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RESEARCH ARTICLE

Conversation disruptions in early childhood predict executive functioning development: A longitudinal study

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Abstract: Conversational turn-taking is a complex communicative skill that requires both linguistic and executive functioning (EF) skills, including processing input while simultaneously forming and inhibiting responses until one's turn. Adult-child turn-taking predicts children's linguistic, cognitive, and socioemotional development. However, little is understood about how disruptions to temporal contingency in turn-taking, such as interruptions and overlapping speech, relate to cognitive outcomes, and how these relationships may vary across developmental contexts. In a longitudinal sample of 275 socioeconomically diverse mother-child dyads (children 50% male, 65% White), we conducted pre-registered examinations of whether the frequency of dyads' conversational disruption during free play when children were 3 years old related to children's executive functioning (EF; 9 months later), self-regulation skills (18 months later), and externalizing psychopathology in early adolescence (age 10–12 years). Contrary to hypotheses, more conversational disruptions significantly predicted *higher* inhibition skills, controlling for sex, age, income-to-needs (ITN), and language ability. Results were driven by maternal disruptions of the child's speech, and could not be explained by measures of overall talkativeness or interactiveness. Exploratory analyses revealed that ITN moderated these relationships, such that the positive effect of disruptions on inhibition was strongest for children from lower ITN backgrounds. We discuss how adult-driven "cooperative overlap" may serve as a form of engaged participation that supports cognition and behavior in certain cultural contexts.

KEYWORDS
conversational turns, discourse analysis, executive function, externalizing, socioeconomic status

1 | INTRODUCTION

Children's early language input from caregivers is associated with linguistic, cognitive, and affective developmental outcomes (Rowe & Snow, 2020). Language input can be indexed by quantitative measures, such as the number of words or utterances spoken to a child, and by qualitative measures, such as the level of interaction in a conversation and how linguistically and conceptually appropriate the conversation is for the child's developmental stage (Rowe & Snow, 2020). While both input quantity and quality are related to cognitive development, the quality of language input tends to be a stronger determinant (for review, see Anderson et al., 2021).

Conversational turn-taking is an important facet of the interactive domain of qualitative language experience. Successful turn-taking is characterized by both temporal contingency (the pattern of passing off who is speaking) and semantic contingency (maintaining the conversational topic across turns) (Casillas, 2014). Temporal exchanges happen very rapidly, with an average of 250 ms between turns in a conversation between native speakers (De Ruiter et al., 2006). Maintaining temporal and semantic contingency during turn-taking is cognitively demanding,

as speakers must monitor the timing and topic of the conversation, predict when their interlocutor(s) will stop talking, and plan their response all within milliseconds (Casillas, 2014). Despite these demands, children rapidly develop turn-taking skills. This begins pre-verbally, as even young infants exhibit contingent turn-taking through cooing back and forth with adults (Gratier et al., 2015; Hilbrink et al., 2015). Turn-taking continues to develop with practice throughout infancy and early childhood, with increased semantic and temporal contingency.

Turn-taking in childhood has been linked to linguistic development. More frequent adult-child turn-taking is associated with better language development, above other well-studied factors such as parental education and family income (Gilkerson et al., 2018; Romeo et al., 2018; Zimmerman et al., 2009). Higher socioeconomic status (SES) is often associated with higher scores across many domains of cognitive development, which is often mediated both by children's language input and their own language skills (Lurie et al., 2021; Romeo et al., 2018, 2022; von Stumm et al., 2020). In children from low-SES backgrounds, joint engagement, shared routines, and fluent and connected turn-taking are associated with decreased disparities in language development (Hirsh-Pasek et al., 2015).

Adult-child turn-taking is also related to non-linguistic domains of cognitive development. Executive functions (EF) refer to a range of cognitive skills that help individuals monitor and control their behavior, such as inhibiting automatic responses, holding information in mind and manipulating it as needed, flexibility in switching tasks, and responding to changes in the environment (Miyake et al., 2000). Development of EF in childhood is supported by scaffolding and learning involvement from caregivers (Bernier et al., 2010; Bibok et al., 2009; Merz et al., 2017). Specifically, contingent conversation with caregivers supports early EF development both directly and indirectly through children's language skills (Masek et al., 2021, 2022). While the direct mechanism is unclear, it is possible that the temporal contingency of turn-taking requires inhibiting one's response until the prior speaker has finished their turn, while the semantic contingency requires cognitive flexibility to keep up with changing topics throughout a conversation (e.g., Merz et al., 2017; Raver, 1996). By facilitating the development of EF skills, turn-taking may ultimately support a number of cognitive outcomes, such higher academic achievement (Cortés Pascual et al., 2019; Noble et al., 2005).

Self-regulation, or a child's ability to manage their emotions and behaviors to promote long-term goals, occurs successfully when a child is motivated to understand expectations and change their behavior (Duckworth & Steinberg, 2015; Hofmann et al., 2012). While the relation between EF and self-regulation is debated, an emerging viewpoint posits that the development of EF precedes and aids successful self-regulation by supporting the ability to change behavior (e.g., by inhibition and flexibility), and hold information about expectations and motivations in mind (e.g., by working memory) (Hofmann et al., 2012). In support of this view, studies with adults show that fluctuations in EF correspond with changes in self-regulation, such that decreased EF capacity due to high cognitive load decreases self-regulatory behaviors, and increased EF capacity from intervention training increases self-regulatory behaviors (see Hofmann et al., 2012 for a review). Although EF and self-regulation appear related, evidence strongly shows that EF and self-regulation are at least "partly separable" and have unique impacts on development (Chevalier et al., 2022).

Research Highlights

In 3-year-olds, more frequent disruptions in mother-child conversations predicted better inhibition skills 9 months later, and positive outcomes were primarily driven by maternal disruptions of the child's speech.

These relationships were marginally moderated by family income-to-needs, such that conversational disruptions were only positively associated with inhibition skills in lower-income families.

Findings suggest nuance in defining "conversational turns" and encourage a deeper, more inclusive investigation of how parent-child communication supports development across diverse participants and contexts.

Adult-child turn-taking may contribute to positive development of self-regulation, both directly and indirectly. Few studies on adult-child turn-taking include self-regulation specifically as an outcome; however, turn-taking cultivates the development of socioemotional skills similar to self-regulation, such as goal-directed emotion regulation, emotion communication under distress, and empathic responses (Gómez & Strasser, 2021; Raver, 1996). The association between turn-taking and these socioemotional skills is likely driven by joint attention, synchrony, and engagement between the two speakers that occurs in adult-child dyads with frequent turn-taking (Gómez & Strasser, 2021). Given the strong effect turn-taking has on these socioemotional skills, turn-taking likely has a direct positive impact on self-regulation. Additionally, turn-taking may have an indirect impact on self-regulation development through the development of language ability. Increased language ability in general allows children increased understanding of and access to their emotions and behavioral expectations, which supports effective regulation of behaviors in service of goals (Salmon et al., 2016). Finally, there may also be an indirect pathway from turn-taking to self-regulation through EF.

Recent evidence suggests that adult-child turn-taking also decreases risk for externalizing psychopathology (King et al., 2021). Externalizing psychopathology, often considered the behavioral manifestation of low self-regulation, includes behaviors such as aggression, poor impulse control, and inattention, which are common in conditions such as attention deficit hyperactivity disorder, oppositional defiant disorder, and conduct disorder. For most children, externalizing symptoms are at their peak at around age 2, as EFs are just beginning to emerge. As EFs mature, children are equipped with more skills to down-regulate externalizing behaviors, and most children show a drop-off in these behaviors (Hosch et al., 2021; Perry et al., 2018; Schoemaker et al., 2013). However, when EF and self-regulation do not

develop sufficiently, externalizing behaviors persist (Hosch et al., 2021; Perry et al., 2018; Schoemaker et al., 2013). While early cognitive and socioemotional predictors of externalizing psychopathology have been well studied, there is little longitudinal research on how turn-taking may scaffold self-regulation and externalizing psychopathology either directly or through EF.

Despite this burgeoning literature on the importance of early adult-child turn-taking for early child development, most studies thus far have focused either on the frequency of turn-taking—as is measured by Language ENvironment Analysis (LENA), a common tool for collecting measures of children's language environment (Ganek & Eriks-Brophy, 2018; Gilkerson et al., 2017)—or on features of semantic contingency, such as whether the adult responds to the child's conceptual focus. Few, if any, have investigated the role of temporal contingency on developmental outcomes. Throughout early childhood, children exhibit decreased frequency of temporal disruption (i.e., interrupting or overlapping the speech of another) (Gratier et al., 2015; Hilbrink et al., 2015). However, the frequency of temporal disruption remains high in child speech, with about 20% of turns overlapping temporally with a prior speaker (Gratier et al., 2015; Hilbrink et al., 2015), although there is great individual variation. In one view, conversational disruption may represent a failure of verbal inhibition, which suggests that more frequent disruptions could predict worse EF, either as a function of the child's own inhibitory failure, or through social modeling by caregivers. Disruptions by both children and their caregivers may inhibit the practice of turn-taking and limit its positive impacts on cognitive and socioemotional development discussed previously, which may increase the risk for externalizing psychopathology. In another view, temporal disruptions to turn-taking may not necessarily indicate a breakdown of contingency in the conversation. For example, a speaker may disrupt the conversation by overlapping or interrupting another speaker in a way that signals attention (e.g. "Yeah!"), referred to as "back-channeling" (Yngve, 1970). In this view, more frequent conversation disruptions may scaffold attention and predict higher EF and self-regulation, and less externalizing.

In the present pre-registered study, we explore whether dyadic conversation disruptions in early childhood are associated with executive functioning, self-regulation, and externalizing psychopathology in a large, longitudinal socioeconomically diverse sample of mother-child dyads over the course of 8 years. Specifically, we investigate whether conversational disruptions by both speakers as a proportion of total utterances at age 3 are associated with EF (9 months later), self-regulation in early childhood (18 months later), and externalizing in early adolescence (7–9 years later). We hypothesize that more frequent conversation disruptions by both speakers will be related to lower EF, lower self-regulation, and more externalizing symptoms, and that difficulties with EF will mediate the association between disruptions and self-regulation or externalizing psychopathology. Additionally, exploratory analyses examine whether any associations are driven by mother- or child-initiated disruptions, and how relationships vary across income-to-needs (ITN).

2 | METHODS

2.1 | Participants

Participants were drawn from a longitudinal study of children ($n = 306$, 152 males) and their mothers in the Seattle area, which was designed to investigate the impact of SES on the development of effortful control in preschool (Lengua et al., 2015). Participants were initially recruited at 3 years old (T1, M = 3.07 years, SD = 0.07), with follow-up visits 9 months later (T2, M = 3.84 years, SD = 0.09), 18 months later (T3, M = 4.59 years, SD = 0.09), and 8 years later (T4, M = 11.47, SD = 0.47). Measures of interest were drawn from sequential time points to allow for longitudinal mediation analyses. The present study includes the sub-sample of participants who successfully completed a parent-child interaction task at the first measurement ($n = 286$). Of those 286, participants were excluded if their parent-child interactions were mostly in a language other than English ($n = 9$), if there was a second child present ($n = 1$), or if the child got sick during the recording ($n = 1$), for a final sample of 275 mother-child dyads (137 males). Mothers reported their child's race and ethnicity by selecting all that applied from the following: White or European American ($n = 249$), Black or African American ($n = 39$), Latino or Hispanic ($n = 34$), Asian ($n = 20$), Native American or Native Alaskan ($n = 22$), and Native Hawaiian or Pacific Islander ($n = 9$) (note $n = 77$ selected multiple races/ethnicities). Although race and ethnicity are reported for descriptive purposes, neither is used as an independent variable or covariate based on current best practices in favor of more proximal potential explanatory factors (APA Task Force on Race and Ethnicity Guidelines in Psychology, 2019; Helms et al., 2005).

2.2 | Conversation disruptions

At T1, children and their mothers were videotaped during a 7-min free-play session in which they were instructed to play with their child as they normally would, with any toys available. Videos were transcribed verbatim at the utterance level using CHAT, a standardized set of conventions and principles for transcription from the Child Language Data Exchange System (CHILDES; MacWhinney, 2000). Per these conventions, overlaps are marked at the beginning of utterances that overlap with the previous speaker's utterance, and interruptions are marked at the end of utterances that are interrupted by another speaker. Conversation disruptions were operationalized as the total number of utterance overlaps and interruptions by either speaker as a proportion of total utterances during the videotaped interaction. In planned exploratory analyses, disruptions were further split into mother-initiated disruptions, where the mother interrupted or overlapped the child, and child-initiated disruptions, where the child interrupted or overlapped the mother. Utterances where the speakers overlapped because they were singing or talking in unison were not counted. When an interrupted utterance was followed by an overlap,

only the interruption was counted. Thus, the responsibility of the disruption always fell upon the second speaker.

2.3 | Language skills

Children's language skills at T1 were measured by the Comprehension of Instructions subtest of the NEPSY-II (Korkman et al., 2007), in which children point to the appropriate picture in response to oral instructions of increasing semantic and syntactic complexity. Task performance was the proportion of correct trials out of 33 total trials, with higher scores indicating better performance.

2.4 | Executive functioning

EF was measured at T2 from tasks assessing cognitive and behavioral inhibition and cognitive flexibility. Behavioral inhibition was measured by the first two sections of the Head, Toes, Knees, Shoulders task (Ponitz et al., 2009). In this task, participants are asked to touch the opposite body part of what is said (e.g. touch toes when asked to touch head). Behaviors were coded as 0 if they touched an incorrect body part, 1 if they self-corrected, or 2 if they touched the correct body part. Task performance was the total score across all 20 trials as the proportion correct of the total possible score (40 points). Cognitive inhibition was measured by the Day/Night task (Gerstadt et al., 1994). In this task, participants are asked to say "day" when shown a picture of moon/stars and "night" when shown a picture of the sun. Task performance was the proportion of correct trials out of 16 total trials. Cognitive flexibility was measured by the Dimensional Card Sort task (Zelazo, 2006), in which participants are presented with a series of cards with bivalent images varying in shape and color. They are asked to sort first by shape (pre-switch trials), then by color (post-switch trials), and finally by both dimensions as cued at the beginning of a trial (mixed trials). Task performance was the proportion of correct trials out of the total 36 trials. For all EF tasks, higher scores indicate better performance. $N = 262$ parent-child dyads participated in the visit at T2, however 29 participants had unusable behavioral inhibition data, 40 participants had unusable cognitive inhibition data, and 40 participants had unusable cognitive flexibility data. Data were excluded if the child was non-compliant (e.g., refused to participate, quit the task early, etc.), if the childs performance was impeded in some way (e.g., they did not understand the instructions, did not know the necessary verbal responses, etc.), or for experimenter error (e.g., early discontinue, did not administer enough practice trials, etc.). Additionally, assessments with <80% valid responses (i.e., not skipped because of child or experimenter error) were excluded.

2.5 | Self-regulation

Self-regulation at T3 was measured by the Self-Control subscale of the Social Skills Rating System (SSRS-P), a standardized parent-report questionnaire that assesses child social behaviors and serves as a robust early indicator of later externalizing psychopathology (Vazsonyi & Huang, 2010). This scale assesses the frequency of 10 self-control behaviors (e.g., controls temper, follows directions) rated on a scale of 0 (never), 1 (sometimes), and 2 (always) (Gresham & Elliott, 1990). Following the scoring guide, if two or fewer responses were missing, they were replaced with a 1, but if more than two responses were missing, a score was not calculated. Item scores were summed, for a possible score of 0 to 20. Higher scores indicate higher self-regulation. $N = 264$ parent-children participated in the visit at T3 and all had usable data on the SSRS.

2.6 | Externalizing psychopathology

Externalizing at T4 was measured by parental report and youth self-report on the Childhood Behavioral Checklist and Youth Self Report (CBCL/YSR; Achenbach & Rescorla, 2001), a standardized, norm-referenced 113-item scale of behavioral and emotional problems in children and adolescents. A symptom was counted if either the parent, child, or both endorsed it, which is a standard approach for diagnosing psychopathology in population-based studies of children and adolescents (Kessler et al., 2012). The outcome of interest was the age- and gender-normed T-score on the broadband externalizing scale, which combines items from rule-breaking behavior and aggressive behavior subscales, with higher scores indicating more symptoms of externalizing psychopathology. $N = 209$ parent-children participated in the visit at T4 and reported usable data on the CBCL/YSR.

2.7 | Income to needs

At T1, mothers reported total family income (inclusive of wages, investments, child support/alimony, and state/federal aid) in 14 bins calibrated to correspond to the federal poverty guidelines at T1 (2009–2010) ranging from less than $14,570 to more than $150,000. Bins were recoded to the median value except for the lowest and highest bins, which were assigned $7285 (center of $0-14,570) and $150,000, respectively. Parents also reported the number of family members dependent on that income (inclusive of all adults and children), from which the federal poverty threshold for a family of that size was determined. A family's income-to-needs (ITN) ratio, a component of SES, was calculated as the ratio of the total family income to the federal poverty level, such that values less than one indicate income below the poverty line, and values greater than one indicate income above the poverty line.

2.8 | Statistical analysis

The analysis plan was preregistered at https://osf.io/td4mf. All statistical analyses were conducted in R version 4.2.1 (2022-06-23). To investigate whether T1 disruptions were associated with EF, self-regulation, and externalizing symptoms, we estimate a series of linear

regressions, controlling for child sex, family ITN, and child age at the time of the outcome measure. Outcomes include T2 EF measures (including both inhibition measures and cognitive flexibility), T3 self-regulation, and T4 externalizing. FDR-corrections were implemented at the level of the hypothesis, and thus corrected for the presence of two inhibition measures. We also completed sensitivity analyses additionally controlled for children's T1 language skills, which have been found to prospectively relate to EF skills in this sample (Romeo et al., 2022). Planned exploratory analyses further split the disruptions by speaker to investigate whether mother-initiated or child-initiated disruptions drive any effects.

The next set of analyses examined whether T2 EF measures mediate associations of T1 disruption frequency with T3 self-regulation and T4 externalizing. Bootstrapped mediation models with 5000 repetitions and bias-corrected confidence intervals were estimated. Indirect effects were estimated even in absence of significant direct effects, as consistent with modern best practices (Hayes, 2009; Rucker et al., 2011).

To account for missing data, participants who had missing data for a given predictor, moderator, or outcome variable were excluded from analyses involving that variable (listwise deletion).

2.9 | Exploratory analysis

After conducting the pre-registered analyses, we additionally conducted several exploratory analyses to examine unexpected results. First, we looked at total number of utterances and number of speaker exchanges as separate predictors of our outcomes of interest. Second, we included maternal interactiveness as an additional covariate for sensitivity analyses. Videos were also globally coded for the maternal interactiveness, including verbal engagement, showing interest in the interaction, degree of eye contact, physical proximity, and/or affection on a scale of 0 to 5. Scores of 0 indicates that the parent was not engaged with the child or the interaction at all, whereas scores of 5 indicates that the parent both initiated and responded eagerly and consistently to the child (modified from Cowan & Cowen, 1992; Rubin & Cheah, 2000). Interactiveness was coded in 1-min epochs and then averaged across the full 7 min. Inter-rater reliability was assessed by independent double-coding of 20% of videos, and the mean ICC was 0.85 (range 0.80–0.90). Third, to investigate whether the links between disruptions and relevant outcomes varies as a function of ITN, we examined ITN as a potential moderator of each association. Finally, to contextualize the robustness of the main results of interest, we use the MASS package in R to calculate iterated re-weighted least squares (IRLS) with Huber weights.

3 | RESULTS

3.1 | Frequency of disruptions

Table 1 shows descriptive statistics and Table 2 shows zero-order correlations among all variables of interest. During the 7-min free-play, families averaged 174.19 utterances (SD = 41.36, min = 67, max = 402) and on average there were 8.12 disruptions (SD = 5.4, min = 0, max = 31), for an average of 4% of utterances disrupted (SD = 2%, min = 0%, max = 13%; Figure 1).

3.2 | Conversational disruptions, executive function, and externalizing symptoms

Contrary to predictions, after controlling for covariates, conversation disruptions were *positively* associated with T2 behavioral inhibition (B = 1.58, SE = 0.69, $p = 0.02$, FDR adjusted $p = 0.02$; robust $p = .01$, Figure 2a) and T2 cognitive inhibition (B = 2.08, SE = 0.78, $p = 0.008$, FDR adjusted $p = 0.02$; robust $p = 0.004$, Figure 2b), but were not significantly associated with T2 cognitive flexibility (B = 0.70, SE = 0.58, $p = 0.23$; Figure 2c). More frequent disruptions were marginally associated with higher T3 self-regulation (B = 11.93, SE = 7.29, $p = 0.10$; robust $p = 0.08$, Figure 2d) and lower T4 externalizing (B = −39.00, SE = 22.70, $p = 0.09$, robust $p = 0.07$; Figure 2e).

3.3 | Sensitivity analyses

When additionally controlling for T1 language ability, disruptions were still associated with higher T2 behavioral inhibition (B = 1.30, SE = 0.62, $p = 0.04$, FDR adjusted $p = 0.04$, robust $p = 0.04$) and higher T2 cognitive inhibition (B = 1.93, SE = 0.78, $p = 0.01$, FDR adjusted $p = 0.03$, robust $p = 0.008$) and marginally associated with higher T3 self-regulation (B = 12.01, SE = 7.34, $p = 0.10$, robust $p = 0.07$) and lower T4 externalizing (B = −39.41, SE = 22.78, $p = 0.09$, robust $p = 0.06$). When controlling for language ability, the association between disruptions and T2 cognitive flexibility remained insignificant (B = 0.53, SE = 0.51, $p = 0.29$).

3.4 | Mediation models

Although T1 disruptions were only marginally associated with T3 self-regulation and T4 externalizing, we still examined potential indirect effects through T2 EF based on current recommendations for mediation analysis (Hayes, 2009; Rucker et al., 2011). There were no significant indirect effects of conversation disruptions on T3 self-regulation through T1 behavioral inhibition (95% CI [−1.30, 5.06], $p = 0.44$), cognitive inhibition (95% CI [−7.90, 1.36], $p = 0.22$), or cognitive flexibility (95% CI [−1.88, 1.59], $p = 0.99$). There were also no significant indirect effects of conversation disruptions on T4 externalizing through T1 behavioral inhibition (95% CI [−18.46, 2.82], $p = 0.27$), cognitive inhibition (95% CI [−14.79, 10.31], $p = 0.72$), or cognitive flexibility (95% CI [−3.79, 4.45], $p = 0.95$).

3.5 | Disruptions by speaker

Disruptions caused by the mother and disruptions caused by the child were positively correlated ($r(273) = 0.37$, $p < 0.01$). When both are

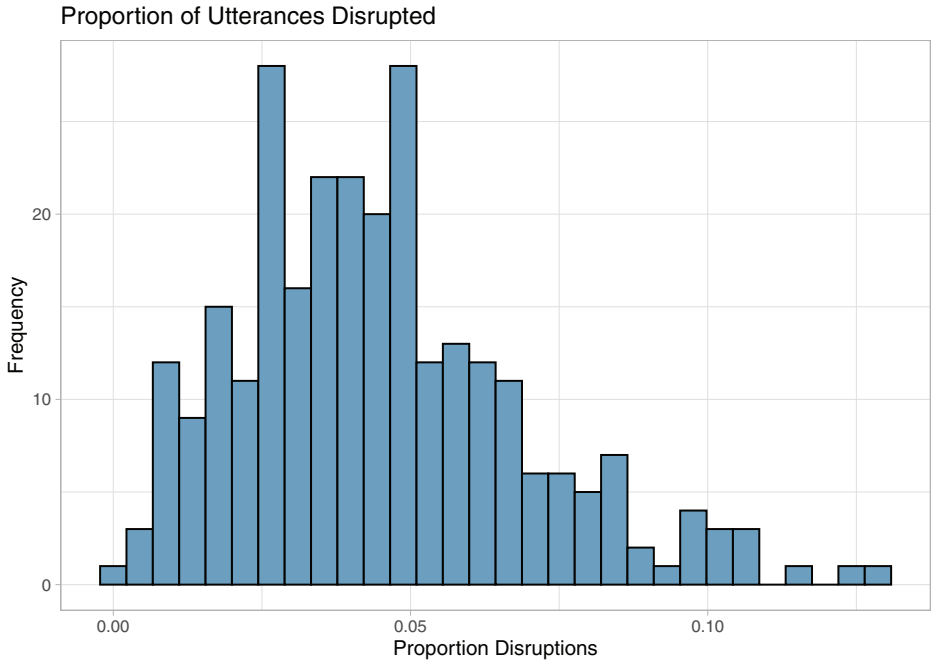

FIGURE 1 Histogram of proportion conversation disruptions across all participating dyads.

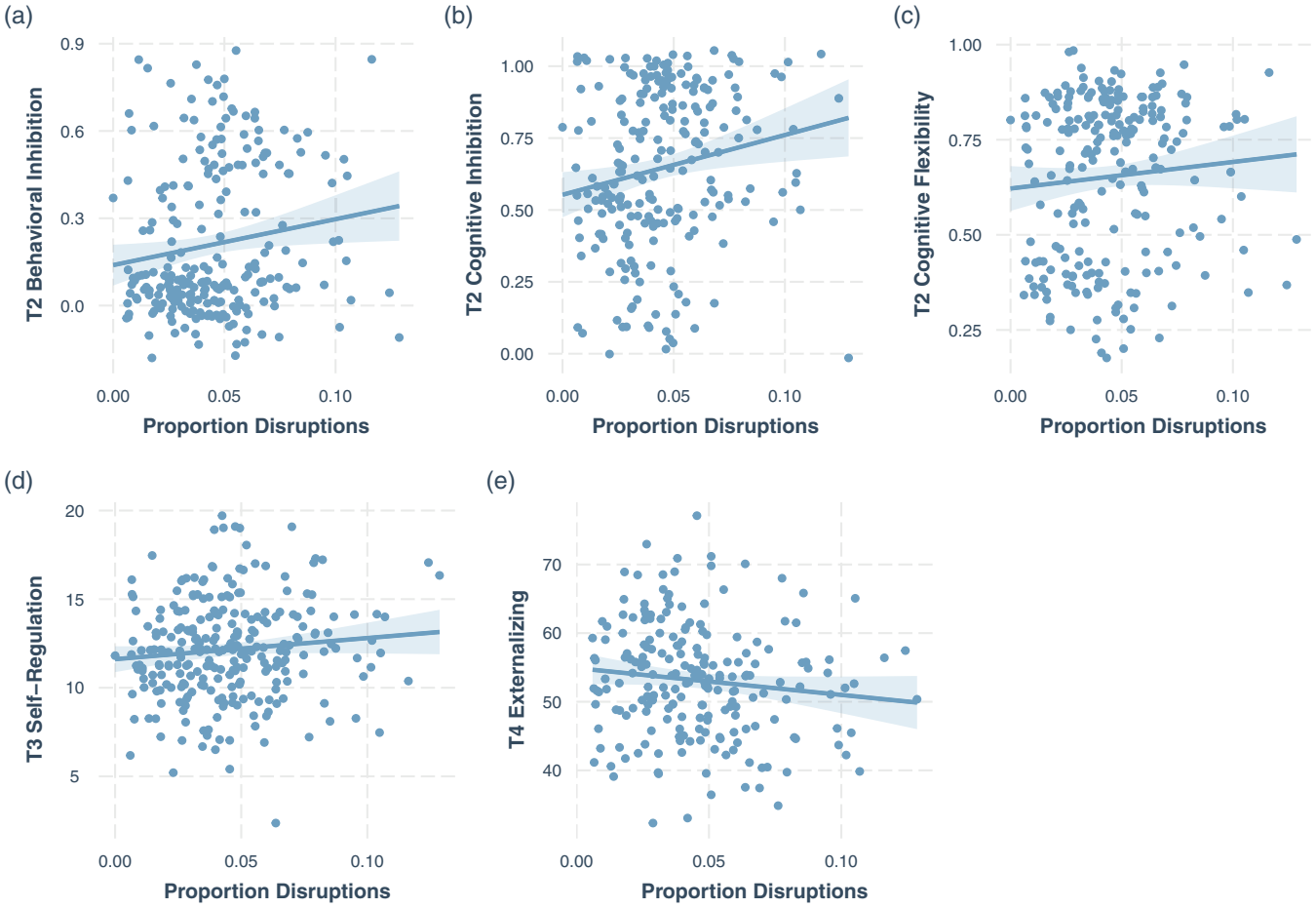

FIGURE 2 Executive function, self-regulation, and externalizing outcomes as a function of early conversational disruptions. Outcomes are partial residuals after controlling for ITN, sex, and age at outcome measures.

TABLE 1 Descriptive statistics for all variables of interest.

	n	M	SD	Skewness	Kurtosis	Range
Total proportion disruptions	275	0.04	0.02	0.78	3.55	0.0–0.13
Mother proportion disruptions	275	0.03	0.02	0.60	3.06	0.0–0.08
Child proportion disruptions	275	0.02	0.01	1.13	4.72	0.0–0.07
Income-to-needs	275	2.93	1.90	0.76	2.80	0.22–8.19
T2 behavioral inhibition	233	0.21	0.27	0.90	2.32	0.0–1.0
T2 cognitive inhibition	222	0.65	0.28	−0.45	2.26	0.0–0.85
T2 cognitive flexibility	222	0.65	0.22	−0.60	1.70	0.17–1.0
T3 self-regulation	264	7.84	2.83	−0.01	3.40	2–20
T4 externalizing	209	53.11	8.47	0.14	2.87	33–80

included in regression models, only maternal disruptions were associated with T2 behavioral inhibition (B = 3.46, SE = 1.16, $p < 0.003$, adjusted $p = 0.006$, robust $p = 0.001$) and T2 cognitive inhibition (B = 2.49, SE = 1.27, $p = 0.05$, adjusted $p = 0.05$, robust $p = 0.04$), and were marginally associated with T2 cognitive flexibility (B = 1.63, SE = 0.98, $p = 0.10$, robust $p = 0.09$) and T3 self-regulation (B = 19.63, SE = 11.78, $p = 0.10$, robust $p = 0.06$). Child disruptions were not significantly associated with any outcomes (all $p > 0.32$). Neither maternal disruptions nor child disruptions were associated with T4 externalizing psychopathology when both were included in the same model (both $p > 0.13$).

3.6 | Exploratory analyses

Given the unexpected direction of our findings (more frequent disruptions being associated with better outcomes), we additionally conducted exploratory analyses not described in the preregistration to investigate potential explanatory variables and moderators. We examined total number of utterances and total number of speaker exchanges ("turns") as predictors of our outcome measures, and neither significantly predicted EF, self-regulation, or externalizing (all $p > .19$). We also looked at maternal interactiveness as a potential predictor. Conversation disruptions and maternal interactiveness were positively related, $r(273) = 0.20$, $p = 0.001$. When additionally controlling for maternal interactiveness as a covariate, disruptions still were associated with higher T2 behavioral inhibition (B = 1.56, SE = 0.71, $p = 0.03$, adjusted $p = 0.03$, robust $p = 0.02$) and T2 cognitive inhibition (B = 1.85, SE = 0.79, $p = 0.02$, adjusted $p = 0.03$, robust $p = 0.009$), and were marginally associated with T4 externalizing psychopathology (B = −37.83, SE = 23.08, $p = 0.10$, robust $p = 0.08$). Thus, the relationship between disruptions and relevant outcomes was not explained by increased interactiveness (and in most cases, relationships with interactiveness were explained by disruptions).

Finally, we investigated whether ITN moderated the relationship between disruptions and outcomes by including an interaction term between disruptions and ITN in all regressions, controlling for sex and age at outcome. Interactions between disruptions and ITN were marginally associated with T2 behavioral inhibition (B = −0.72, SE = 0.34, $p = 0.04$, adjusted $p = 0.06$, robust $p = 0.03$; Figure 3a), T2 cognitive inhibition (B = −0.71, SE = 0.38, $p = 0.06$; adjusted $p = 0.06$, robust $p = 0.13$; Figure 3b), and T2 cognitive flexibility (B = −0.52, SE = 0.29, $p = 0.07$, robust $p = 0.08$; Figure 3c). Simple slopes analyses revealed that for all interactions, disruptions were more strongly associated with EF outcomes for children from lower ITN backgrounds, while there were reduced or absent relationships between disruptions and EF for children from higher ITN backgrounds. Interaction terms were not significant for T3 self-regulation nor T4 externalizing (all $p > 0.55$; Figure 3d,e). No interaction results changed if variables were mean centered prior to regression.

4 | DISCUSSION

The present study examined prospective relationships between the frequency of mother-child conversational disruptions and later EF, self-regulation, and externalizing psychopathology. Across dyads, temporal disruptions were fairly common; however there was also wide variability across dyads. Surprisingly, more frequent disruptions when children were 3 years were associated with *greater* inhibition EF. These associations were primarily driven by maternal disruptions, and were marginally moderated by ITN, such that the positive associations of disruptions with EF were stronger for children from lower ITN backgrounds.

These findings add to the growing literature on the role of early adult-child conversational interaction in shaping EF and psychological development (Gómez & Strasser, 2021; King et al., 2021; Masek et al., 2021, 2022; Salmon et al., 2016), which largely reports that more frequent adult-child turn-taking predicts better EF and socioemotional skills. Notably, instead of focusing purely on the frequency of conversational turns, we focused on temporal contingency and temporal disruption as a proportion of total utterances. Contrary to predictions, more conversational disruptions, especially by the mother, were related to better inhibition. One possible explanation is that more overlap in a conversation was not a breakdown of temporal contingency per se, but instead indicated that these dyads had faster processing

TABLE 2 Zero-order correlations among all variables of interest.

	Total proportion disruptions	Mother proportion disruptions	Child proportion disruptions	Income-to-needs	T2 behavioral inhibition	T2 cognitive inhibition	T2 cognitive flexibility	T3 self-regulation	T4 externalizing
Total proportion disruptions	1								
Mother proportion disruptions	0.87*	1							
Child proportion disruptions	0.78*	0.37*	1						
Income-to-needs	0.05*	0.05*	0.03*	1					
T2 behavioral inhibition	0.16*	0.21*	0.05*	0.22*	1				
T2 cognitive inhibition	0.18*	0.17*	0.13*	0.13*	0.25*	1			
T2 cognitive flexibility	0.10*	0.14*	0.03*	0.28*	0.43*	0.21*	1		
T3 self-regulation	0.10*	0.11*	0.05*	0.11*	0.12*	−0.03*	0.10*	1	
T4 externalizing	−0.13*	−0.13*	−0.08*	−0.23*	−0.16*	−0.03*	−0.10*	−0.37*	1

*$p < 0.05$.

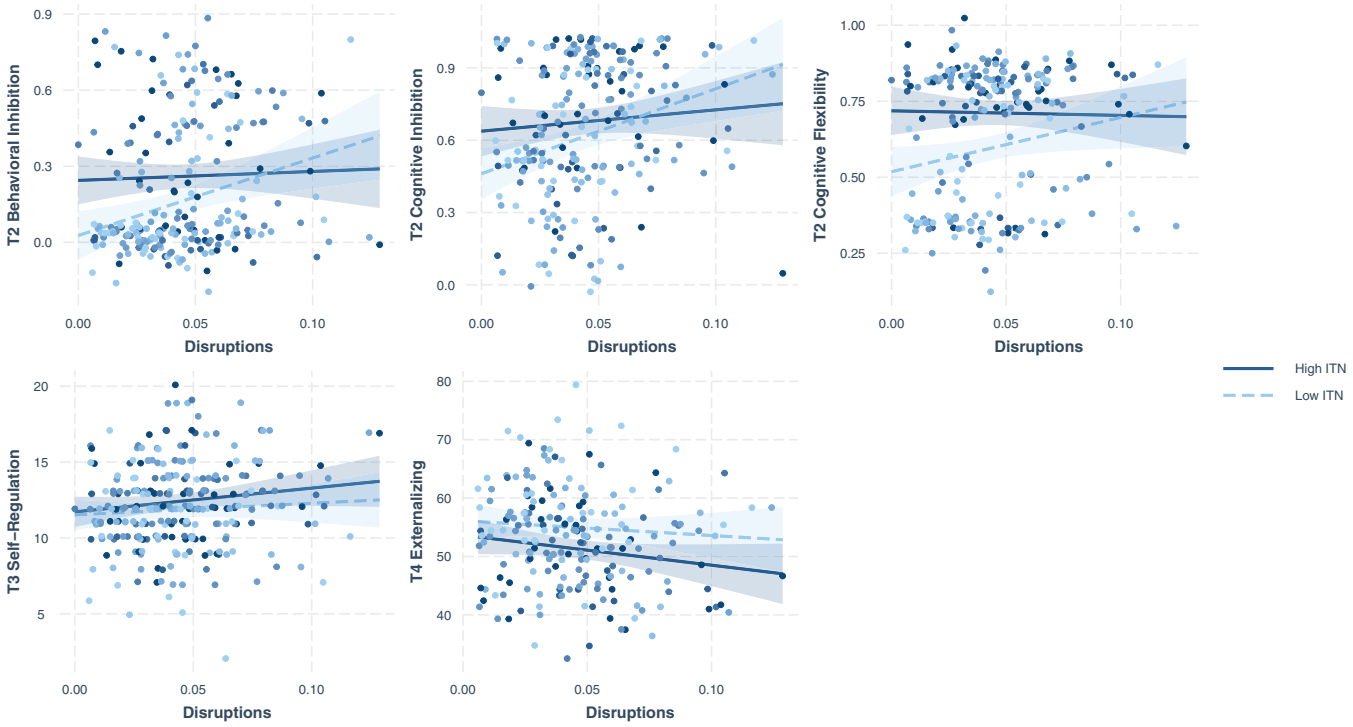

FIGURE 3 Executive function, self-regulation, and externalizing outcomes as a function of conversational disruptions and ITN. Outcome variables are partial residuals after controlling for sex and age. Points are represented on a continuous color scale by ITN, such that darker blue reflects higher ITN, while lighter blue reflets lower ITN. Best-fit regression lines show a median split on ITN for visualization purposes; however, ITN was treated continuously for analyses.

speeds and therefore needed less time between turns to plan their responses. It is also possible that disruptions actually scaffold inhibition skills, such that when a parent interrupts a child, the child must inhibit their response to let their parent speak. In this way, children with more disruptive parents may learn inhibitory skills more quickly.

An alternative explanation, and in our view the most likely, is that disruptions as measured here are a proxy for verbal engagement and synchronous attention in the conversation, such that disruptions are "cooperative" and function as a signal that the disrupter was paying attention while continuing the semantic contingency of the conversation. In discourse analysis, this is referred to as "back-channeling," when a listener uses verbal and non-verbal cues to indicate attention without taking the conversational turn of the speaker (Yngve, 1970). Notably, the effect of disruptions was not explained by a general measure of maternal interactiveness, so this account would suggest that there is something uniquely positive about *verbal* back-channeling. This suggests that semantic contingency may outweigh the importance of temporal contingency in conversational turn-taking, though further research is needed to qualitatively describe and categorize types of cooperative and uncooperative disruptions to directly compare their influence on cognitive development.

Furthermore, marginal results indicate the positive influence of disruptions was not consistent across participants from varying ITN backgrounds. Specifically, disruptions had a stronger positive association with inhibition for children from lower ITN backgrounds, and a minimal association in children from higher ITN backgrounds. Low ITN is often negatively associated with EF, however proximal caregiver engagement and interaction in conversation and other aspects of a child's daily life may protect against these negative effects (Lurie et al., 2021; Merz et al., 2017). The present findings are consistent with this literature, suggesting that frequent disruptions during parent-child conversations may help to buffer against the negative influence of low ITN on EF. Indeed, lower ITN children with the most disruptions exhibited EF skills on par with their higher ITN peers. This adds additional support to the interpretation that disruptions are a proxy for verbal engagement, and that having a caregiver who exhibits high levels of this engagement is protective for children from lower ITN backgrounds who may otherwise be at risk for reduced EF. However, these results should be intepreted with caution, since interaction terms for inhibition*ITN and cognitive flexibility*ITN were just above the conventional significance threshold ($p = 0.06$ and $p = 0.07$, respectively), and thus further research is needed to replicate these findings.

Interestingly, conversational disruptions were not strongly related to self-regulation 18 months later or to early adolescent externalizing psychopathology, nor were early EF skills related to these outcomes either. This contributes to a growing body of literature that executive function and self-regulation, although conceptually related, are at least "partly separable" constructs, however it does not support the hypothesis that EF contributes to the development of self-regulation (Chevalier et al., 2022; Hofmann et al., 2012). Further, it suggests that preschool EF (at least that measured by lab-based tasks) may not

be a strong predictor of externalizing symptoms. Further research is needed to determine whether parent-reported measures of children's EF skills in real-world functioning would be a better predictor, and if this is in any way related to parent-child conversational dynamics.

There are several noteworthy limitations of this study. First, measures of conversation disruptions were recorded from a 7-min free play interaction between children and their mothers in a laboratory setting where participants knew they were being recorded, which may have led to particular demand characteristics which would be less present in a naturalistic context. Additionally, 7 min is short period of time, and although prior research suggests that this time scale is sufficient to achieve internal consistency in interactional features (Leech et al., 2018; Tamis-LeMonda et al., 2017), it is possible that longer recordings in more ecologically valid scenarios might yield different patterns. Second, the present measure of disruptions quantified the frequency of overlapping and/or interrupted speech as a proportion of total utterances, but did not take into account the duration of overlapping speech. It is possible that there are differential influences of shorter versus longer overlaps, and/or how quickly the interrupted prior speaker stops talking (if at all). Additionally, although this analysis excluded utterances spoken or sung in unison, we do not otherwise characterize the content of the overlapping/disrupted utterances to determine how this may potentially affect the influence of the disruptions. Finally, although the racial, ethnic, and socioeconomic diversity of participants represents the geographic location where the study was conducted, it may not be representative of patterns found in other sociodemographic contexts. Further research is especially needed in other cultures and linguistic traditions with differing views of conversational disruption and parent-child conversation more broadly. Despite these limitations, this study still provides novel insight on the role of temporal contingency in parent-child conversation on multiple developmental outcomes, and motivates future studies both replicating our findings and extending the literature on temporal contingency. Given turns with overlapping speech are not distnguished from turns without overlap by Language ENvironment Analysis (LENA), one of the most common tools for collecting naturalistic linguistic data (Ganek & Eriks-Brophy, 2018; Hilbrink et al., 2015), developing better technology for measuring temporal contingency is also a future direction of this work.

In conclusion, we find unexpected positive relationships between conversational disruptions and the development of inhibitory control. Importantly, given the rapidly expanding literature on conversational turn-taking and its impact on multiple developmental domains, these findings suggest caution in restrictive conceptualizations of idealized conversation and what constitutes a conversational turn. We encourage future research to investigate multiple dimensions of conversational turn-taking to better understand how early linguistic interaction supports cognitive and affective development across diverse participants and contexts.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest to declare.

DATA AVAILABILITY STATEMENT

All code and statistical output required to replicate these analyses is found at https://osf.io/732xz/. The preregistration is also found in this repository. The data that support the findings of this study are available on request from the corresponding author.

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