until young adulthood, we also expected that inhibitory control would improve over time for children in all three groups.

2 | METHODS

2.1 | Participants

The analytic sample of the present study included 129 children in middle childhood: 76 children with Child Protective Services (CPS) involvement due to risk for abuse or neglect when they were infants, and 53 low-risk children without histories of CPS involvement. None of the CPS-involved children were removed from their biological families at the time when they participated in the intervention. The CPS-involved families were referred to the study in infancy and were randomly assigned to receive either the ABC intervention (n = 32) or the DEF intervention (n = 44). The low-risk comparison group included children who were living with their biological parents with no prior family history of psychiatric hospitalization, homelessness, illicit drug dependence history, or incarceration. Families in the low-risk group were recruited at age 8 through advertisements in school or local community centers. The sample was racially diverse, with about 85% of the sample identifying as Black or biracial (see Table 1 for demographic information).

2.2 | Procedures

First, CPS-involved families received the ABC or the DEF intervention when children were infants. Infants in the two groups did not differ in their average age at the time of their first intervention session (M_{ABC} =10.476 months old, M_{DEF} = 9.403 months

TABLE 1 Demographic characteristics

Child Demographics	ABC group N = 32		DEF group (control intervention) N = 44		Low-risk group N = 53	
	%	*n*	%	*n*	%	*n*
Gender, Female	43.75	14	47.72	21	47.17	25
Race						
African American	65.62	21	65.91	29	52.83	28
Caucasian	6.25	2	9.09	4	30.19	16
Biracial/other	25	8	4.54	2	13.21	7
Other	-	-	-	-	3.77	2
Hispanic ethnicity	15.62	5	25	11	20.75	11
Parental education						
High school not completed	40.62	13	18.18	8	1.88	1
GED	18.75	6	15.9	7	1.88	1
High school diploma	21.87	7	43.18	19	22.64	12
Some college	15.62	5	13.64	6	41.51	22
4-year college degree	-	-	6.82	3	15.09	8
Postgraduate degree	-	-	8.92	3	15.09	8
Unknown	-	-	-	-	16.98	9
	Min–Max	**Mean (SD)**	**Min–Max**	**Mean (SD)**	**Min–Max**	**Mean (SD)**
Age						
8-year data collection	8.00–9.00	8.52 (0.37)	8.00–9.00	8.46 (0.37)	8.00–9.08	8.54 (0.32)
10-year data collection	10.00–12.00	10.63 (0.44)	9.75–11.67	10.56 (0.43)	10.00–11.08	10.54 (0.34)
WJ Cognitive Score	49–111	82.43 (13.94)	61–106	82.97 (11.92)	71–123	94.95 (12.77)
Income (average)	$1080–74,000	$25,306 (17,165)	$3,168–207,600	$30,595 (36,129)	$14,000–225,000	$70,978.15 (48,332)

Note: ABC, attachment and biobehavioral catch-up intervention; DEF, developmental education for families intervention; SSRT, stop signal reaction Time; WJ Cognitive Score, Woodcock Johnson Test of Cognitive Abilities, Brief Ability Index Score.

old, $t(74) = 0.792$, $p = 0.431$) and there was no group difference in the number of completed intervention sessions ($M_{ABC} = 9.66$, $M_{DEF} = 9.34$, $t(74) = 0.728$, $p = 0.469$). When children were 8 and 10 years old, they came to the lab for a research visit and completed the Stop Signal Reaction Time (SSRT) task (Logan & Cowan, 1984). At age 9, children's intellectual ability was measured using the Woodcock-Johnson III Tests of Cognitive Abilities (Schrank, 2011). We obtained written consent from parents who accompanied the children to the research visit, and assent from children, before children participated in the data collection. The University of Delaware Institutional Review Board approved the data collection procedures.

2.2.1 | Interventions

The ABC and the DEF intervention are both 10-session, weekly, manualized interventions that were delivered by trained parent coaches in the families' homes.

Attachment and biobehavioral catch-up intervention

The Attachment and Biobehavioral Catch-up (ABC) intervention was designed to enhance children's behavioral and biological regulation (Dozier & Bernard, 2019). The intervention achieves these targets by encouraging parents to: 1) nurture children when children are distressed; 2) follow children's lead when not distressed; 3) and reduce intrusive and frightening parental behaviors. During intervention sessions, parent coaches frequently provide live commenting on the quality of the parent's interaction with the child, which hones and encourages nurturing parent behavior and sensitivity to the child's needs (Caron et al., 2018).

Developmental education for families, DEF (control intervention)

The DEF intervention was developed to enhance motor and language skills. Initially, it was a home-visiting intervention, which proved to be successful at shaping children's intellectual development (Brooks-Gunn et al., 1993; Ramey et al., 1982, 1984). The sessions were manualized and covered general psychoeducation about developmental milestones and intellectual activities which the parents could use during their daily interactions with the child. The sessions were also adjusted to each child's developmental level and need. Importantly, unlike ABC, the DEF interventions did not target maternal sensitivity.

2.3 | Measures

2.3.1 | Measures of inhibitory control

We used the Stop Signal Reaction Time (SSRT) task as our primary measure of response inhibition, which is one specific type of inhibitory control. The SSRT value represents the time necessary to inhibit an already initiated behavioral response (Logan & Cowan, 1984). In addition to the SSRT, children also completed the Flankers task (Eriksen & Eriksen, 1974) and Kochanska's dinky toys task (Kochanska et al., 1996), but the results of these two measures are not included in the manuscript.

SSRT procedure

Following parental consent and child assent, children completed the SSRT task (Logan & Cowan, 1984) at age 8 and 10 in a laboratory setting. We collected EEG data while children completed the SSRT task, but the EEG results are not yet available. The task was presented to children using Presentation software (Neurobehavioral Systems, Inc.). During the task, children were seated in front of a computer screen and a button box with two active buttons. On each trial, at approximately 50% probability, a green arrow pointing right or left was displayed in the middle of the screen (see Figure 1). When the green arrow (or go signal) appeared, children were instructed to press either the right or the left button as fast as they could, corresponding to the direction of the arrow on the screen. On approximately one-third of the trials, at asynchronous onsets after the appearance of the green arrow, a red circle (or stop signal) emerged, superimposed on the arrow. When the stop signal appeared, children were instructed to inhibit their responses and not press any buttons. Importantly, it was conveyed to children that they should press the buttons as fast as they could once the green arrow appeared on the screen and not to wait for the stop signal to emerge. Participants did not receive feedback about their performance and the order of go and stop trials was fully randomized. The length of time between the appearance of the go and stop signal (stop signal delay or SSD) was adjusted based on performance through the use of a tracking procedure (van der Molen et al., 2003). The task was programmed so that participants could inhibit their button presses on approximately 50% of the stop trials. At the beginning of the task the SSD was set at 200 ms. Following a failure of response inhibition (unsuccessful stop trial or USST), 50 ms was subtracted from the previous SSD to increase the probability of a successful stop trial. Following a successful stop trial (SST), 50 ms was added to the preceding SSD in order to increase the difficulty of the task and reduce the likelihood of successful response inhibition. This varying of the SSD throughout the task allowed us to calculate the maximum SSD length that is sufficient for participants to process the emergence of the stop signal but still inhibit the motor response.

In the presence of a trained research assistant—who was unaware of the participant's intervention assignment—children completed two practice blocks of 50 trials each (a total of 100 trials). During the first practice block, the research assistant provided constructive feedback to the child and emphasized the importance of speedy button presses following the appearance of the green arrow (see Figure 1). During the second block, the research assistant watched the child's performance without providing any feedback to confirm that he or she acquired the task rules adequately and made button presses without purposefully waiting for the stop signal (red circle) to appear. Additional practice blocks were administered if needed until the rules were acquired. Following the practice trials, the research assistant left the room and the child completed four task blocks, with a total of 240 trials (60 trials in each block) lasting 1200 ms each and with 2000 ms intervals between trials. Between

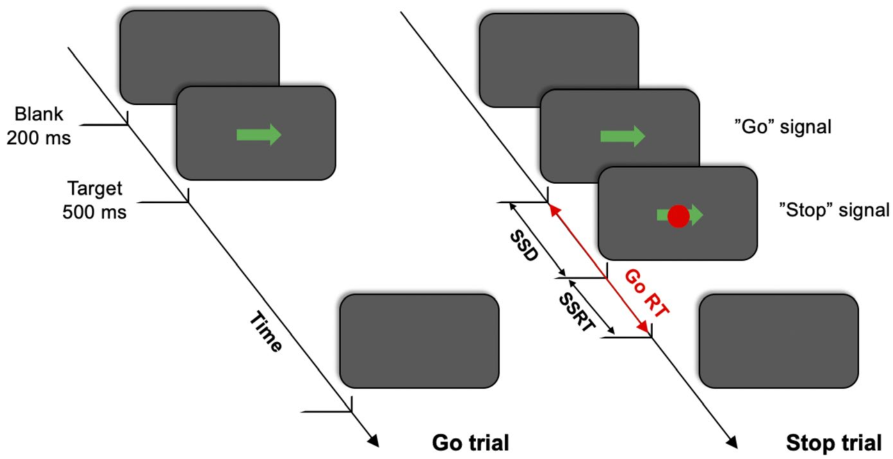

FIGURE 1 Experimental procedure of the Stop Signal Reaction Time (SSRT) Task. During go trials, children were instructed to press the button corresponding to the pointing direction of the green arrow (go signal). However, if the red circle (stop signal) appeared superimposed on the arrow (stop trial), children were instructed to withhold their motor responses. SSD, Stop Signal Delay.

blocks, the research assistant returned to the participant room for a brief break and gave the children stickers to help track progress, incentivize them to stay attentive throughout the task, and remind them of the task rules. Following the short break, the research assistant left the room and the child continued working on the task. The activity lasted approximately 30 minutes, after which the child was reunited with his or her parent.

Calculation of SSRT

We used the integration method (with replacement of go omissions) to calculate each participant's SSRT (Verbruggen et al., 2019). First, we calculated the percentage of successful stop trials (SST or stop accuracy rate) for each study participant, which is the ratio between the number of successful stops and the total number of stop trials across all four task blocks. The percentage of successful stop trials was 50.46% at age 8 and 51.55% at age 10, which indicates that the tracking procedure successfully adjusted the SSD based on the participant's performance throughout the task so that it would result in approximately 50% successful stop trial. Then we calculated the individual average SSD—the average time that elapsed between the appearance of the go signal/green arrow (onset of the go process) and the appearance of the stop signal/red circle (onset of the stop process). This allowed us to determine, on average, how long after the onset of the go process the stop process was initiated. Then each participant's omitted go reaction times were substituted with 1200 ms (the length of the go trial), after which the go reaction times were rank ordered. Using the previously calculated stop accuracy rate, we separated the rank ordered distribution of reaction times into two parts: (1) reaction times associated with unsuccessful stop trials and (2) those associated with successful stop trials. For example, if a participant demonstrated a stop accuracy rate of 45%, it would mean that the ranked ordered reaction time at the 55th percentile (dotted line in Figure 2) would separate the trials at which the go process was too fast to be successfully inhibited (lower 55%) or slow enough to result in the successful inhibition of the button press (upper 45%). Using these data, we then calculated the SSRT by subtracting the average SSD from the reaction time associated with the boundary between unsuccessful and successful stop trials (dotted line in Figure 2). Following Verbruggen et al.'s (2019) recommendations, participants who met any of the following criteria were excluded from the analysis sample: had 1) less than 30% of successful stop trials, 2) more than 25% of omitted go trials, 3) more than 25% incorrect go trials, and 4) if the length of the participant's average unsuccessful stop trial was longer than the length of his or her average go trial. See Table 2 for descriptive information of the SSRT task parameters.

2.3.2 | Woodcock-Johnson III tests of cognitive abilities (WJ-Cog)

The Woodcock-Johnson III Test of Cognitive Abilities is an individually administered test of overall cognitive functioning (Schrank, 2011). When children were 9 years old, three subtests of the WJ-Cog (Verbal Comprehension, Concept Formation, and Visual Matching) were administered by trained graduate students. Test administration took about 30 minutes to complete. These three subtests measure children's verbal knowledge and reasoning, use of inductive logic

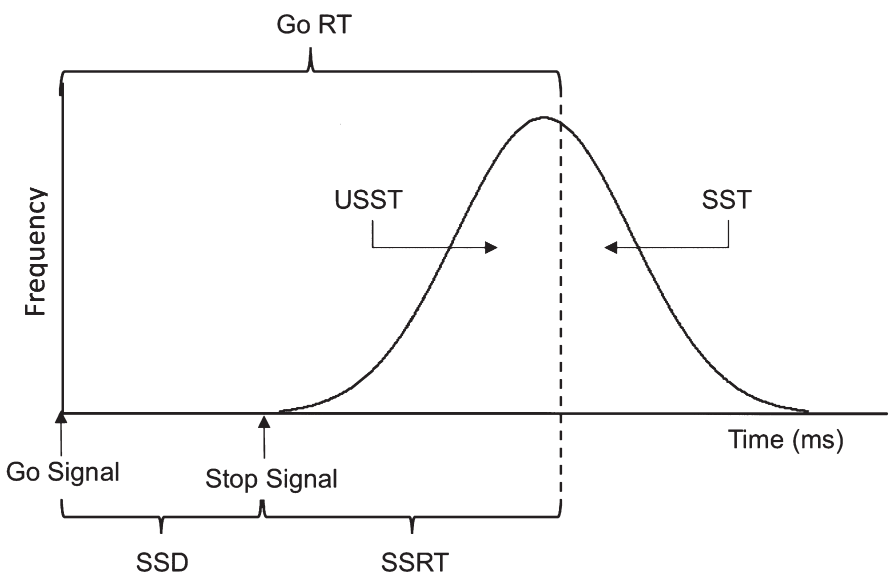

FIGURE 2 Illustration of rank ordered go reaction times across go trials and timeline of the stop process. This image has been adapted from Palmwood, Krompinger, & Simons (2017). The image illustrates a hypothetical participant's rank ordered distribution of SSRT reaction times on go trials, with the dotted line indicating the reaction time that separates unsuccessful stop trials (USST) from successful stop trials (SST). For this hypothetical participant the dotted line is at 55thpercentile of go reaction times, which indicates that the upper 45% of the rank ordered go reaction times would result in successful stop trials (SST), whereas the lower 55% would result in unsuccessful stop trials (USST) because the go process would be complete before the stop process.

TABLE 2 Descriptive statistics for the parameters in the integration method

	Group	pOmit	pOmit SD	Go RT	Go RT SD	pUST	pUST SD	ssd SST	ssd SST SD	ssd UST	ssd UST SD	SSRT	SSRT SD
Age 8	ABC	0.088	0.064	677.087	66.348	0.489	0.039	339.436	94.885	389.319	112.101	313.88	80.917
	DEF	0.085	0.069	699.28	103.931	0.51	0.035	293.376	96.113	328.639	101.356	388.692	117.76
	Low-risk	0.064	0.056	692.053	107.067	0.484	0.041	356.703	109.253	412.156	124.978	309.047	133.507
Age 10	ABC	0.071	0.068	633.967	106.261	0.49	0.033	321.235	104.03	369.663	121.213	289.629	83.062
	DEF	0.083	0.065	686.231	101.698	0.487	0.05	369.396	97.526	414.871	121.392	296.306	120.995
	Low-risk	0.059	0.055	668.026	116.179	0.484	0.051	373.735	122.377	428.229	145.913	269.366	102.021

Note: ABC, Attachment and Biobehavioral Catch-up intervention; DEF, Developmental Education for Families intervention; pOmit, average probability of omitted Go trials; pOmit SD, the standard deviation of the average probability of omitted trials; Go RT, average reaction time on Go trials; Go RT SD, the standard deviation of the average reaction time on Go trials; pUST, average probability of unsuccessful stop trials; pUST SD, the standard deviation of the average probability of unsuccessful stop trials; ssd SST, average stop signal delay on successful stop trials; ssd SST SD - the standard deviation of the average stop signal delay on successful stop trials; ssd UST - average stop signal delay on unsuccessful stop trials; ssd UST SD - the standard deviation of the average stop signal delay on unsuccessful stop trials; SSRT, average stop signal reaction time; SSRT SD - the standard deviation of the stop signal reaction time.

and cognitive flexibility, and cognitive efficiency. From these three subtests, children's Brief Intellectual Ability (BIA) scores were derived, which is a reliable measure of intelligence recommended for use in research settings (Schrank, 2011). Because intelligence was considered an important covariate for analyses, children who did not have a BIA score were excluded from the analytic sample (see Missing data section for more information on missingness).

2.4 | Data analytic strategy

We used R (Version 1.2.1335; R Core Team, 2019) for data preprocessing, data cleaning and data visualization, and Mplus 8 (Version 1.6; Muthén & Muthén, 1998–2017) for data analysis. Latent growth curve modeling (LGCM) was used to test hypotheses. LGCM is a flexible developmental modeling technique that is appropriate for capturing individual differences in intercepts and rates of change in multi-wave data. Specifically, a two-occasion LGCM was performed to estimate group differences in SSRT at age 8 and 10 and compare the change trajectories in SSRT outcomes over time. Because there are two repeated assessments of inhibitory control, residual variance must be constrained to zero in order for the model to be identified, resulting in an approach comparable to a paired t-test (Voelkle, 2007). Important benefits of the two-occasion LGCM over a paired t-test are the capacity to incorporate multiple predictors of the change over time and handle missing data on either time point of the repeated outcome under the missing at random assumption.

3 | RESULTS

3.1 | Missing data

3.1.1 | Age 8

One hundred and sixty-eight children completed the SSRT task at age 8. Forty-seven participants met at least one of the exclusion criteria, and therefore were excluded from the analytic sample (ABC_{excl} = 15 participants; DEF_{excl} = 17 participants; $COMP_{excl}$ = 15 participants; $\chi^2(2) = 1.901$ $p = 0.396$). Of the remaining 121 participants, 35 did not have IQ test scores at age 9, and therefore were excluded from the sample. The final 8-year-sample included 86 children: 23 in the ABC group, 25 in the DEF group, and 38 in the low-risk group. The groups did not differ in age ($F(2, 83) = 0.391$, $p = 0.678$) or gender distribution ($\chi 2$ (2, $N = 86$) = 0.810, $p = 0.667$).

3.1.2 | Age 10

One hundred and sixty children completed the SSRT task at age 10. Twenty-four participants met at least one of the exclusion criteria (ABC_{excl} = 8 participants; DEF_{excl} = 7 participants; $COMP_{excl}$ = 9 participants; $\chi^2(2)$ = 0.241 p = 0.886). Of the remaining 136

TABLE 3 Parameter Estimates for the Latent Growth Curve Model of Children's Inhibitory Control as a Function of Intervention Group. N = 129

Fixed effects (intercept, slopes)	*Estimate (SE)*	*t(120)*	p^a	CI_{95}[b] Lower	Upper
Reference Group: ABC					
Intercept – ABC	307.68 (24.16)	12.74	0.000	260.32	355.03
DEF Intervention Group	83.70 (32.29)	2.59	0.011	20.41	147.00
Low-risk Group	22.94 (31.66)	0.72	0.473	−39.12	85.00
WJ-Cognitive Score[c]	−0.255 (0.10)	−2.57	0.011	−0.45	−0.06
ABC Group by Wave	−20.91 (26.16)	−0.80	0.425	−72.19	30.37
DEF Intervention Group by Wave	−77.58 (35.03)	−2.21	0.029	−146.24	−8.92
Low-risk by Wave	−41.27 (35.51)	−1.16	0.248	−110.87	28.34
WJ-Cognitive Score by Wave	0.199 (0.110)	1.81	0.073	−0.16	41.50
Reference Group: Low-risk Group					
Intercept – Low-risk Group	330.61 (19.54)	16.920	0.000	292.32	368.91
DEF Intervention Group	60.76 (30.37)	2.001	0.048	1.24	120.28
Low-risk Group by Wave	−62.17 (23.14)	−2.686	0.008	−107.53	−16.80
DEF Intervention Group by Wave	−36.31(34.44)	−1.054	0.294	−103.82	31.20
Reference Group: DEF (control intervention)					
Intercept – DEF Intervention	391.38 (22.83)	17.147	0.000	346.64	436.12
DEF Intervention Group by Wave	−98.48 (25.19)	−3.909	0.000	−147.86	−49.10

Random Effects ([co-]variances)	Estimate (SE)	*z*	*p*	CI_{95}[c] Lower	Lower
Intercept	13,239.8 (2367.3)	5.593	0.000	8599.9	17,879.7
Wave[d]	15,372.7 (3229.3)	4.760	0.000	9043.3	21,702.1
Covariance	−9062.8 (1950.8)	−4.646	0.000	−12,886.4	−5239.2

Note: n = 129.

The table presents the fixed intercept and slope effects when the ABC group was the reference group in the model. The table can be interpreted as follows: (1) the first intercept estimate represents the initial level of SSRT at age 8 for the typical child in the ABC group; (2) the DEF intervention and low-risk group intercept estimates represent the differences in levels of age 8 SSRT relative to the ABC group; (3) the reference slope estimate represents the change in SSRT outcomes between ages 8 and 10 for the typical child in the ABC group; (4) the DEF intervention and low-risk group slope estimates represent the differences in slope relative to that of the ABC group. At the bottom of Table 3 are the model's between person random effects indicating the extent to which children vary from each other in initial level of SSRT and change over time in SSRT (after accounting for the predictors in the model). ABC, Attachment and Biobehavioral Catch-Up; DEF, Developmental Education for Families; WJ-Cognitive, Woodcock Johnson Test of Cognitive Abilities, Brief Ability Index score.

[a]All p-values are two-tailed except in the case of variances, where one-tailed p-values are used (because variances are constrained to be non-negative).

[b]Confidence intervals for variances were computed using the Satterthwaite method (see Littell, Milliken, Stroup, Wolfinger, & Oliver, 2006).

[c]WJ-Cognitive Score effects are the same for each reference group.

[d]Wave (time) is coded as follows: Age 8 data collection = 1, Age 10 data collection = 2.

participants, 28 did not complete the IQ test at age 9, and therefore they were excluded from the sample. The final 10-year-sample included 108 children: 30 in the ABC group, 39 in the DEF group, and 39 in the low-risk group. The groups did not differ significantly in age ($F(2, 105) = 0.414$, $p = 0.662$) or gender distribution ($\chi 2$ (2, $N = 108$) = 0.958, $p = 0.619$).

The analytic sample included 129 participants with at least one valid SSRT value (at age 8, 10, or both) and a WJ-Cog BIA score. Of the 129 participants, 86 had valid SSRT values at age 8, 108 at 10 years of age, 65 (ABC = 21 participants, DEF = 20 participants, COMP = 24 participants) had values at both age 8 and 10, and all of the participants had a WJ-Cog BIA score at age 9.

3.2 | Integration Method Model Results of Response Inhibition Change Over Time

We fitted a LGCM that allows for the estimation of a random intercept and a random rate of change (slope) over time. To bolster the assumption that the missing data were missing at random

(Enders, 2010), we included gender, family income, and maternal educational background at ages 8 and 10 as auxiliary variables in our model. Results were unaffected by the auxiliary variables which suggests that the probability of missingness in our dataset is unrelated to SSRT outcomes. The results are detailed in Table 3 and the central findings are illustrated in Figure 3. Consistent with our initial hypotheses, we found a significant difference in SSRT at age 8 between the ABC (M_{ABC} = 307.68, SE_{ABC} = 24.16) and the DEF intervention (M_{DEF} = 391.38, SE_{DEF} = 22.83) groups. Specifically, the average SSRT for children in the ABC intervention group was significantly shorter than the average SSRT for children in the DEF group, suggesting better inhibitory control in the ABC group at age 8 (*Cohen's d* = 0.92). Average SSRT values for the ABC and the low-risk comparison (M_{COMP} = 330.61, SE_{COMP} = 19.54) groups did not differ significantly from each other at age 8. Children in the DEF group and children from the low-risk group showed statistically significant decreases in SSRT between ages 8 and 10, whereas the ABC group did not show a significant change in SSRT between age 8 and age 10. The three groups did not differ significantly from each other at age 10. The DEF group demonstrated significantly more improvement over time than the ABC group but not significantly more than the low-risk comparison group. Using Maximum Likelihood Estimation, we completed supplementary analyses in Mplus that allowed us to include children with missing IQ data in our analyses by estimating their IQ or SSRT scores. The results were identical to the results presented above (see Supplementary Table S1 for more details).

In order to further examine the difference in SSRT between groups, we completed subsequent analyses using Bayesian Parameter Estimation. We used the BEESTS software with trigger failures to estimate the Ex-Gaussian parameters (μ, σ, and τ; for more information on these parameters and the software, see Matzke et al., 2013) and completed Bayesian ANOVAs using the JASP software (JASP Team, 2020) to assess group differences (van den Bergh, et al., 2019). The Bayesian SSRT estimates were very similar to those computed using the integration method, with the DEF group showing a longer SSRT than the ABC and the low risk group at age 8. At age 10, the SSRT in the DEF group remained longer than the SSRT in the low risk group. The SSRT in the ABC group at age 10 was intermediate and did not differ from either of the other two groups. We did not find group differences in the probability of trigger failures or distributional differences on any of the Go-trial parameters at age 8 or 10, both of which are thought to be associated with attentional fluctuations. Group differences were observed on stop trials, with the DEF group showing faster μ at age 8 (but not age 10) but a larger value of τ as compared to the ABC and the low risk group at age 8 and compared to the low risk group at age 10. The τ values very closely reflected the Bayesian SSRT computations at both ages. See Supplementary Tables S2 and S3 for descriptive statistics of the ex-Gaussian hierarchical Bayesian model parameters at ages 8 and 10 and Supplementary Table S4 for the model results.

4 | DISCUSSION

The present study investigated the long-term efficacy of a 10-session parenting intervention delivered in infancy on response inhibition among children in middle childhood with histories of CPS involvement. Our results indicate that children who participated in the ABC intervention in infancy had better response inhibition than children in the DEF group at 8 years of age. Moreover, the ABC group's performance was not significantly different from the low-risk comparison group at both timepoints. Significant group differences did not emerge at age 10 when SSRT was computed using the integration method. Finally, the DEF and low-risk comparison groups of children showed significant improvement in their response inhibition over time and the difference in the rates of change between the three groups was not statistically significant. Our complementary analyses using Bayesian techniques were conducted to explore parameters of the ex-Gaussian distribution believed to best describe RT distributions. Although there is, at present, no known correspondence between specific ex-Gaussian parameters and specific cognitive processes (Logan et al., 2014), we chose to employ a procedure that accounts for trigger failures (failure to process either the stop or go signal) which can bias SSRT computation and may indicate attentional variability rather than inhibitory processes (Matzke et al., 2017). With no between-group differences in the probability of trigger failures or other attention sensitive parameters associated with the go reaction time (Go RT) distribution, it is tempting to think of tau, our most group-sensitive parameter, as most closely related to the inhibitory processes reflected in the SSRT. This conclusion, of course, begs confirmation by additional research. Considered together, these results extend the evidence base of the ABC intervention and demonstrate that participation in the ABC intervention reduced the gap in inhibitory control typically seen between high- and low-risk children.

Early adversity predisposes children to vulnerabilities across multiple domains of functioning that commonly manifest in poor behavioral control and self-regulation during middle childhood (Cicchetti & Dawson, 2002; Cicchetti & Handley, 2019; Masten & Cicchetti, 2010; Nelson, Zeenah, & Fox, 2019). Poor inhibitory control during middle childhood is associated with a wide range of negative outcomes, including poor academic achievement (Allan et al., 2014), internalizing problems (McLaughlin et al., 2017), aggressive, disruptive, and substance-use problems (Cicchetti & Handley, 2019), and impairment in peer relations (Holmes et al., 2016). Results of the present study suggest that the ABC intervention may disrupt this cascade of negative developmental outcomes by improving inhibitory control during middle childhood. This is a hopeful insight as it points to an effective tool for enhancing the course of development among adversity-exposed children.

Although intervention effects were detected at age 8, these effects were not seen at age 10. Instead, the DEF group achieved inhibitory control capabilities that were not significantly different from the ABC and low-risk groups by age 10. The reasons behind this improvement among children in the DEF group are unclear but it is possible that these children experienced an initial delay

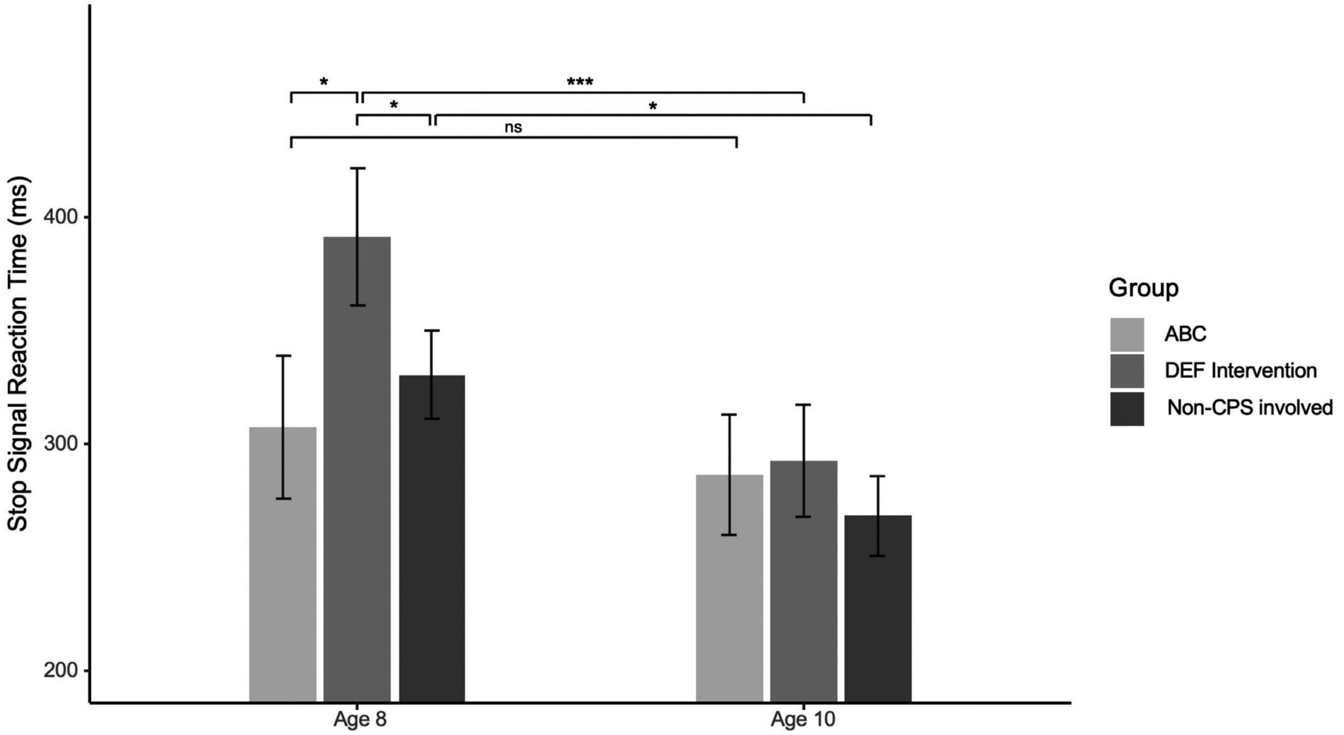

FIGURE 3 Marginal mean differences and longitudinal changes in SSRT outcome at age 8 and 10. Larger SSRT values represent worse response inhibition. ABC, Attachment and Biobehavioral Catch-up; DEF, Developmental Education for Families. *$p < 0.05$. ***$p < 0.001$.

and subsequent catch-up in cortical maturational factors. In the Bucharest Early Intervention Project, Wade et al. (2019) found a similar pattern of change from age 8 to adolescence in children's visual-spatial memory and new learning capability. Specifically, children in the foster care group showed an increased rate of improvement over time as compared to the never institutionalized group and the care as usual group. These findings along with our results demonstrate that some catch up in executive function outcomes is possible over time. Moreover, in a recent study Bick et al. (2019) found that the children in the DEF group showed electrophysiological profiles characteristic of cortical immaturity relative to the ABC and the low-risk group at age 8. Cortical maturational lag is an indicator of disrupted developmental timing in the emergence of cognitive modalities, with the cognitive performance of a child with maturational delays resembling the performance of a younger child (Levy, 2018; Vanderwert et al., 2016). Therefore, it might be that due to delayed cortical maturation, children in the DEF intervention group displayed poorer performance on the SSRT task at age 8 but were not significantly delayed by age 10.

The present study has limitations that are important to note. Prior research suggests that different types of early-life adversities (abuse vs. neglect) have differential impact on development, which supports the use of complex, multivariate approaches to study the developmental impact of early adversities (Lambert et al., 2017; McLaughlin & Sharidan, 2016). Information about the type, severity, frequency, and timing of adversity would have allowed us to test more nuanced models about the complex associations between the nature of adversity and its consequences on inhibitory control.

In sum, the present study adds to the evidence base supporting the efficacy of the ABC intervention—a short, 10-session parenting program designed to increase parental sensitivity and responsiveness. Results indicate that the ABC intervention has long-lasting beneficial effects on CPS-involved children's inhibitory control many years after its implementation. The findings also suggest that early parenting interventions can accelerate the development of self-regulatory capacities and can possibly prevent a cascade of social, emotional, cognitive, and behavioral problems among children exposed to early adversity.

CONFLICT OF INTEREST

The authors have no conflicts of interest to report.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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