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Executive Functions in Children: Associations with Aggressive Behavior and Appraisal Processing

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Abstract

This study investigated whether and how deficits in executive functioning and distortions in appraisal processing are related to subtypes of aggressive behavior. The sample included 83 boys assessed using multi-informant reports and performance measures. Deficits in two executive functions, response inhibition and planning ability were related primarily to reactive aggression. Hostile attributional biases moderated relations between planning ability and proactive and reactive aggression subtypes, with minimal relations between planning deficits and aggression at low levels of hostile attributional bias. As the level of hostile attributional bias increased, the relation between planning deficits and reactive aggression became increasingly large in a positive direction whereas the relation between planning deficits and proactive aggression became increasingly negative. Additionally, hostile encoding moderated the relation between behavioral inhibition and reactive aggressive behavior. Results also suggested a mediational role for response inhibition in the relation between planning ability and reactive aggression.

Keywords

executive functions; antisocial behavior; social information processing; children

Introduction

Aggression and antisocial behavior are two of the most common childhood mental health problems requiring substantial intervention (Burke, Loeber, & Birmaher, 2002). Individuals who engage in significant levels of antisocial behavior are a heterogeneous group, with multiple developmental processes likely underlying the course and maintenance of these problem behaviors. Identifying cognitive impairments that distinguish school-aged children who engage in significant levels of aggressive behavior from those who do not exhibit such difficulties may assist in early detection and consequent appropriate intervention, for at least a subgroup of these children. The current study explored whether and how impairments in executive functioning are related to problems in conduct as well as social cognition.

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Executive functions are higher order cognitive abilities that develop from late infancy through adulthood and facilitate successful goal attainment via strategic planning, self-regulation, mental representation, and effective problem-solving (Séguin & Zelazo, 2005; Weyandt, 2005). Executive functions have been linked to a number of psychological processes believed to provide a foundation for effective problem solving, such as selective attention, planning, the ability to shift cognitive sets, rule use, inhibitory control, recall of salient information, and working memory (Morgan & Lilienfeld, 2000). Relations among many of the processes involved in executive functions operate hierarchically as well as interact to accomplish higher order cognitive tasks (Zelazo, Carter, Reznick, & Frye, 1997; Zelazo & Müller, 2002).

Consistent relations have been found between executive functions and aggressive behavior throughout the childhood period (Goldstein, Hahn, Hasher, Wiprzycka, & Zelazo, 2007; Lewis et al., 2008; Séguin & Zelazo, 2005). For instance, youth exhibiting high levels of aggressive behavior have been found to experience difficulties with disinhibition (Coolidge, DenBoer, & Segal, 2004), sequential and recall memory, the ability to effectively use feedback to correct responses, and cognitive perseveration (Séguin, Arseneault, Boulerice, Harden, & Tremblay, 2002). Utilizing meta-analytic techniques, Morgan and Lilienfeld (2000) found a robust relation between antisocial behavior and executive functioning deficits. Given this evidence, it may be helpful to consider deficits in executive functioning as problem solving failures that contribute to conduct disordered behavior.

Zelazo and colleagues (Zelazo et al., 1997; Zelazo & Müller, 2002) proposed a framework designed to place the hierarchical structure of executive functions within the context of four problem solving phases. During the first phase, labeled Problem Representation, perceptual sets are created and modified. Zelazo et al. (1997) highlight that selective attention plays a crucial role within this phase. The second phase, Planning, involves the generation, selection, and use of strategies designed to solve problems. The third phase, Execution, relates to one's ability to "keep the plan in mind long enough to guide one's thought or action" (Zelazo et al., 1997, p. 201) as well as complete the intended behavior. In this phase, the use of rules plays an important role. The final phase, Evaluation, involves an assessment of the effectiveness of one's chosen course of action. Within this phase, errors are detected and steps are made to correct or revise behavior.

Deficits in executive functions have been hypothesized to increase youths' risk for social problem solving difficulties which may, in part, explain the link between executive functions and aggressive behavior (Eisenberg & Morris, 2002; Lough, Gregory, & Hodges, 2001). Social information processing theories suggest that social behaviors, including conduct problems, are influenced by higher order cognitive-emotional processing (Lösel, Bliesener, & Bender, 2007). Within this conceptualization, children are believed to develop internally consistent patterns of social information encoding and processing that, over time, begin to acquire distinct personality-like characteristics (Cervone, 1999; Zelli & Dodge, 1999). Grigsby and Stevens (2000) have suggested that an ability to engage in appropriate social behavior as well as to inhibit inappropriate behavioral responses likely requires intact executive functioning.

Crick and Dodge (1996; Dodge, 1986) have formulated a six-step sequential model that links aggressive behavior to distortions /deficits in either the appraisal or the processing of social information. The first two steps of the model involve appraisals of social behavior, whereas the subsequent four steps involve processing of socially-based information. One implication of this model is that internally consistent patterns of encoding are developed and become stable over time so that children selectively attend to what is most salient to them. Whereas some children may attend to multiple aspects of social situations, children with high levels of aggressive behavior may show a tendency towards hypervigilance to perceived threats. Supporting this perspective, a number of studies have found that children with high levels of aggressive behavior consistently encode fewer interpersonal cues before making decisions about the intentions of their peers (e.g., Cervone, 1999; Zelli & Dodge, 1999). In particular, these youth have difficulty using and remembering relevant aspects of their interactions with others, and frequently attend to the most recent cues as opposed to attending to all cues presented, when making attributions about the behaviors of others (Milich & Dodge, 1984).

Another consistent finding in the social-information processing literature is that many children exhibiting aggressive behavior display hostile attributional biases (Arsenio & Lemerise, 2001; Crick, Grotpeter, & Bigbee, 2002), which occur at the second step of Crick and Dodge’s (1996) model and reflect a tendency for children to make hostile interpretations about social events that increase the likelihood of aggressive behavior. The process by which children with high levels of aggressive behavior construct meaning in social situations appears to represent an interaction between the information provided by the environment, and the knowledge (either accurate or inaccurate) that these children bring to situations (Cervone, 1999).

Such restricted cue encoding and biased interpretations of behavior appear to be related primarily to one subtype of aggressive behavior, reactive aggression, which is characterized by anger and hostility and is often retaliatory in nature. Proactive aggression, in contrast, is generally unprovoked and used for personal gain, to influence, or to coerce others. Research has demonstrated that although proactive and reactive aggression are highly correlated and elevated levels often are manifested in the same individual (e.g., Barker, Tremblay, Nagin, Vitaro, & Lacourse, 2006), they do have distinct correlates and developmental outcomes (Fite, Colder, Lochman, & Wells, 2007; McAuliffe, Hubbard, Rubin, Morrow, & Dearing, 2006). For example, in contrast to proactive aggression, reactive aggression is associated with poor impulse control, poor peer relationships, poor school performance, and increased internalizing symptoms (e.g., Card & Little, 2006; Dodge et al., 1997; Prinstein & Cillessen, 2003).

An increased propensity for angry reactivity, negative emotionality, and emotional dysregulation also are associated with reactive aggression (Vitaro, Barker, Boivin, Brendgen, & Tremblay, 2006). Research on social information processing has found that reactive aggressive behavior is frequently fueled by hostile attributional biases and is related to significant reductions in the number and quality of effective solutions generated in response to conflicts in ambiguous provocation situations (Hubbard, Dodge, Cillessen, Coie, & Schwartz, 2001). Reactive aggressive behavior has also been found to be associated with deficits in the development of an appropriate attentional focus on interpersonal interactions (Schippell, Vasey, Cravens-Brown, & Bretveld, 2003). Further, difficulty in the employment of effective problem-solving skills during complex and contradictory social situations has been associated with reactive aggressive behavior (Dodge, Lochman, Harnish, Bates, & Pettit, 1997).

In contrast, proactive aggression tends to be less associated with social cognitive deficits and anxiety symptoms than reactive aggression (Dodge et al., 1997). As compared to reactive aggression, proactive aggression is associated with higher levels of social skills, higher levels of peer acceptance, lower levels of social rejection, and an increased likelihood of association with deviant peers (Poulin & Boivin, 2000; Prinstein & Cillessen, 2003). Proactive forms of aggression tend to be primarily behaviorally motivated by the expectation of external rewards and involve more effective social problem solving skills than reactive forms of aggression (Dodge & Coie, 1987; Smithmyer, Hubbard, & Simons, 2000).

Although research has linked executive functioning and social information processing difficulties to aggressive behavior, relatively little attention has been focused on how deficits in these two conceptually related risk domains are associated with subtypes of aggression, and how they function together. A growing body of evidence suggests that interactive relations exist between social information processing styles and various risk factor domains (e.g., emotional state, social context) in the prediction of aggressive behavior (Dodge & Pettit, 2003). Because executive functioning deficits also represent a risk factor for aggressive behavior, evaluating the potential interactive relationship between social information processing and executive functioning deficits in the prediction of aggressive behavior subtypes may provide further insight into the development of aggression.

Using a cognitive processing framework, the present study examined three models involving unique and interactive relations between executive function deficits, social information processing distortions, and subtypes of aggressive behavior. The first of these models predicts that appraisal processing (encoding, attributions) distortions and executive function deficits will be associated with reactive but not proactive aggressive behavior. Research suggests that central executive control processes such as behavioral inhibition tend to be recruited when attempts are made to modulate the expression of negative affect (Richards & Gross, 2000). This finding suggests that the emotionality associated with reactive aggressive behavior may result, at least in part, from executive function deficits. Because proactive aggression is not associated with emotional responding but appears to be primarily controlled by the expectation that the aggression will be rewarded or reinforced (Dodge, 1991; Kempes, Matthys, Maassen, van Goozen, & van Engeland, 2006), it seems less likely that this form of aggression would be associated with executive function difficulties.

The types of executive dysfunction linked to reactive forms of aggression may be influenced by distortions in the appraisal of social information. That is, it is possible that the effects of executive dysfunction are moderated by distortions in the encoding of social cues and/or distortions in the interpretation of social cues (i.e., hostile attributional biases), particularly in regards to reactive aggression. Consequently, a second model focuses on interactions among social information processing and executive function deficits in their relation to subtypes of aggressive behavior.

Finally, Zelazo and Müller’s (2002) problem solving model suggests that executive function processes operate sequentially, interactively, and hierarchically to influence behavior. Given that Zelazo and Müller’s Planning Phase of problem solving occurs prior to the Execution Phase, it may be that deficits in the Execution Phase mediate the effects of the Planning Phase on aggressive behavior. Consequently, we also tested the mediational role of response inhibition in the relation between planning ability and reactive aggressive behavior. Because the final phase of the model relates to evaluation of behavioral outcomes (i.e., it occurs after the behavior), we did not propose a meditational relation between the Execution Phase and the Evaluation Phase in the prediction of reactive aggressive behavior.

Method

Participants

Because higher rates of antisocial behavior generally are exhibited among boys (Zahn-Waxler et al., 2008), the present sample was restricted to males. Eighty-three male elementary students enrolled in grades four and five from eight public schools in the Southeastern region of the United States were involved in the project. Of these participants, data from 3 youths (4%) were not included in the analyses because of missing information. The mean age of participants was 10.25 years (SD = .82, range 9-12), with 51% of the sample self-identified as African-American, 2% Asian-American, 46% Caucasian, and 1% other. The mean full scale IQ score obtained by participants on the Wechsler Abbreviated Scale of Intelligence (WASI; Psychological Corporation, 1999) was 101.83 (SD = 11.83).

The majority of primary adult caregivers were the biological parents of the children (81% were mothers; 15% were fathers), with the remaining classified as "other." The average family household size was four (SD = 1.07, range 2-7). The majority of children lived in households in which their parents were married (57%), with 18% having divorced parents, 5% with separated parents, 16% with unmarried parents, and 4% with widowed parents. Three percent of the mothers had not completed high school, 31% either completed high school or obtained a general education degree (GED), 43% attended college, 13% graduated from an undergraduate institution, and 10% obtained advanced degrees; 3% of fathers had not completed high school, 26% either completed high school or earned a GED, 38% attended college, 11% obtained an undergraduate degree, and 4% held advanced degrees. Eighteen percent of the caretakers reported not knowing the father's highest level of education.

Procedure

To recruit participants, presentations about the research study were provided to all fourth and fifth grade children in eight elementary schools. Information sheets were sent home with the children that asked parents to provide phone numbers and addresses if they wished to receive more information about the study. A second visit was arranged with each classroom so that the information forms could be collected. Prizes were given to the class at each grade level that returned the most information sheets (regardless of the parents' responses). Classroom prizes included posters, footballs, and basketballs signed by local university athletes as well as university paraphernalia (i.e., pencils and key chains). Once the forms were collected, phone calls were made to interested parents and appointments were scheduled. Of the 529 students who returned parent permission slips, a total of 172 parents of male children indicated an interest in receiving further information about the research study. A concerted effort was made to ensure the sample consisted of a representative proportion of highly aggressive boys. Consequently, as many as 10 attempts to schedule and reschedule data collection sessions with boys rated as highly aggressive by teachers were made. An overall response rate of 21.7% for highly aggressive boys was achieved. All study recruitment and research procedures were approved by and conducted in compliance with the university's Institutional Review Board's policies.

Each participant was accompanied to the evaluation by his caretaker. After obtaining consent from the caretaker and child, the caretaker was asked to complete a demographics questionnaire. Youth data collection sessions involved three segments, with 15 minute breaks between segments. Administration sessions were conducted individually and lasted approximately 2 hours. The evaluation began with each child being administered the Wechsler Abbreviated Scale of Intelligence (WASI; Psychological Corporation, 1999). Following a 15 minute break, the battery of neuropsychological tests was administered. Following a second 15 minute break, participants completed the Recall Task (Milich & Dodge, 1984) and the Intent Attribution Instrument (Dell Fitzgerald & Asher, 1987). Questions were read by an interviewer to offset any reading difficulties that participants may have experienced. Each boy received a toy donated by a local store and caregivers received $10.00.

Measures

Cognitive and executive functioning—The Wechsler Abbreviated Scale of Intelligence (WASI; Psychological Corporation, 1999) was used to estimate of participants' full scale intelligence quotient (Full Scale IQ) for sample description purposes. The WASI is a measure of verbal and nonverbal intelligence that can be administered to individuals ranging from ages 6 to 89. Participants' Full Scale IQ scores were estimated using the two-subtest format. Reliability coefficients between .92 and .95 have been established for a WASI Full Scale IQ based on the Vocabulary and Matrix Reasoning subtests in child samples. Scores earned on the WASI have been found to be comparable to those obtained via non-abbreviated intelligence tests (Psychological Corporation, 1999). Content, convergent, and discriminant validity have been established for the WASI (Hays, Reas, & Shaw, 2002; Zhu, Tulsky, & Leyva, 1999).

The Wisconsin Card Sorting Test (WCST; Grant & Berg, 1948; Harris, 1990) was administered to measure participants' flexibility of cognitive set. The WCST requires participants to strategically plan, conduct organized searches, utilize environmental feedback when shifting cognitive sets, to direct their behavior toward achieving a goal, and modulate their impulsive responding (Welsh & Pennington, 1988). A computerized version of the WCST was used. Participants were asked to sort on the computer a double stack of 64 cards into four categories, as identified by stimulus cards (the first had one red triangle, the second had two green stars, the third had three yellow crosses, and the fourth had four blue circles on it). The cards could be sorted by color, form, or number. As participants sorted the cards, they were given feedback regarding the accuracy of their performance. After participants completed 10 consecutive correct sortings, the computer program changed the criteria for correct sortings without the participants' knowledge. The WCST has been normed for individuals between the ages of 6 and 89 years. Research has shown the WCST to be a sensitive measure of set shifting in children (Romine et al., 2004). The total number of perseverative-errors was used for the present study. The psychometric properties of the WCST are well established, and reliability as well as validity have been demonstrated for the WCST (e.g., Anderson, Damasio, Jones, & Tranel, 1991; Ozonoff, 1995; Wiedl, Schottke, & Garcia, 2001).

A Tower of Hanoi computerized simulation task was used to measure planning ability (TOH; León-Carrión et al., 1991; Simon, 1975). The TOH required participants to plan a sequence of disk movements across three pegs. Disks of varying size were initially shown in one configuration on the first peg. Participants were asked to reconstruct the disks on the third peg, using the second peg as a support peg, in the least amount of moves possible. Participants were instructed to complete the task with the following stipulations: (a) a larger disk could not be placed on a smaller disk, (b) only disks from the top row could be moved, (c) a move could not be made from a position that did not contain a disk, and (d) no blocks could be moved to the same position it occupied. The total number of moves it took to complete the task was used as a measure of each child's problem-solving and planning ability. Internal consistency values for the computerized version of the TOH range from .60 to .96 (León-Carrión et al., 1991), and a variety of studies have demonstrated its validity (e.g., León-Carrión et al., 1998).

The Stroop Color-Word Interference Task (Laplante, 1988; Stroop, 1935) was used as a measure of response inhibition. The Stroop Task required participants to select relevant information while suppressing irrelevant cues, by inhibiting their dominant response tendency to read a color name instead of the color of the ink in which color name was presented. In the present study, the number of self corrections made during the third part of the task was used. Researchers have found the Stroop Task to be a sensitive measure of response inhibition (e.g., Streeter et al., 2008).

Behavioral Measures—The Teacher-Report (Dodge & Coie, 1987) was used to assess teacher perceptions of reactive and proactive aggressive behavior. This questionnaire contains three reactive aggression items (e.g., "When this child has been teased or threatened, he or she gets angry easily and strikes back.") and three proactive aggression items (e.g., "This child uses physical force in order to dominate other kids."). Each item is rated on a 5-point Likert scale ranging from 1 (never) to 5 (almost always). High internal consistency estimates have been demonstrated for this measure (e.g., Ahonniska, Ahonen, Aro, Tolvanen, & Lyytinen, 2000), and construct and criterion validity have been demonstrated (e.g., Dodge et al., 1997). Internal consistency coefficients of .94 and .92 for the proactive aggression subscale and reactive aggression subscale respectively were found for the present sample. As is typical, reactive and proactive aggression were highly correlated in this sample ($r = .69$, $p < .001$).

Social information processing—The Intent Attribution Instrument (IAI; Dell Fitzgerald & Asher, 1987) was used to measure hostile attribution biases. The IAI contains ten stories describing provocation situations in which the intent of the agitator is ambiguous. Participants were asked to answer one question for each story, assessing their assumptions of the agitator's intent. Each child was asked to circle one of four reasons for the described incident, with two of the four possible responses reflecting a hostile intent and two reflecting an innocuous intent. Participants were given a score of 1 on an item if they endorsed a response that reflected a hostile intent; otherwise they received a score of 0 for the item. Participant responses for this question were summed across the 10 stories to obtain a total score. This score was used as an indicator of a hostile attributional bias. A Chronbach's alpha of .88 was found for the current sample.

A Recall Task (Milich & Dodge, 1984) was used to evaluate cue-encoding deficits. Participants listened to three audiotaped interviews of children describing nine different interactions with peers. The behaviors described included benevolent, hostile, and neutral acts. Participants were asked to recall as many of the statements in each interview as possible. Participant scores were based on a ratio of the number of hostile cues to the total number of cues remembered correctly recalled.

Results

Overview of the Analyses

A number of the variables were significantly skewed, likely resulting from the fact that measures of psychopathology were assessed in a nonclinical sample. To increase their normality, scores from the Proactive/Reactive Rating Scale, the Tower of Hanoi, Stroop Color-Word Interference Task, and the Wisconsin Card Sorting Task were log transformed.

A meta-analysis conducted by Card and Little (2006) suggests that reactive and proactive aggression may be difficult to distinguish empirically when assessed with measures that do not separate the functions served by these two forms of aggressive behavior, as very high correlations are typically observed between these subtypes of aggression. Because of this, in our analyses predicting reactive aggression, we included proactive aggression as a covariate, and vice versa. In addition, we also conducted our analyses twice, once including the linear term for proactive aggression when predicting reactive aggression (as noted above), and then adding the quadratic term to this analysis (and vice versa for when predicting proactive aggression). We found that curvilinear models utilizing the quadratic term best fit the data, and therefore we report these analyses.

Correlation Analyses

Correlation analyses were used to estimate first-order relations among the individual neuropsychological, social appraisal processing, and child disruptive behavior variables (see Table 1). Measures of reactive and proactive aggression were highly correlated. As expected, reactive aggression was significantly positively correlated with response inhibition difficulties and deficits in planning ability; the relation between reactive aggression and cognitive flexibility (from the WCST) was not significant, however. Relations between reactive aggression and the measures of social information processing were non-significant. As expected, proactive aggression was not significantly correlated with any of the executive function or social information processing variables.

Hierarchical Linear Regression Analyses

Each regression analysis was conducted twice, once with reactive aggression as the dependent variable, once with proactive aggression as the dependent variable. For each set of analyses, variable entry order was: (a) Proactive aggression and it's quadratic term (when the dependent variable was reactive aggression), to control for overlap between the two forms of aggression (and vice versa, when proactive aggression was the dependent variable); and Full Scale IQ, to control for differences in cognitive ability; (b) cue encoding distortions and hostile attributional bias; (c) an executive function variable (planning deficits, response inhibition difficulties, or switching cognitive set); (d) the two-way interaction between cue encoding or hostitle attributional bias and the executive function variable, with the interaction term centered to prevent collinearity problems (Aiken & West, 1991).

Thus, in the first set of analyses reactive aggression served as the dependent variable, and linear and quadratic effects for proactive regression as well as Full Scale IQ were entered as control variables, next the two social information processing (SIP) variables (encoding and attributions) were entered, then an executive functioning (EF) variable entered (see Table 2). For Response Inhibition Difficulties, the effect was significant, $\Delta R2 = 0.046$, $F(6, 80) = 18.859$, $\beta = .23$, $p<.01$, but neither SIP variable was significant. The interaction between Response Inhibition Difficulties and Hostile Attributions was not significant but the interaction between Response Inhibition Difficulties and Cue Encoding Distortions was significant, $t\ (74)= 1.99$, $\beta = .80$, $p < .05$. To interpret this interaction, we used procedures for describing continuous variable interactions outlined in Aiken and West (1991). Relations between Response Inhibition Difficulties were estimated at high (1 SD above the mean), moderate (the mean), and low (1 SD below the mean) levels of Cue Encoding Distortions (see Figure 1). At high levels of Cue Encoding Distortions, there was a strong relation between Response Inhibition Difficulties and Reactive Aggression but as the level of Cue Encoding Distortions decreased, the relation between deficits in Response Inhibition and Reactive Aggression decreased. This suggests that difficulties with response inhibition may be particularly problematic vis-a-vis reactive aggression when a child also has high levels of hostile cue encoding distortions.

There were no significant effects in the model analyzing the executive function Set Switching variable. When analyzing effects of the Planning Ability executive function variable, there also were no main effects for the EF or SIP variables, but there was a significant interaction between Planning Ability Deficits and Hostile Attributions, $t\ (74) = 2.18$, $\beta = .69$, $p < .05$. We again used Aiken and West's (1991) procedures to describe the interactions (see Figure 1). At low levels of Hostile Attributional Bias, the relation between deficits in Planning Ability and Reactive Aggression was minimal, but as the level of Hostile Attributional Bias increased, the relation between deficits in Planning Ability and Reactive Aggression increased. What this suggests is that poor planning abilities become particularly problematic vis-a-vis reactive aggression when a child also has high levels of hostile attributional biases.

These analyses were conducted again, switching the roles of proactive and reactive aggression (i.e., proactive aggression was the dependent variable, the linear and quadratic terms for reactive aggression, and Full Scale IQ served as the control variables) (see Table 2). In these models, there were no main effects for any of the EF or SIP variables but there was a significant interaction effect. The interaction between Hostile Attributional Biases and Planning Ability was significant, $t(74) = -2.29$, $\beta = -.56$, $p < .05$. Again, the procedures for describing continuous variable interactions outlined in Aiken and West (1991) were used (see Figure 2). At high levels of Hostile Attributions, elevated levels of Proactive Aggression were significantly associated with fewer deficits in Planning Ability, but as the level of Hostile Attributions became lower, the relation between Planning Ability Deficits and Proactive Aggression became minimal.

Tests of Mediation

To examine the role of response inhibition as a mediator between deficits in planning ability and reactive aggression, three additional regression analyses were performed. In order to demonstrate mediation, four conditions must be met (Baron & Kenny, 1986). First, the independent variable (planning ability deficits) must be related to the dependent variable (reactive aggression). Second, the independent variable (i.e., planning ability deficits) must be related to the mediator (i.e., response inhibition difficulties). Third, the mediator (response inhibition difficulties) must predict the dependent variable (reactive aggression) while controlling for the independent variable (planning ability deficits). Finally, the relation between the independent and dependent variables should become smaller or non-significant when the mediator is included in the model. Following the steps previously outlined, the relation between deficits in planning ability and reactive aggression was significant, $\beta = .24$, $p < .05$. The relation between planning ability deficits and response inhibition difficulties was also significant, $\beta = .34$, $p < .01$. For the third and fourth step, a multiple regression analysis was conducted using the independent variable (planning ability deficits) and the proposed mediating variable (response inhibition difficulties) to predict the dependent variable (reactive aggression). Response inhibition difficulties significantly predicted reactive aggression, $\beta = .31$, $p < .01$, whereas the effect of planning ability deficits on reactive aggression became non-significant, $\beta = .14$, p = ns. A Sobel test for mediation (Sobel, 1982) was subsequently conducted to test the significance of the mediation effect; this test was significant, $z = 2.08$, $p < .05$. Thus, in our data, response inhibition difficulties appeared to mediate the relation between deficits in planning ability and reactive aggression.

Discussion

Consistent with previous research, these results suggest that deficits in executive functions are related to behavioral difficulties, specifically reactive aggression but not proactive aggression. Probably the most notable finding was that support was garnered for Dodge and Pettit’s (2003) contention that social information processing deficits interact with risk factors (in this case executive function deficits) to predict aggressive behavior. At the broadest level, these findings support previous research indicating that reactive and proactive aggression have distinct correlates (e.g., Fite et al., 2007; McAuliffe et al., 2006). These results also suggest support for the position that unlike reactive aggression, proactive aggression does not primarily result from cognitive or emotional processing difficulties or biases; our results extend these findings to executive functions.

The present study’s analyses suggest that although deficits in planning ability may generally cause an individual problems with social relationships or academic learning (e.g., Altemeier, Jones, Abbott, & Berninger, 2006), difficulties in planning may be irrelevant in regards to reactive aggression if there is minimal hostile attributional bias. One explanation for this finding is that without a hostile attributional bias, there likely is little consideration of behaving aggressively. On the other hand, as hostile attributional biases become increasingly large, deficits in planning ability appear to become increasingly linked to reactive aggression. This is perhaps because poor planning ability negatively influences strategy selection and makes it more difficult for children to effectively generate and prioritize prosocial solutions to problems. As a result, reactively aggressive behavior may occur in response to biased interpretations of social cues (i.e. the hostile attributional bias).

In regards to proactive aggression, we found that as the level of hostile attributional bias increased, the relation between deficits in planning ability and proactive aggression became increasingly negative. It may be that high levels of hostile attributional bias increase the planning demands required to be successful with proactive aggression, and hence children with poor planning abilities and a hostile attributional bias are unlikely to be successful at proactive forms of aggression. Consequently, they may show less proactive aggression since proactive aggression is controlled by its consequences (Dodge, 1991; Kempes et al., 2006).

Similar to the findings related to the interactive relation between reactive aggression, hostile attributional bias, and planning ability deficits, the results of the present study suggest that deficits in response inhibition may be irrelevant to reactive aggression when there are low levels of cue encoding distortions. As with hostile attributional biases, without cue encoding distortions there likely is little consideration of behaving aggressively. However, as cue encoding distortions become increasingly large, difficulties in response inhibition become increasingly linked to reactive aggression. This perhaps occurs because children with limited ability to control their responses may be rapidly reacting to their perceptions, with their responses shaped by hostile cue encoding, thus resulting in reactive aggression.

Finally, our analyses suggested that poor problem solving and an inability to foresee the consequences of one’s actions may result in problems with response inhibition which, in turn, may result in increased reactive aggressive behavior. These findings support the hierarchical nature of Zelazo and Müller’s (2002) problem solving model suggesting that the influence of planning strategies on ultimate behavioral outcomes (i.e. reactive aggressive behavior) is at least in part indirect and occurs as a function of one’s ability to effectively inhibit more automatic behavioral responses.

Research suggests that there may be two relatively distinct sets of processes involved in decision making (e.g., Séguin, Arseneault, & Tremblay, 2007; Zelazo & Müller, 2002). ‘Hot’ decision making involves processes that are emotionally-based and influenced whereas ‘cool’ decision making is more effortful, reflective, and rational (Séguin et al., 2007). Executive functions and appraisal processing have been implicated in both types of processing and problem solving. Given the differences in emotionality in reactive and proactive aggression and in regards to executive functions, and social information processing, it may be useful for future research to more fully evaluate how executive functions and appraisal processing operate under ‘hot’ versus ‘cool’ decision making.

A primary clinical implication of our results is that assessment of executive functions as well as social cognitive tendencies may be essential aspects of treatment planning for intervening with problems in aggressive behavior, particularly in regards to reactive forms of aggressive behavior. Further, effective behavioral management training for predominantly reactive aggressive youth may need to go beyond teaching these children and their caregivers behavioral, negotiation, and social skills but also address cognitive deficits and/or overall decision making processes that may be contributing to behavioral and emotion regulation difficulties.

There are several caveats that should be noted. First, because the large majority of individuals exhibiting serious antisocial and aggressive behavior are male, our sample was restricted to males. The extent to which our findings might generalize to females thus is unclear. Second, our overall sample size was relatively small, with 22% of the sample exhibiting highly aggressive behavior, which may have affected statistical power. However, we did find a number of significant effects, including three interactions, which suggests that our sample size was sufficient for the purposes of the present study. Third, the measures of reactive and proactive aggression used in the present study were highly correlated, as has been reported in most studies investigating these constructs. Although statistical methods were structured so as to identify unique components of each construct, the high correlation between the reactive and proactive aggression variables also may have reduced our statistical power. In addition, our assessment of reactive and proactive aggression was based solely on teacher report. Although other informants (as is true for teacher report) have their own unique limitations (e.g., observations can be made for only a relatively limited time period, as opposed to multiple week or month timeframes for other informants; peer informants' reports may be influenced by social reputation effects, as well as by the target child's actual behavior), inclusion of other informants might have expanded the generalizability of our findings.

Another limitation involves our measure assessing hostile attributional biases. With this measure, children were not responding to actual potential threat interactions but rather to vignettes. It is possible that our results might have been stronger if children had been assessed under conditions of emotional arousal elicited by actual rather than hypothetical situations. However, the conceptualization of social information processing utilized within this study was based on that of Dodge (1986) and Crick and Dodge (1996), and within this conceptualization children are believed to develop internally consistent patterns of encoding and interpreting social information that, over time, take on aspects of acquired personality characteristics (Cervone, 1999; Zelli & Dodge, 1999). Although the model does not assume that children will exhibit social information processing biases completely independent of situational context, it does suggest that measures such as the Intent Attribution Instrument will provide a reasonably accurate snapshot of participants' most characteristic responses within particular types of situations. Finally, in contrast to the other two executive function tasks, the Wisconsin Card Sorting Task was not significantly related to any of our dependent variables. It is not clear if a different measure of set shifting would have produced different results.

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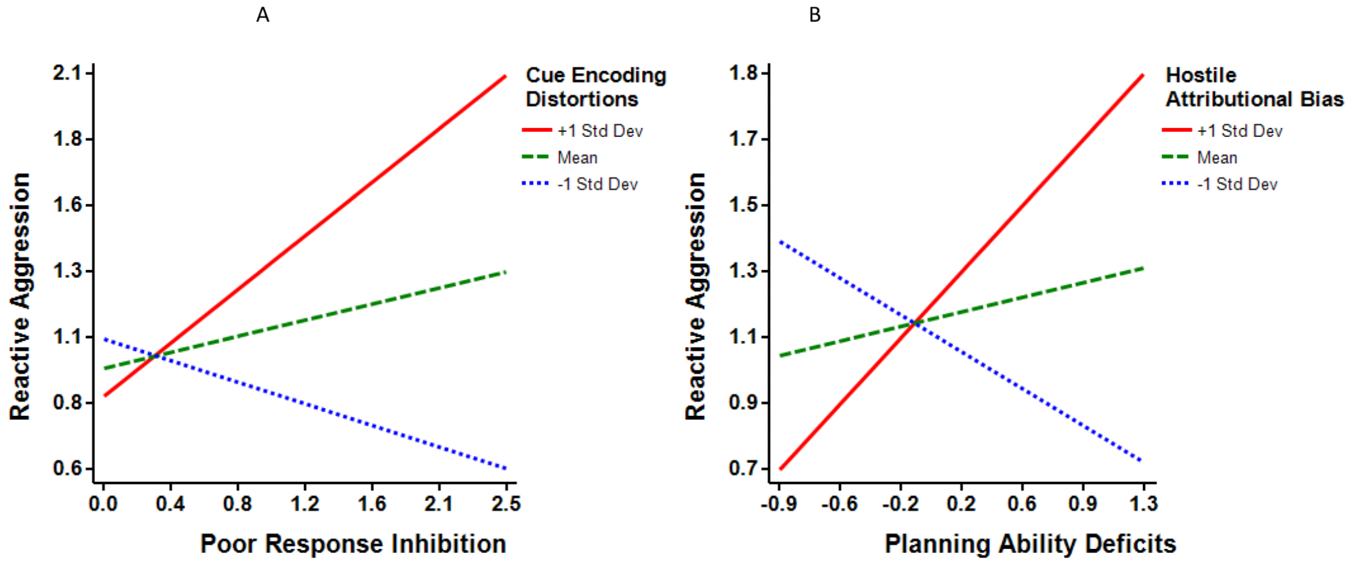

Figure 1.
(A) Relation between Reactive Aggression and Response Inhibition Difficulties at Low, Moderate, and High Levels of Distortions in Cue Encoding. (B) Relation between Reactive Aggression and Planning Ability Deficits at Low, Moderate, and High Levels of Hostile Attributional Biases.

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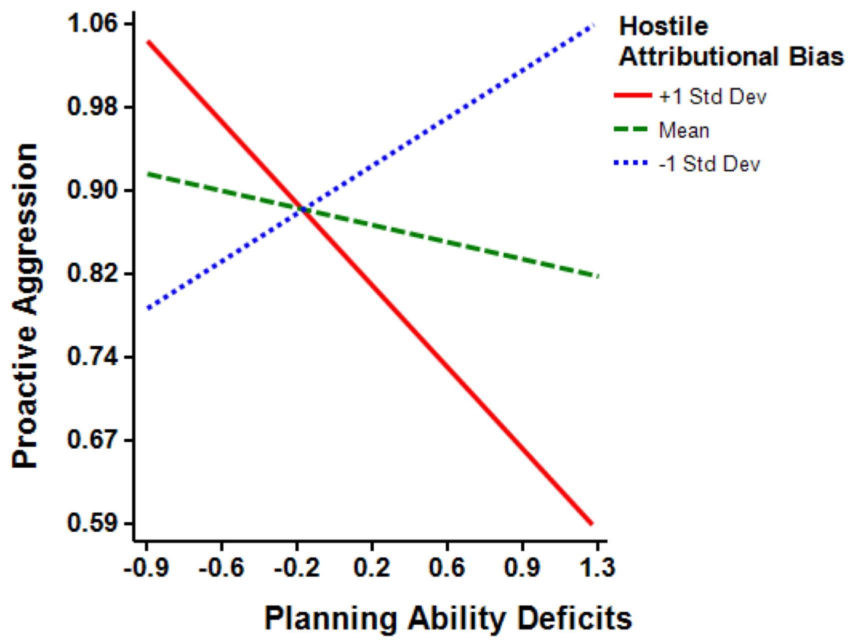

Figure 2.

Relation between Proactive Aggression and Planning Ability Deficits at Low, Moderate, and High Levels of Hostile Attributional Biases.

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Table 1

Zero-Order Correlations for All Variables

Variable	1	2	3	4	5	6	7	9
1. Reactive Aggression	-							
2. Proactive Aggression	.68**	-						
3. Hostile Encoding	.16	.01	-					
4. Hostile Att. Bias	.18	.05	.04	-				
5. Poor Planning Ability	.24*	.06	.35**	.02	-			
6. Switching Cog. Set	.14	.15	−.01	.10	.34**	-		
7. Response Inhibition Difficulties	.35**	.09	.18	.05	.34**	.14	-	
8. Full Scale IQ	−.09	−.10	−.02	−.07	−.45**	−.50**	−.26*	-
M	2.35	1.52	.46	.50	50.41	27.16	3.14	101.24
SD	1.30	.92	.14	.14	32.89	14.00	2.40	12.07

Note.

* $p \leq .05$,

** $p \leq .01$.

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Table 2

Summary of Hierarchical Regression Analysis for Variables Predicting Reactive Aggression

Variable	B	*(SE)*B	*t-value*
Model 1:			
Step 1			
Proactive Aggression	3.18	.81	3.93**
Proactive Aggression^2	−1.03	.36	−2.84**
Full Scale IQ	−.00	.00	−1.14
Step 2			
Hostile Encoding	.23	.24	1.74
Hostile Att. Bias	.39	.21	1.81+
Planning Ability	.10	.06	1.60
Step 3 *(Individually)*			
Hostile Encoding × Planning Ability	.36	.38	.95
Hostile Att. Bias × Planning Ability	.69	.32	2.18*
Model 2:			
Step 1			
Proactive Aggression	3.18	.81	3.93**
Proactive Aggression^2	−1.03	.36	−2.84**
Full Scale IQ	−.00	.00	−1.14
Step 2			
Hostile Encoding	.27	.21	1.27
Hostile Att. Bias	.36	.20	1.79+
Response Inhibition	.15	.05	2.93**
Step 3 *(Individually)*			
Hostile Encoding × Response Inhibition	.80	.40	1.99*
Hostile Att. Bias × Response Inhibition	.17	.34	.48
Model 3:			
Step 1			
Proactive Aggression	3.03	.81	3.74**
Proactive Aggression^2	−.97	.36	−2.68**
Full Scale IQ	−.00	.00	−1.39
Step 2			
Hostile Encoding	.38	.22	1.72+
Hostile Att. Bias	.34	.21	1.60
Set Switching	−.00	.07	−.04
Step 3 *(Individually)*			
Hostile Encoding × Set Switching	−.10	.44	−.22
Hostile Att. Bias × Set Switching	.55	.49	1.12

Note.

Proactive Aggression^2 = the quadratic term for proactive aggression. Although interaction analyses are simultaneously depicted in step 3 of each model, each interaction analysis was conducted individually at step 3.

$^+p < .10$,

$^*p < .05$,

$^{**}p < .01$.

Table 3

Summary of Hierarchical Regression Analysis for Variables Predicting Proactive Aggression

Variable	B	*(SE)*B	*t-value*
Model 1:			
Step 1			
Reactive Aggression	−1.15	.50	−2.27*
Reactive $Aggression^2$	.71	.21	3.33**
Full Scale IQ	.00	.00	−.19
Step 2			
Hostile Encoding	−.19	.18	−1.03
Hostile Att. Bias	−.25	.16	−1.51
Planning Ability	−.03	.05	−.58
Step 3 *(Individually)*			
Hostile Encoding × Planning Ability	.03	.28	.10
Hostile Att. Bias × Planning Ability	−.56	.25	−2.29*
Model 2:			
Step 1			
Reactive Aggression	−1.15	.50	−2.27*
Reactive $Aggression^2$	.71	.21	3.33**
Full Scale IQ	.00	.00	−.19
Step 2			
Hostile Att. Bias	−.24	.16	−1.46
Response Inhibition	−.04	.04	−.93
Step 3 *(Individually)*			
Hostile Encoding × Response Inhibition	−.19	.33	−.59
Hostile Att. Bias × Response Inhibition	−.23	.27	−.85
Model 3:			
Step 1			
Reactive Aggression	−1.15	.52	−2.22*
Reactive $Aggression^2$	.71	.22	3.27**
Full Scale IQ	−.00	.00	−.28
Step 2			
Hostile Encoding	−.21	.17	−1.23
Hostile Att. Bias	−.26	.17	−1.56
Set Switching	.05	.05	.95
Step 3 *(Individually)*			
Hostile Encoding × Set Switching	.53	.33	1.60
Hostile Att. Bias × Set Switching	.03	.36	.08

Note.

Reactive $Aggression^2$ = the quadratic term for reactive aggression. Although interaction analyses are simultaneously depicted in step 3 of each model, each interaction analysis was conducted individually at step 3.

+ $p < .10$,

* $p < .05$,

** $p < .01$.