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ORIGINAL ARTICLE

Inhibitory Control in Early Childhood Aggression Subtypes: Mediation by Irritability

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Abstract

The present study tested irritability as a mediator of inhibitory control's (IC) associations with crossed form and function aggression subtypes over one year in early childhood ($N = 300$, $M_{age} = 44.70$ months, $SD = 4.38$ months). We hypothesized lower IC would predict increases in irritability, which would in turn predict increases in aggression overall (severity) and a predominance of reactive over proactive subtypes (directionality), and considered moderation by gender. Irritability mediated IC's relations in the predicted direction for physical severity for girls only and relational severity for both genders. Lower IC predicted increases in irritability, which in turn predicted increasing predominance of reactive over proactive physical and relational aggression. The predicted indirect effect was significant for physical but not relational directionality. Findings highlight the viability of directionality scores for disentangling these effects, and that developmental associations between IC, irritability, and reactive functions of aggression are evident in early childhood.

Keywords Inhibitory control · Irritability · Aggression · Early childhood

Aggression, defined as actions intended to hurt or harm another [1], is associated with negative outcomes across psychological, social, and academic domains [e.g., 2]. It is known to have correlated but distinct physical (e.g., kicking, hitting, shoving) and relational (e.g., social exclusion) forms, with physical aggression serving as the modal form for boys, and relational aggression as the modal form for girls [3, 4]. Both forms of aggression can be expressed proactively to achieve instrumental goals or reactively in response to a perceived threat [4]. These forms and functions can be crossed to create four aggression subtypes (i.e., proactive and reactive physical aggression, proactive and reactive relational aggression) with distinct developmental correlates and outcomes [5, 6]. For example, reactive functions of aggression tend to be both predicted by and predictive of dysregulated negative emotionality, whereas proactive aggression tends to be associated with fearlessness, disruptions in moral development, and later antisocial behavior [e.g., 5–8]. Aggressive behavior is especially common in early childhood [9]. It may also be particularly impactful during this time, as developing social connections and learning to navigate peer interactions is considered a key developmental task during this period [10], and peer difficulties including conflict, antagonism, and relational aggression emerge during this time [11]. Therefore, disruptions to the establishment of peer competence in early childhood through the engagement in aggressive behavior may place children particularly at risk for maladaptive developmental trajectories across domains [10]. Together, from a developmental psychopathology perspective, this makes early childhood a particularly important period for understanding mechanisms behind the development of aggression [10].

Inhibitory control (IC) and irritability also show measurable change in early childhood, despite being relatively stable at later ages [e.g., 12–14]. A component of both executive functioning (EF) and temperamental effortful control (EC) constructs, inhibitory control (IC) involves the ability to intentionally inhibit behaviors that are incompatible with task goals, instruction, or expectation [14–16]. Irritability, defined as a low threshold for experiencing anger in response to frustration or threat [17, 18], is considered a facet of negative affectivity coupled with higher approach and appetitive reward tendencies [17–20]. Lower IC is associated with higher levels of trait anger in early childhood [e.g., 14, 21], and has been implicated in both the longitudinal course of

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irritability [18] and as a maintaining mechanism of high levels of irritability [17, 22–24].

In turn, both poor IC and higher irritability are associated with aggression generally, and have theorized and empirically-supported differential associations with aggression subtypes [e.g., 8, 25]. However, these distinctions have been inconsistent in young children [e.g., 26–28]. This is potentially due to the high co-occurrence of aggression subtypes in early childhood, which may be addressed through the use of aggression severity and directionality scores reflecting the overall level/amount of aggression (i.e., severity), and the predominance of one function relative to the other (i.e., directionality) within form [29, 30]. This study tests a model whereby difficulties learning to inhibit prepotent behavioral responses (i.e., poor IC) make it more difficult for children to learn to regulate negative emotional tendencies and avoid frustrative situations (i.e., irritability), which is in turn associated with higher levels of aggression, using severity and directionality scores [29] to disentangle theoretically distinct associations between aggression subtypes. Specifically, it was hypothesized that poorer IC would be associated with increases in irritability, which would in turn predict increases in aggression overall (severity), and growing predominance of reactive over proactive subtypes (directionality).

Inhibitory Control and Aggression

Executive functioning deficits broadly and poor IC specifically have well-documented associations with higher levels of aggression and externalizing behavior in early childhood [e.g., 27, 31–33]. IC abilities improve rapidly during early childhood, occurring with development of the prefrontal cortex (PFC) during this developmental period [13, 16]. These increases in IC occur simultaneously with mean decreases in aggressive behavior and externalizing problems [34]. Given the impulsive, dysregulated nature of reactive aggression, and consistent with frustration-aggression hypotheses [e.g., 7, 35], IC deficits are theorized to be associated particularly with reactive functions of aggression. Indeed, specific associations between deficits in IC and related constructs (i.e., EF, EC) with higher levels of reactive aggression have been well-supported in past work [e.g., 36–39]. However, these prior studies have focused on primarily middle-childhood and adolescent samples, and none specifically considered physical and relational forms of aggression.

Some work has suggested that IC's role in aggression may differ for physical and relational forms, including in early childhood [40]. However, only one study to our knowledge [27] has considered IC's role in crossed form and function aggression subtypes in early childhood, and found lower inhibition abilities were associated with higher levels of all subtypes of aggression. However, this study was cross-sectional and did not account for the co-occurrence of aggression subtypes in models [27]. Together, this work suggests that poor IC may be especially associated with reactive functions of aggression, but more work is needed to understand how this may extend to form and function subtypes, especially in early childhood.

Irritability

Irritability is distributed continuously in the population, with higher levels considered a risk factor for negative outcomes across a variety of domains [12, 17, 22]. Like aggression, normative levels of irritability peak in early childhood and decline, co-occurring with neurodevelopment associated with improving IC [18, 23, 41]. Additionally, lower IC is associated with poorer emotion regulation in early childhood [13, 24], and negative correlations between IC and dispositional frustration/anger are well-established [e.g., 14, 21, 24]. Indeed, a recent study using functional near infrared spectroscopy (fNIRS) with preschoolers found PFC activation during an IC task was specifically associated with irritability, above and beyond any other temperament construct [42]. Furthermore, prior work has implicated deficits in IC as a maintaining mechanism of irritability [e.g., 17, 23, 24], and suggested a causal relation between poor IC and increases in irritability. Specifically, poor EF abilities, including IC, make it more difficult for children to learn to modulate their displays of negative emotional responses broadly, increasing them over time [18]. Deficits in IC in particular have been theorized to limit children's abilities to inhibit approach impulses toward frustrating situations, resulting in increasing affective experiences of frustration and associated temper outbursts [23, 43].

Irritability, in turn, is consistently associated with higher levels of aggression [e.g., 25], as well as increasing externalizing problems longitudinally at low levels of IC [18, 44]. Consistent with frustration models of aggression [e.g., 7, 35], irritability and anger have stronger associations with reactive than proactive aggression theoretically and empirically at older ages [e.g., 5, 17, 25, 45]. However, previous work in early childhood has not found expected associations, especially when both form and function of aggressive behavior are taken into account. For example, Ostrov and colleagues found anger to be associated with proactive and reactive physical aggression and proactive relational aggression, but not reactive relational aggression, in early childhood [26].

Two known studies have examined IC, irritability or related constructs, and aggression in early childhood. Temperamental anger and IC were found to interact in predicting general

aggression in early childhood in one study [31], but no significant simple slopes were found. In another study, high levels of negative emotionality were associated with more physical aggression for boys with lower than average levels of IC [33]. However, neither of these studies considered functions or relational forms of aggression, which could have masked effects due to the theorized differential associations by function of aggression [e.g., 5, 17]. Furthermore, both studies were cross-sectional and therefore could not examine directionality of effects.

Aggression Severity and Directionality

Prior work in early childhood has failed to find expected distinct associations between IC, irritability and related constructs, and functions of aggression, prompting suggestions that these distinctions may not emerge consistently until later ages when aggressive behavior becomes more specialized [e.g., 8, 27, 46]. Alternatively, past studies may have been unable to statistically detect these differential associations due to high intercorrelation of functions of aggression generally [5], and during this developmental period [e.g., 40].

The use of directionality and severity scores may help disentangle distinct associations between IC, irritability, and subtypes of aggression while accounting for high levels of overlap of these behaviors. Extending the aggression directionality and severity scores approach championed by Essex and colleagues [29] to examine aggression functions in addition to forms, physical and relational severity scores were created using an average of subscale z-scores across functions (i.e., $[z_{proactive} + z_{reactive}]/2$), whereas directionality scores were created by taking the half difference across functions (i.e., $[z_{reactive} - z_{proactive}]/2$). This creates two orthogonal variables for each form of aggression, one reflecting the overall level/amount of aggression (i.e., relational and physical severity), and the other reflecting the predominance of one function relative to the other (i.e., relational and physical directionality) [29, 30]. Importantly, the use of these variables allows for the consideration of what these aggression subtypes share, as well as what differentiates them, while mitigating concerns surrounding loss of power and unstable results due to collinearity if they are included as separate variables in the same model [29].

Current Study

In sum, the present study aimed to test irritability as a mediator of IC's associations with aggression subtypes, using aggression severity and directionality scores to disentangle theorized distinct associations among these constructs. Specifically, it was hypothesized that lower IC would predict increases in irritability, which would in turn predict increasing levels of aggression overall, and an increasing predominance of reactive over proactive subtypes. Additionally, theory and empirical work has demonstrated gender differences in displays of aggressive behavior, with relational aggression the modal form of aggression for girls and physical aggression modal for boys [e.g., 3, 4, 47]. Risk factors for aggression, such as IC and irritability, have also been found to be stronger predictors of modal forms of aggression within gender, including in early childhood [e.g., 27, 28, 31]. Therefore, this study tests gender as a moderator of hypothesized models, predicting that associations with relational aggression severity and directionality would be stronger for girls than for boys. This was done in a developmental period critical for learning to navigate social relationships (i.e., early childhood) [10], during which there are rapid improvements in IC abilities [e.g., 13] and measurable change in both irritability levels [12] and aggressive behavior [34]. Furthermore, the present study considers both form and function of aggression, which has been largely neglected in past work, and uses a short-term longitudinal design with largely independent reporters for each construct to provide a stringent test of hypothesized indirect effects of IC to aggression through irritability.

Methods

Participants and Procedures

Four cohorts were recruited over a four-year period through partnerships with ten National Association for the Education of Young Children (NAEYC) accredited or recently accredited early childhood education centers in a large northeastern city and surrounding suburbs. Each year, information and consent forms were distributed to families of all children in participating preschool classrooms by teachers. Ultimately, approximately 56% of eligible families returned consent forms to participate in the study; no potential participants who returned consents were excluded from participating. Cohorts were merged to create a final sample of 300 preschoolers ($n = 132$ female), which was middle to upper-middle class on average and—although primarily white—included children from diverse ethnic and racial backgrounds (3.0% African American/Black, 7.6% Asian/Asian American/Pacific Islander, 1.0% Hispanic/Latinx, 11.3% multi-racial, 62.1% White, and 15.0% missing/unknown). Data were collected at three time points over two academic years/one calendar year [spring/summer of year 1 (T1), fall of year 2 (T2), and spring of year 2 (T3)]. At T1, children were between 3–4 years old (T1 $M_{age} = 44.70$ months, $SD = 4.38$ months) on average [for additional details, see 48].

All study procedures were approved by the local university institutional review board (IRB). The present study uses teacher and observer reports from T1, teacher reports at T2, and observer reports at T3. Although the larger study included parent report questionnaires at T1, these were available for only a subset of participants ($n = 157$), and were collected at different time points (i.e., T2) for some children. Additionally, due to changes in academic year, only a small minority ($n = 36$) of the sample had the same teacher completing questionnaires from T1 to T2, mitigating concerns surrounding shared method variance in path analyses. Therefore, we opted to use teacher reports only in the current study. Parents provided written consent for children's participation, and teachers provided written consent before completing teacher reports.

Measures

Inhibitory Control

Inhibitory control was measured using teacher report at T1 on the inhibitory control subscale of the Child Behavior Questionnaire–Short Form (CBQ-SF) [18, 49]. This subscale contains 6 items rated on a 7-point scale from 1 (*Extremely Untrue)* to 7 (*Extremely True*) averaged to create a subscale score (possible range 1.00–7.00). This scale has been used extensively, with documentation of reliability and validity of the larger measure [20] and short form [49]. In the present study, teacher report on this subscale at T1 showed good internal consistency (Cronbach's $\alpha = .80$). Furthermore, although limited available data precluded the use of parent report, teacher report significantly correlated with parent report ($r = .39$, $p < .001$).

Irritability

Irritability was assessed at T1 and T2 and was constructed as a composite from teacher reports on the Anger/Frustration subscale of the CBQ-SF [20, 49] and four items assessing displays of anger adapted from an observational method [45]. The Anger/Frustration subscale of the CBQ-TF [20, 49] contains six items assessing tendency to experience anger and frustration scored on a 1 (*Extremely Untrue*) to 7 (*Extremely True*) scale, averaged to create a subscale score. The scale contains items assessing tendency to experience frustration generally (e.g., "Gets angry when s/he can't find something s/he wants to play with") and within the context of limit-setting (e.g., "Gets quite frustrated when prevented from doing something s/he wants to do"), both of which are considered consistent with the present study's operationalization of irritability. The subscale has been validated [49] and has been used in studies measuring similar constructs in this age group [e.g., 12, 31]. Four items assessing displays of anger, adapted from an observational method [45], were also incorporated. The items include: "expresses anger with peers," "gets angry during play," "uses toys or classroom materials roughly (e.g., throwing toys or slamming toys down when frustrated)," and "displays frustration (e.g., swinging fist, hitting objects, hitting one's own head with the palm of the hand)." Each item is responded to on a 1 (*Never*) to 4 (*Almost Always*) scale and are averaged to create a subscale score.

Both measures showed good internal consistency at T1 and T2 (Cronbach's $\alpha s = .74–.91$), and moderate stability across time points ($rs = .46–.49$, $ps < .001$). Teacher reports on both forms were correlated significantly with parent report at T1 ($rs = .17–.24$, $ps < .05$), and scales were moderately correlated with each other at T1 ($r = .68$, $p < .001$) and T2 ($r = .59$, $p < .001$). Subscale scores were standardized and averaged to create irritability composites. The composite showed good internal consistency at T1 (Cronbach's $\alpha = .89$) and T2 (Cronbach's $\alpha = .86$). Additionally, all 10 items loaded significantly and substantially onto a single irritability factor at each time point, and these one-factor CFA models provided adequate fit to the data (see supplemental materials for details).

Aggression

Proactive and reactive physical and relational aggression were measured using observer reports on the Preschool Proactive and Reactive Aggression-Observer Report (PPRA-OR) at T1 and T3 [50]. This measure, adapted from a psychometrically-strong teacher report measure (PPRA-TR) [4], includes three items assessing each subtype of aggressive behavior (e.g., Proactive physical—"This child often hits, kicks or pushes to get what s/he wants"; Reactive relational—"When this child is upset with others, s/he will often ignore or stop talking to them"), rated from 1 (*Never or Almost Never True*) to 5 (*Always or Almost Always True*). Items were averaged within aggression subtype (possible range for each subtype = 1.00–5.00).

These reports were completed by trained undergraduate research assistants (RA's) after completing observations in classrooms. Specifically, using a focal child sampling with continuous recording procedure [51, 52], each child was observed during free play for approximately eight 10-min sessions over an eight-week period (80 min total at each time point). Observers recorded instances of children engaging in relational and physical aggression, as well as instances of victimization and prosocial behavior. These direct observations were reliable based on 15% which were independently coded by a second observer (ICCs = .62–.81). However, these direct observations did not include functions of aggression, and so were not used in the current study.

Following the conclusion of observations at each time point, one observer from each classroom was randomly selected to complete observer report questionnaires. Approximately 30 RA's completed these observer reports across the full study. Past work has found RA's to be reliable and valid reporters of children's behavior using similar procedures [50]. All subscales of the PPRA-OR showed good internal consistency at both time points (Cronbach's αs = .80–.91). Additionally, although concerns about restricted range prevented the use of direct observations, PPRA-OR scores were significantly correlated with observations of aggression at both time points (*r*s = .17–.32, *p*s < .05). Moreover, as expected and supporting our use of severity and directionality scores to address multicollinearity concerns among aggression subtypes, subscales on the PPRA-OR were highly correlated (*r*s = .83–.96, *p*s < .001).

Analytic Plan

Data were subject to a number of cleaning procedures prior to data analysis. Descriptive statistics were obtained, and outliers (i.e., scores greater than 3 standard deviations from the mean) were winsorized to this limit [53]. Proactive physical aggression had the largest number of outliers at both T1 ($n = 9$) and T3 ($n = 7$). No other variable had more than 4 outliers. After outliers were adjusted, standardized scores for aggression subtypes were saved, and directionality and severity scores were created for each form of aggression at each time point. Following procedures by Essex and colleagues [29], physical and relational severity scores were calculated by taking the average of subscale z-scores across functions (i.e., $[z_{\text{reactive}} + z_{\text{proactive}}]/2$), with higher scores indicating higher overall levels of physical and relational aggression. Directionality scores were calculated as the half difference across functions (i.e., $[z_{\text{reactive}} - z_{\text{proactive}}]/2$), with more positive scores indicating a greater predominance of reactive over proactive aggression (and negative scores indicating predominance of proactive aggression) within form.

All variables were then assessed for non-normality. Skew and kurtosis statistics were within normal limits as defined by Kline [53] (skew = − 1.02 to 2.31; kurtosis = − 0.33 to 4.75) with the exception of the kurtosis value for physical directionality at T1 (kurtosis = 14.86). We considered using maximum likelihood with robust standard errors (MLR) in Mplus to accommodate this kurtosis value. However, bootstrapping, which was considered critical for appropriately testing hypothesized indirect effects, is not available using MLR. Additionally, the T1 physical aggression directionality variable was included only in one model as an exogenous covariate, and associations with this variable were not central to the research question. Therefore, ML estimation was retained for all models.

Finally, data were also examined for systematic missingness. The majority of participants were retained through all three time points, with data missing for 29.3% ($n = 88$) from T1 to T2 and 35.3% ($n = 106$) from T1 to T3. The presence of missing data was anticipated given the longitudinal nature of the study, and occurred primarily during the transition between academic years. This was likely largely due to children moving to kindergarten, changing schools for reduced cost universal pre-kindergarten programs, or moving from the area. Additionally, due to administrative error, RA reports of aggression were unavailable for one cohort at T1 ($n = 126$), and another smaller cohort at T3 ($n = 18$). Little's MCAR test showed data were likely not missing completely at random [$\chi^2(80) = 101.06$, $p = .06$]. Missingness was not associated with significant differences on key predictor or outcome variables, gender, or age. Lower SES was associated with missingness at T2 [$t(82.70) = -2.27$, $p = .03$, $d = .37$] and T3 [$t(68.82) = -2.89$, $p = .005$, $d = .48$]. However, the current dataset used a limited measure of SES based on parent occupation which was also unavailable for 24% of participants ($n = 73$). School code was also associated with missingness at T2 [$\chi^2(9) = 26.84$, $p = .001$, Cramer's $V = .30$] and T3 [$\chi^2(9) = 38.54$, $p < .001$, Cramer's $V = .36$]. Further, schools significantly differed in proportions of high vs. low SES participants [$\chi^2(9) = 20.99$, $p = .01$, Cramer's $V = .27$], and school code was available for all participants. Therefore, consistent with prior adopted procedures [28], schools were rank ordered by proportion of high vs. low SES participants (based on a median split in parental occupation code), and this rank-ordered school code was included as a covariate. This school SES variable was in turn associated with missingness at T2 [$\chi^2(9) = 28.16$, $p = .001$, Cramer's $V = .31$] and T3 [$\chi^2(9) = 31.10$, $p < .001$, Cramer's $V = .32$]. As missingness was related to a known variable, missing data was accommodated using full information maximum likelihood (FIML) [54].

Path analyses were conducted in Mplus 8.4 [55] using maximum likelihood estimation (ML) and indirect effects testing to test mediation models. Models were run separately for severity and directionality scores, consistent with prior work [29, 30] and due to concerns surrounding limited power. In both models, T3 RA-reported aggression severity or directionality was regressed on T1 IC and T2 irritability, and T2 irritability was in turn regressed on T1 IC. T1 levels of aggression variables and irritability, as well as school SES, were included as covariates. Indirect effects were tested using 5000 bootstrap samples and 95% bias-corrected confidence intervals in conjunction with standardized indirect effect estimates [56, 57]. Gender was then entered as a grouping variable, and models were run with paths constrained to equivalence across gender. Paths were examined for gender differences using sequential use of modification indices [58], with values > 3.84 indicating significant

improvement in model fit if that path were freed to vary [59]. Initial path models were just-identified, and therefore fit statistics were not applicable. However, in overidentified models, overall model fit was assessed using a likelihood ratio χ^2 test with $p > .05$ indicating good model fit. The comparative fit index (CFI) [60], of which values > .95 suggest good fit, the standardized root mean square residual (SRMR), where values < .05 represent good fit [61] and the root mean square error of approximation (RMSEA) [62], where values < .06 indicate close fit [63, 64] were also considered.

Results

Preliminary Analyses

Bivariate correlations and descriptive statistics of predictor and outcome variables are presented in Table 1 (the same information with raw aggression variables can be found in Supplemental Table 1). Of note, irritability showed moderate stability from T1 to T2 and was negatively correlated with IC at both time points. Forms of aggression severity and directionality were correlated within time points (*r*s = .14–.50). IC at T1 was negatively correlated with T3 physical severity and directionality, indicating lower IC was associated with greater levels of physical aggression overall, and a predominance of reactive over proactive physical aggression. Finally, T2 irritability was positively correlated with T3 physical and relational severity and T3 physical directionality (i.e., associated with predominance of reactive physical aggression). Girls had higher levels of IC at T1 [$t(290) = -3.73$, $p < .001$, $d = .44$], and lower levels of irritability at T1 [$t(290) = 2.32$, $p = .02$, $d = .28$] and T2 [$t(209) = 3.80$, $p < .001$, $d = .54$]. Conversely, boys showed higher levels of physical aggression severity at T1 [$t(171) = 3.45$, $p = .001$, $d = .54$] and T3 [$t(190.84) = 2.31$, $p = .02$, $d = .33$]. There were no significant gender differences on any other predictor or outcome variables.

Severity Model

Standardized coefficients for the severity model are presented in Fig. 1. Models were just-identified. Consistent with predictions, lower IC was associated with increases in irritability from T1 to T2 (β = − 0.18, 95% CI [− 0.33, − 0.03], $p = 0.02$). Irritability, in turn, predicted increases in both physical (β = 0.19, 95% CI [0.03, 0.35], $p = 0.02$) and relational (β = 0.29, 95% CI [0.12, 0.45], $p = 0.001$) severity. IC did not predict significant increases in either form of aggression directly (βs = 0.03–0.05, *p*s = 0.60–0.77). Significant indirect effects emerged in the expected direction for relational (β = − 0.05, 95% CI [− 0.13, − 0.007]) but not physical (β = − 0.03, 95% CI [− 0.11, 0.00]) severity.

Gender was then entered as a grouping variable, with paths of interest constrained to equivalence. Fit statistics generally suggested the fully constrained model provided poor fit to the data [$\chi^2(5) = 13.38$, $p = 0.02$, CFI = 0.95, RMSEA = 0.11, SRMR = 0.03]. The highest theoretically meaningful modification index (MI) was for the parameter from T2 irritability to T3 physical severity (MI = 4.12). After freeing this path, a significant MI also emerged for freeing the path from T1 IC to T3 physical severity (MI = 3.91). With both of these paths freed, the model showed good fit to the data [$\chi^2(3) = 3.99$, $p = 0.26$, CFI = 0.99, RMSEA = 0.05, SRMR = 0.02]. In this model, contrary to predictions, higher T2 irritability predicted increases in physical aggression severity for girls (β = 0.46, 95% CI [0.17, 0.53], $p < 0.001$), but not boys (β = 0.11, 95% CI [− 0.09, 0.31], $p = 0.28$). Likewise, the indirect effect of lower IC predicting increases in physical aggression severity, mediated by higher levels of irritability, was significant for girls (β = − 0.08, 95% CI [− 0.28, − 0.002]) but not boys (β = − 0.02, 95% CI [− 0.08, 0.004]). Although not significant, there was a trend toward higher IC also predicting increases in physical aggression severity for girls directly, above and beyond the significant indirect effect (β = 0.24, 95% CI [− 0.002, 0.48], $p = 0.05$).

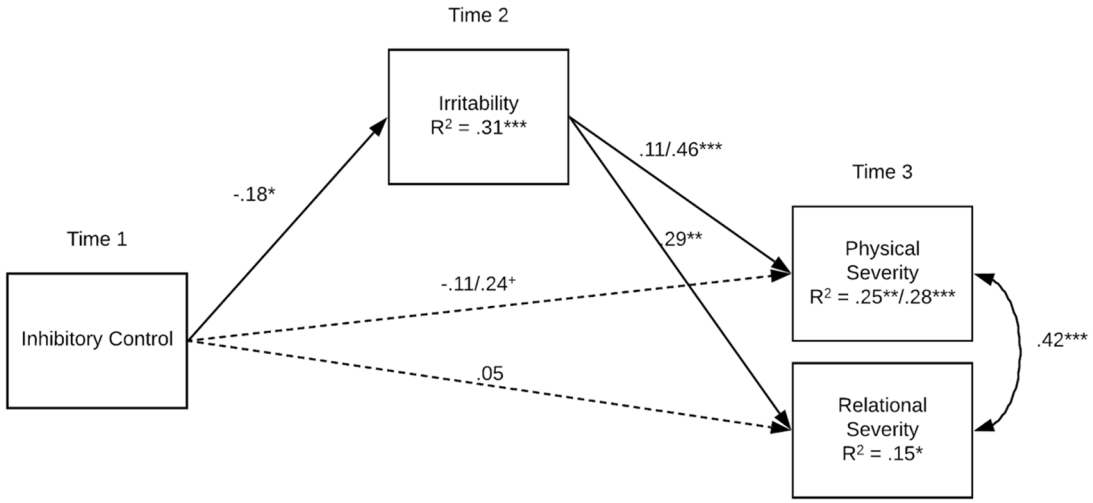
Directionality Models

Final standardized coefficients for the directionality model are presented in Fig. 2. Models were just-identified. As in the severity model, lower levels of IC predicted increases in irritability from T1 to T2 (β = − .25, 95% CI [− .36, − .09], $p = .001$). Consistent with predictions, higher T2 irritability predicted increasingly positive levels of physical (β = .20, 95% CI [.01, .11], $p = .02$) and relational (β = .19, 95% CI [.01, .12], $p = .03$) directionality, indicating higher levels of irritability predicted increasing predominance of reactive over proactive functions of both physical and relational aggression, respectively. Direct effects of IC on forms of directionality were nonsignificant (βs = −.16 to .09, *p*s = .10–.33). Bias-corrected bootstrapped confidence intervals showed the predicted indirect effect was significant for physical (β = − .05, 95% CI [− .14, − .002]) but not relational (β = -.05, 95% CI [-.15, .01]) directionality. In other words, lower levels of IC predicted increasing predominance of reactive over proactive physical aggression, mediated by increasing levels of irritability. With gender entered as a grouping variable, the constrained model showed excellent fit to the data [$\chi^2(5) = 2.42$, $p = .79$, CFI = 1.00, RMSEA = .00, SRMR = .01] and no significant (i.e., > 3.84) MI's were found, suggesting gender did not moderate any paths in this model.

Table 1 Bivariate correlations and descriptive statistics of key variables

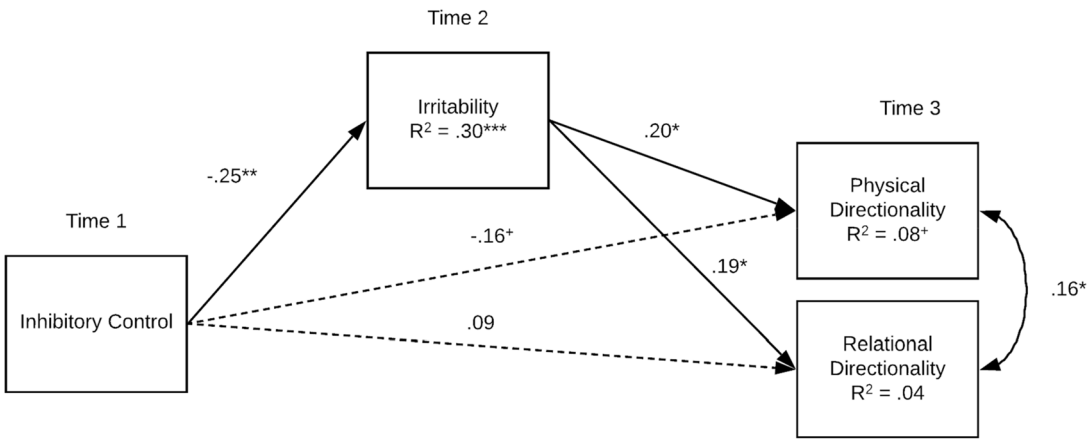
	1	2	3	4	5	6	7	8	9	10	11	12
1. School SES	–											
2. T1 IC	.23***	–										
3. T1 Irritability	− .10	− .59***	–									
4. T2 Irritability	− .02	− .41***	.46***	–								
5. T1 Phys Sev	.26***	− .30***	.26**	.31***	–							
6. T1 Rel Sev	.17*	− .08	.25**	.03	.35***	–						
7. T1 Phys Dir	.16*	− .05	.05	.24**	.00	− .08	–					
8. T1 Rel Dir	.26**	− .07	− .001	.08	− .01	.00	.14	–				
9. T3 Phys Sev	.12	− .18*	.37***	.30***	.08	− .05	.14	− .14	–			
10. T3 Rel Sev	.06	− .08	.25**	.28***	− .11	− .02	− .01	− .10	.50***	–		
11. T3 Phys Dir	− .07	− .17*	.08	.18*	.17	− .01	− .05	.04	.00	.001	–	
12. T3 Rel Dir	− .04	.07	− .07	.11	− .11	− .18	.02	.06	− .08	.00	.17*	–
M	5.17	4.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SD	2.36	1.18	0.91	0.89	0.96	0.96	0.29	0.29	0.96	0.96	0.27	0.28
Range	0.00 to 10.00	1.27 to 6.83	− 1.28 to 2.66	− 1.31 to 2.79	− 0.05 to 3.34	− 0.81 to 3.24	− 2.03 to 1.07	− 1.09 to 0.91	− 0.56 to 3.27	− 0.95 to 3.04	− 0.87 to 1.28	− 0.88 to 1.33

SES Socioeconomic status, *IC* Inhibitory control, *Rel* Relational, *Phys* Physical, *Sev* Aggression severity, *Dir* Aggression directionality. Positive directionality = predominance of reactive aggression. School SES is a rank-ordered school variable with higher values indicating higher SES (see main text). Means are zero for variables 3–12 because they were computed using standardized scores. Inhibitory control and irritability are teacher report, aggression severity and directionality are observer report. T1 = Time 1, T2 = Time 2, T3 = Time 3. *$p < .05$, **$p < .01$, ***$p < .001$



Note: Aggression severity is computed as ([$z_{reactive}$ + $z_{proactive}$]/2), with higher scores indicating higher levels of physical and relational aggression across function (see Analytic Plan in main text). Time 1 levels of mediation and outcome variables and school SES are statistically controlled. Solid lines are significant direct effects, dashed lines are nonsignificant. Slash values represent moderation of paths by gender, shown boys/girls. Indirect effects are significant predicting relational severity for both genders (95% CI [-.13, -.007]) and physical severity for girls only (95% CI [-.28, -.002]; see main text for details).
+$p < .10$, *$p < .05$, **$p < .01$, ***$p < .001$.

Fig. 1 Standardized regression coefficients for severity model



Note. Aggression directionality is computed as ([$z_{reactive}$ - $z_{proactive}$]/2), with more positive scores indicating greater predominance of reactive over proactive functions of physical and relational aggression (see Analytic Plan in main text). Time 1 levels of mediation and outcome variables and school SES are statistically controlled. Solid lines are significant direct effects, dashed lines are nonsignificant. Indirect effect is significant for predicting physical directionality only (95% CI [-.14, -.002]; see main text for details). +$p < .10$, *$p < .05$, **$p < .01$, ***$p < .001$.

Fig. 2 Standardized regression coefficients for directionality model

Discussion

This study examined irritability as a mediator of IC's associations with aggression using directionality and severity scores to disentangle theorized distinct associations between aggression subtypes. This was tested over approximately one calendar year with largely independent reporters at each time point. Consistent with predictions, lower IC predicted increases in irritability, and irritability predicted increases in both physical and relational aggression severity, as well as increasing predominance of reactive functions of aggression. However, mixed support was found for hypothesized indirect effects, and gender differences were contrary to expectations. Specifically, indirect effects emerged for poor IC, mediated by higher irritability, predicting increases in relational aggression severity and reactive physical aggression directionality for both genders, but physical aggression severity for girls only.

Findings that lower IC predicted increases in irritability are highly consistent with prior work demonstrating negative correlations between IC and trait anger [e.g., 14, 21, 24]. These findings also lend support to recent proposals that poor EF abilities, including IC, may make it more difficult for children to learn to modulate displays of negative emotions [18], and that deficits in IC in particular may limit children's abilities to inhibit approach impulses toward frustrating situations, resulting in increasing experiences of frustration [23]. These processes may be especially relevant and detectable during early childhood, given rapid changes in IC abilities and irritability during this time [e.g., 12, 14]. Furthermore, findings were consistent across two models, emerged for both boys and girls, and were detectable within a relatively short follow-up period, highlighting the potential robustness of this association.

Additionally, this study provided only the second known prospective examination of irritability and form and function aggression subtypes in early childhood. Consistent with prior work examining irritability and related constructs' associations with general aggression [31] and physical aggression [32] in early childhood, irritability predicted increases in overall levels (i.e., severity) of both physical and relational aggression. This highlights the potential role of irritability as an overall risk factor for higher levels of aggressive behaviors in early childhood. However, these associations were further clarified by the use of directionality scores, which showed irritability specifically predicted increasingly reactive displays of both physical and relational aggression. This is consistent with both theory and empirical work at older ages [e.g., 17, 25, 34, 35], suggesting irritability and related constructs specifically predict reactive, rather than proactive, functions of aggression. However, these specific associations have not been consistent in early childhood [e.g., 26, 28, 46], perhaps due to high levels of co-occurrence of these behaviors during this developmental period. The present study provides novel evidence that developmental associations between irritability and reactive functions of both physical and relational aggression are evident as early as the preschool years, and that directionality scores [29] may provide a viable option for disentangling these associations.

Some evidence emerged for hypothesized associations of poor IC predicting increases in aggression severity and reactive directionality indirectly through increases in irritability. Consistent with hypotheses, lower IC predicted increasing physical and relational aggression severity and increasingly reactive physical aggression directionality, through increasing irritability. This provides evidence for the emergence of a dysregulated, predominantly reactive pathway for engaging in aggressive behavior [e.g., 7, 18] in early childhood, especially for physical aggression. However, since indirect effects that reached statistical significance were of similar magnitude to nonsignificant indirect effects, conclusions regarding the relative theoretical importance of significant relative to nonsignificant indirect paths (i.e., predicting physical vs. relational directionality) await further investigation and replication.

That both indirect and direct irritability paths to increasing physical aggression severity were significant for girls, but not for boys, was contrary to hypotheses. Physical forms of aggression have been shown to be more common in boys, whereas relational forms are modal for girls [e.g., 3, 4]. However, some work has suggested that individuals showing higher levels of the non-modal form of aggression (i.e., physical aggression for girls, relational aggression for boys) show more psychosocial maladjustment [e.g., 47, 65]. Furthermore, prior work found reactive physical aggression, and no other aggressive subtypes, was specifically associated with higher levels of functional impairment in early childhood [66]. Therefore, the dysregulated pathway to aggression (i.e., poorer IC and higher levels of anger/frustration) highlighted in these models may predict increases in non-modal forms of aggression, especially for girls displaying reactive physical aggression. Additionally, this association may reflect that girls showed lower irritability than boys on average in this sample, such that high levels of irritability may also reflect a gender non-normative feature for girls and put them at-risk for aggressive behavior. Therefore, girls who are higher on irritability may be more likely to show this maladaptive outcome than boys and future work should continue to examine this intriguing possibility.

Limitations

The study's findings must be considered within the context of several methodological limitations. First, as detailed in the methods section, a significant number of participants were missing data on aggression at T1, and there was moderate attrition. Although missing data was accommodated using FIML, this likely reduced our ability to detect small effects in these models. In an effort to reduce model complexity related to these power concerns, and consistent with prior work [29, 30], we opted not to test aggression directionality and severity within the same models. Severity and directionality scores are orthogonal within form and time point, and bivariate correlations were generally not significant across these variables. However, including both directionality and severity scores in models could help further clarify associations.

Additionally, the use of teacher reports on the CBQ for both T1 levels of IC and T2 levels of irritability could raise concerns surrounding shared method variance. Although the majority of children had different teachers, and therefore different reporters, at T1 and T2, and irritability was constructed as a composite on two measures, the similarities in measurement could inflate associations. Furthermore, although the CBQ has been widely validated, behavioral assessments of IC are also widely used [e.g., 67], and could provide a more direct assessment of IC in future research. Past work has also demonstrated the relevance of additional EF and EC components, especially attentional regulation, in the regulation of internal emotional states, including negative emotionality [e.g., 43]. Information on attentional regulation was not collected in the present study; therefore, we were unable to examine the relative importance of IC and attentional regulation in increases in irritability and aggression. Replication efforts considering other EF and EC components, especially attentional regulation, are needed.

Finally, although our sample included participants from a variety of racial and ethnic backgrounds, it was predominantly white and middle to upper-middle class. Furthermore, all children were recruited from high-quality child care centers and represent a modest subset of eligible families who chose to participate, which may limit generalizability. Likewise, although clinical levels of emotional and behavioral problems were not exclusionary, the sample was primarily typically developing. Therefore, findings may not generalize to clinical samples.

Conclusions and Future Directions

Despite these limitations, this study has a number of strengths and novel findings with implications for future work. This study provided the first known examination of irritability as a potential mediator of IC's associations with crossed form and function subtypes of aggression in early childhood. The use of a short-term longitudinal design, with largely independent reporters at each time point, as well as accounting for initial levels of both mediator and outcome variables and alternate forms of aggression in all models, provided a stringent test of hypotheses.

This study also focused on early childhood, a potentially particularly relevant, yet often neglected, developmental period for the constructs of interest. Given rapid changes in IC development [e.g., 13], measurable change in irritability levels [12], and the importance of learning to navigate social relationships [10] during this developmental period, this is a particularly pertinent time for understanding directional relations among these constructs. Despite this, past work has focused largely on middle-childhood and adolescent samples when examining associations among these and related constructs [e.g., 36–39]. This study provides initial evidence that, in early childhood, poorer IC predicts increases in irritability levels, which in turn predicts increases in both physical and relational aggression levels overall, and an increasing predominance of reactive functions of aggression. Although indirect effects were small and inconsistent and suggestions of clinical relevance would be premature, findings are consistent with theory [e.g., 7, 18, 23], and deserve further investigation and replication.

Finally, the use of directionality and severity scores to examine overlapping and distinct associations across functions of aggression within relational and physical forms provided a novel examination of distinct associations among these constructs. As both poor IC and higher irritability have theorized and empirically supported predominant associations with reactive functions of aggression [e.g., 7, 25, 38], the ability to test distinct relations across aggression subtypes is critical for furthering our understanding of these constructs. Prior work has called for additional efforts to disentangle differential associations with functions of aggression [5], including in early childhood [e.g., 40]. This study provides novel, initial evidence that severity and directionality scores [29], may provide a viable way to examine these distinct associations which have remained elusive in previous work with related constructs in early childhood [e.g., 26, 27, 47]. Future work should continue to examine the viability of this method for examining distinct associations across functions of aggression, which may provide exciting opportunities to further develop our understanding of the development of aggression subtypes.

Summary

Aggression is especially common and potentially impactful in early childhood. Inhibitory control (IC) and irritability also show developmental change at this time, despite being relatively stable at later ages. Both IC and irritability have

differential associations with aggression subtypes, but these distinctions have been inconsistent in young children. The present study tested irritability as a mediator of IC's associations with aggression subtypes, using directionality and severity scores to disentangle hypothesized distinct associations with reactive over proactive functions. Moderation by gender was also examined. The sample consisted of 300 preschoolers (M_{age} at T1 = 44.70 months, n = 132 female), with data collected at three time points over two academic years. Consistent with hypotheses, lower IC predicted increases in irritability, which in turn predicted increases in overall levels (i.e., severity) of physical aggression for girls, and relational aggression for both genders. Likewise, lower T1 IC predicted increases in irritability, which in turn predicted increasing predominance of reactive over proactive physical and relational aggression (i.e., directionality), although the indirect effect was significant for physical aggression only. The present study provides novel evidence that developmental associations between IC, irritability, and reactive functions of aggression are evident as early as the preschool years, and that directionality scores may be a viable option for disentangling these effects.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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

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