HHS Public Access
Author manuscript
Early Educ Dev. Author manuscript; available in PMC 2017 March 22.

Published in final edited form as:
Early Educ Dev. 2016 ; 27(6): 788–804. doi:10.1080/10409289.2016.1148481.

A Longitudinal Investigation of Conflict and Delay Inhibitory Control in Toddlers and Preschoolers

Amanda W. Joyce[a], **Jessica H. Kraybill**[b], **Nan Chen**[b], **Kimberly Cuevas**[c], **Kirby Deater-Deckard**[d], and **Martha Ann Bell**[b]

[a]Murray State University

[b]Virginia Tech

[c]University of Connecticut

[d]University of Massachusetts - Amherst

Abstract

Research Findings—Eighty-one children participated in a longitudinal investigation of inhibitory control (IC) from 2 to 4 years of age. Child IC was measured via maternal report and laboratory measures under conditions of conflict and delay. Performance on delay IC tasks at 3 years was related to performance on these same tasks at 2 and 4 years, but performance on conflict IC tasks was not related over time. Delay IC task performance was concurrently related to conflict IC task performance in 3- and 4-year-olds but not related in 2-year-olds. Measures of IC varied in their associations with measures of verbal ability and maternal report IC. Such findings highlight important similarities and distinctions between conflict and delay IC abilities in their relation to one another and to temperament and language over time.

Practice or Policy—Studies of IC and related concepts reveal that children who are regulated enjoy school more and have higher school competence, particularly in mathematics and reading achievement. Because conflict IC and delay IC show unique patterns of development over time, educators can expect classroom behaviors drawing upon the state-like conflict IC to show more fluctuation over time than those drawing on the trait-like delay IC.

Keywords

inhibitory control; toddlers; preschoolers; language; temperament

Introduction

Fleeting attention and impulsivity are developmentally appropriate during the toddler years; yet most children learn to inhibit inappropriate behaviors as they mature. Some children, however, do not. They are consequently at a greater risk for a multitude of problematic outcomes related to low levels of inhibitory control (IC), such as later externalizing problems (e.g., Eisenberg et al., 2009; Lemery, Essex, & Snider, 2002), deficits in social

Correspondence concerning this article should be addressed to: Amanda W. Joyce, Psychology Department, 203 Wells Halls, Murray State University, Murray, KY 42071, awatson22@murraystate.edu., Phone: (270) 809-2097.

competence (e.g., Gewirtz, Stanton-Chapman, & Reeve, 2009; Lengua, 2003), lower levels of school enjoyment (Valiente, Lemery-Chalfant, & Castro, 2007), and general academic difficulties (e.g., Ponitz, McClelland, Matthews, & Morrison, 2009). IC appears to act as a protective factor against future conduct problems for certain children, specifically in children *not* prone to feelings of guilt, high levels of IC offset the risk of developing future conduct problems (Kochanska, Barry, Jiminez, Hollatz, & Woodward, 2009). Thus, children's developing IC plays an important role in their success in the preschool classroom (and beyond), and it is important to examine its development in early childhood.

IC is commonly defined as the ability to resist improper behaviors and instead respond appropriately (e.g., Diamond, 2006; 2013). Thus, IC allows children control over their actions when their natural inclination is in conflict with situationally suitable behaviors (Spinrad et al., 2006). Research on the A-not-B task indicates that rudimentary IC abilities emerge late in the first year (Bell & Fox, 1992; Diamond, 1990). Whereas 7-month-olds are generally unable to inhibit the impulse to reach to a previously rewarded but incorrect location, 12-month-olds are successful (e.g., Diamond, 1990). The most drastic improvement in IC abilities, however, does not occur until the toddler and preschool years – during these years, children display a dramatic increase in performance on tasks assessing IC (e.g., Carlson, 2005; Diamond & Taylor, 1996) and therefore a dramatic improvement in their school readiness (McClelland et al., 2007). Execution of IC relies heavily on the prefrontal cortex, and, not surprisingly, this period of IC development is likewise associated with rapid changes in frontal lobe maturation (Diamond, 2002; Diamond, Barnett, Thomas, & Munro, 2007; Diamond, Prevor, Callendar, & Druin, 1997; Luria, 1973). The rapid developmental changes occurring in this time period make these toddler and preschool years ideal for examining IC development.

Conflict vs. Delay IC

A number of laboratory measures assess children's developing IC abilities. It is common to dichotomize tasks based on the nature of the tasks' inhibitory demands, and one common dichotomy involves categorizing tasks according to whether they require inhibition under conditions of *delay* or under conditions of *conflict* (Carlson & Moses, 2001; Carlson, Moses, & Breton, 2002). Delay IC tasks involve postponing the initiation of a certain dominant response (Carlson & Moses, 2001). For example, in the Tongue task (Kochanska, Murray, & Harlan, 2000), children are instructed to hold a small piece of candy on their tongue for a short while without chewing. This measure, therefore, tests children's ability to delay a tempting candy-eating response. Of course, children must demonstrate their delay IC in not just laboratory settings, but also in their day-to-day lives. Thus, children in the preschool classroom who are high in delay IC would excel at waiting their turn and at tolerating the postponement of rewarding events (e.g., snack time, parental arrival in the late afternoon).

In contrast, conflict IC tasks involve suppressing a dominant response in order to perform a contradictory action. For example, the often-used Day-Night task (Gerstadt, Hong, & Diamond, 1994) asks children to say "day" when shown a picture of a moon and "night" when shown a picture of a sun. Successful completion of the task requires overriding the dominant response of correctly identifying certain images and instead identifying them in the opposite manner. In much the same way, preschoolers' conflict IC abilities are important to their day-to-day activities. Preschoolers high in conflict IC would excel in situations such as raising their hand instead of immediately sharing answers. Because all of these classroom skills are critical for success in preschool, it is important to examine the development of both types of IC in early childhood.

The distinction between conflict IC and delay IC is not universally accepted, due in large part to discrepant ways in which IC, as a whole, is described in different literatures, leading many researchers to call for a more integrated view of self-regulation (Liew, 2012; Zhou, Chen, & Main, 2012). IC falls under an umbrella of the effortful control literature, while simultaneously being described as an aspect of executive function, and definitions in both fields appear to have emerged somewhat independently from one another. For example, Kochanska and colleagues (2000, p.220) describe effortful control as "the ability to suppress a dominant response to perform a subdominant response," which is reminiscent of the definition of conflict IC (from an executive function perspective) described above. To add to the confusion, within the same paper, the authors also admit that they have previously described the same tasks as IC rather than effortful control (Kochanska et al., 2000). Clearly, additional work is necessary in order to create a more integrated view of self-regulation. In this paper, however, we refer to conflict IC and delay IC (rather than effortful control and delay IC) to remain consistent with previous work by Carlson and colleagues (e.g., Carlson & Moses, 2001; Carlson et al., 2002).

Additionally, others may question if conflict and delay IC are distinct concepts from one another. Research in preschool-aged children with principal components analysis has determined a two-factor solution of conflict and delay IC, which, as factors, relate differently to different variables of interest (Carlson & Moses, 2001). Likewise, research in non-human primates as well as in human adults suggests that the ability to delay a response and the ability to withhold a response while producing a conflicting response may have different neural underpinnings (de Jong, Coles, & Logan, 1995; Petrides, 1986). More research is needed in order to determine if these constructs continue to show important differences throughout the human lifespan.

Some studies have examined conflict IC and delay IC abilities in a subset of the toddlerhood and preschool years (e.g., Carlson, Mandell, & Williams, 2004; Carlson & Moses, 2001; Hughes & Ensor, 2005; Kochanska et al., 2000; Morasch & Bell, 2011); however, we know of no study that longitudinally follows the development of both conflict IC and delay IC abilities from 2 to 4 years of age. We used a longitudinal design to investigate conflict and delay IC in these age groups in order to explore age-related associations between these two types of IC within the same group of children. Such research on the development of IC will allow early childhood educators to provide the most developmentally appropriate settings in which children may enhance their IC abilities, thus improving their overall preschool experience and preparing them for later school performance.

Previous research from our lab has demonstrated how laboratory observations of delay IC and conflict IC in toddlers were not related to one another, but were both related to concurrent parental-report measures of temperament-based IC (Blinded for review). Crosssectional research has shown concurrent positive relations between conflict and delay IC tasks in 3- and 4-year-old children, and longitudinal research has demonstrated these concurrent relations in 2- and 3-year-old children (Carlson et al., 2004; Carlson & Moses, 2001). For this reason, we hypothesized that our measures of conflict IC and delay IC would be concurrently positively related at 2, 3, and 4 years of age. It seems logical to assume that conflict and delay IC may relate to one another over time. To our knowledge, however, no study to date has looked at relations between conflict IC at one age and delay IC at another age. Therefore, we made no specific hypotheses regarding these relations and instead proposed an exploratory analysis of these associations.

There is considerable longitudinal stability from toddlerhood to the early school years in maternal IC ratings, as well as stability in children's relative performance on IC batteries composed of both conflict and delay IC tasks collected around 33, 46, and 66 months of age (e.g., Kochanska, Murray, & Coy, 1997; Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996; Rothbart & Bates, 2006). Indeed, children's ability to delay gratification at 4 years during Mischel's Marshmallow Delay is related to, among many other constructs, ability to delay gratification during adolescence (Mischel, Shoda, & Rodriguez, 1989). This suggests that delay IC is stable over time, meaning that early gains in IC may continue to be beneficial in the preschool classroom over time. Furthermore, Hughes and Ensor (2007) demonstrate stability in executive function aggregates, which include Stroop-like tasks, from 2 to 4 years of age, suggesting conflict IC abilities may also be stable in this age group, again suggesting enduring classroom benefits. We therefore hypothesized positive across-age correlations among our delay IC tasks as well as positive across-age correlations among our conflict IC tasks.

IC and Parental Report Temperament

In addition to laboratory measures, we obtained parental report measures of temperament-based IC. Researchers generally advocate using several measures to examine multi-faceted constructs such as IC (e.g., Murray & Kochanska, 2003), as incorporating multiple measures offers a more robust, reliable, and complete examination of various aspects of IC. The use of parental reports offers a reflection of IC abilities in a real world setting. Previous research demonstrates associations between parental-report measures of IC and laboratory measures of both conflict and delay IC (Carlson & Moses, 2001; Kochanska et al., 1997; Morasch & Bell, 2011). We therefore hypothesized that parental report of IC would be positively related to concurrent laboratory measures of conflict IC and delay IC in each age group.

IC and Language

Language development, along with frontal lobe development, may result in advances in the voluntary control of behavior (Ruff & Rothbart, 1996). Indeed, previous research indicates an association between IC and verbal abilities. Performance on expressive and receptive language measures is positively correlated with performance on conflict and delay IC tasks such as the Shape Stroop, Snack Delay and Gift Delay at 2 years; the Snack Delay, Hand Game, Marker Delay, and Gift Delay at 3 years; and IC battery scores at 3 and 4 years (Carlson et al., 2004; Carlson & Moses, 2001, Watson & Bell, 2013). Because of individual differences in verbal abilities, and because of the association between IC and language demonstrated between 2 and 4 years, we examined the association between IC and language. We hypothesized that language would be positively related to concurrent laboratory measures of both conflict and delay IC at all ages. Thus, those children with the best IC would also have the most advanced verbal abilities to further assist them in the classroom.

Present Study

The goal of our study was to examine the associations between delay and conflict IC tasks in early childhood, specifically from 2 to 4 years of age. We also examined the associations among delay IC and conflict IC tasks, parental report of child IC, and language abilities. We hypothesized (1) within-age correlations between conflict and delay IC, (2) across age correlations among conflict IC, (3) across age correlations among delay IC, and (4) relations between IC and concurrent measures of parental-report IC and language. We also explored the cross-lagged associations between conflict and delay IC, though we offered no specific hypotheses regarding these associations due to a lack of previous research in this domain.

Method

Participants

Eighty-one participants (43 boys, 38 girls) represented one cohort of a larger longitudinal study on cognition-emotion integration from infancy through early childhood. This report contains data collected when the children were 2 (M = 2.10, SD = 0.05, Range = 2.01–2.14), 3 (M = 3.13, SD = 0.08, Range = 3.01–3.29), and 4 (M = 4.11, SD = 0.09, Range = 4.01–4.26) years of age. Children and their parents were recruited using birth announcements in the local newspaper and a commercial list of new parent names and addresses. All of the parents who reported educational information had at least a high school diploma at the time of their child's birth. Seventy-four percent of the mothers had college degrees, as did 68% of the fathers. At the time of the child's birth, mothers were approximately 30 years old (range = 20–38) and fathers were approximately 33 years old (range =23–52). All children were full term and healthy at the time of testing. Parents were paid for their children's participation in the study.

The study originally included 106 healthy 5-month-old infants. When the children were 2 years of age, it was possible to locate and contact 95 of the families. Eighty-three families were still in the local area and 81 (43 boys, 38 girls; 4 Hispanic, 77 Non-Hispanic; 73 Caucasian, 2 African-American, 2 Asian-American, 4 Other) agreed to participate in the study. When the children were 3 years of age, 69 families were still in the local area and 68 (37 boys, 31 girls) agreed to participate in the study. When the children were 4 years of age, 69 families were still in the local area and 63 (35 boys, 28 girls) agreed to participate in the study.

Procedures

Upon arrival at our research lab, each participant and his or her mother were greeted by a research assistant who explained the study procedures and obtained signed consent from the mother and verbal assent from the child. Mothers were seated beside and slightly behind the child throughout the visit.

A series of IC tasks was administered at each age, along with a battery of other cognitive and emotion tasks not reported here. All of the tasks required the child to pay attention to a given set of rules, to remember the rules throughout the task, and to inhibit a dominant response tendency, which are the hallmarks of IC tasks. In addition, some of the tasks required the child to delay a dominant response (delay IC tasks), whereas some of the tasks required him or her to inhibit a dominant response in order to perform a conflicting action (conflict IC tasks). A variety of delay IC and conflict IC tasks were used to measure IC abilities within each age group and are explained in detail below.

Delay IC Tasks

Tongue Task (2, 3, and 4 years)—The Goldfish task, also known as the Tongue task, was taken from a battery of tasks designed to assess the effortful control abilities of young children (Kochanska et al., 2000). This task challenged the child to hold a goldfish cracker (or an M&M when extra motivation was needed) on his or her tongue and to inhibit chewing it for increasing intervals of time (i.e., three trials with delays of 10, 20, and 30 s). The total administration time for this task was approximately 3 min. This task was videotaped for off-line coding of accuracy of inhibitory performance. Performance was coded as either successful (did not chew cracker) or unsuccessful (chewed cracker) and a final score was calculated as a percentage based on the number of successful trials (i.e., 3 successes = 100%, 2 successes = 67%, 1 success = 33%, 0 successes = 0%). Interrater reliability was calculated for at least 20% of the sample in each age group and percentage agreement on coding success to inhibit chewing the cracker exceeded 97% in each age group.

Crayon Delay (2 and 3 years)—The Crayon Delay task (Calkins, 1997), adapted from the Telephone task (Vaughn, Kopp, & Krakow, 1984), measures children's ability to inhibit coloring when left alone with coloring supplies. More specifically, at age 2, each child was shown a box of crayons and paper and was asked if he or she would like to color. The box of crayons was opened such that the crayons themselves were readily accessible and visible to the child, and both the crayons and paper were pushed toward the child. The researcher then explained that she needed to leave the room for a short while in order to retrieve materials for a new game. The child was instructed not to color or touch the paper, crayons, or crayon box until the researcher returned. Each child was left with the crayons and paper for 1 min. Task administration was identical at age 3, with the exception of the substitution of markers for crayons and a delay time of 2 min. Child performance was scored based on latency (measured in seconds) to touch the crayon or marker box, crayons or markers, and paper. Scores ranged from 0–60 s at age 2 and from 0–120 s at age 3. Interrater reliability was calculated for at least 20% of the sample in each age group. Percent agreement exceeded 89% in both age groups.

Gift Delay (4 years)—To overcome concern that the Crayon Delay task would no longer be developmentally appropriate for 4-year-old children, the very similar Gift Delay task was used in this age group. The Gift Delay, adapted from the Wrapped Gift task (Kochanska et al., 2000), measures children's ability to inhibit the urge to touch an attractive gift. During this task, the experimenter wrapped a gift (a coloring pad and a box of 64 crayons) for the child while the child was in the room. The child was asked to stand with his or her back to the experimenter and not to peek while the gift was being wrapped (60 s). After the gift was wrapped, the experimenter put it on the table and had the child sit at the table. Before leaving "to get a bow," the experimenter asked the child not to touch the gift until she returned (180 s). Latencies to touch the gift while waiting were scored and ranged from 0–180 s. Interrater reliability was calculated for at least 20% of the sample and exceeded 98% within 1 s.

Conflict IC Tasks

Simon-Says/Bear-Dragon (2, 3, and 4 years)—The Simon-Says task closely followed the Bear-Dragon procedure described by Carlson and Moses (2001; adapted from Reed, Pien, & Rothbart, 1984), except pig and bull puppets (or horse and cow puppets at age 3) were used in place of bear and dragon puppets. More specifically, to begin, the experimenter asked each child to imitate the 10 target actions to confirm that the child could indeed perform these actions (e.g., stick out your tongue, touch your ears, clap your hands, etc.). The experimenter then introduced the two puppets. The first puppet was described as a "nice pig", and the child was instructed to do as the pig said. The pig trials were the activation trials. The second puppet was described as a "mean bull", and the child was instructed *not* to do as the bull said. The bull trials were the inhibition trials – the trials of particular interest in this study. Two practice trials followed, in which the experimenter moved the pig's mouth and said (in a high-pitched voice), "Touch your nose," and then moved the bull's mouth and said (in a low, gruff voice), "Touch your ear." The child passed the practice test if he or she followed the pig's command but inhibited responding to the bull's command. Difficulty passing the bull test trial (i.e., failing two practice trials) resulted in the assistance of a second experimenter (or the mother) to play the game with child and to remind him or her *not* to do as the bull said. After passing practice trials, eight test trials followed (four pig trials and four bull trials, alternating order) in which the child was given no assistance but was praised or encouraged when the experimenter felt he or she needed motivation. This task was videotaped and later scored for accuracy of inhibitory performance. Children were included in analyses if they performed perfectly during activation trials. Children who did not perform perfectly on activation trails were also included in these analyses and given a score of 0. The final score was a percentage based on the number of successful bull (inhibition) trials (i.e., 4 successes = 100, 3 successes = 75, 2 successes = 50, 1 success = 25, 0 successes = 0). Interrater reliability was calculated for at least 20% of the sample and percentage agreement on coding success to inhibit performance on bull trials exceeded 95% in each age group. The total administration time for this task was approximately 3 min.

Dimensional Change Card Sort (2, 3, and 4 years)—The Dimensional Change Card Sort (DCCS) has been used in the developmental literature to assess executive function and rule use in young children (Zelazo, Frye, & Rapus, 1996; Zelazo, Muller, Frye, & Marcovitch, 2003), and requires the skills of focused attention, working memory, and IC. One set of laminated cards (11 cm×7 cm) was used. There were two target cards (i.e., a blue car and a red flower) to be matched to a series of 14 test cards that displayed the same shape but colors opposite of the target cards (i.e., red cars and blue flowers). Each child was first instructed to sort seven test cards by color (pre-switch condition) and then was instructed to switch and to sort the remaining seven test cards by shape (post-switch condition). The dimension (i.e., color or shape) that was relevant during the pre-switch phase was counterbalanced across participants within each age group. In the post-switch condition, the child was reminded of the rule after each trial. However, the child was not told whether or not she sorted the cards correctly; the experimenter simply said, "Okay", and began the next trial. In order to determine that we were measuring the child's inhibition, rather than his or her ability to follow card-sorting rules, we required each child to "pass" the pre-switch condition with at least 83% accuracy in order to be considered for post-switch analyses (e.g., Jacques, Zelazo, Kirkham, & Semcesen, 1999; Towse, Redbond, Houston-Price, & Cook, 2000). As above, additional children who participated in the task but who did not pass the pre-switch trials were scored as "0" for the purpose of these analyses. The total administration time of this task was approximately 7 min. The percentage correct of post-switch sorts was of interest in this analysis. Typically, children do not perform well on this task until 4 years of age (see Garon, Bryson, & Smith, 2008, for review). However, by exploring the continuity of task performance over time, we were able to examine those enduring early inhibitory characteristics that later develop into strong early childhood IC. Interrater reliability was calculated for the post-switch trials for at least 20% of the sample at all ages, and percentages agreement on coding success to sort correctly at these ages exceeded 96%.

Measures of Temperament

Early Childhood Behavior Questionnaire (2 years)—The Early Childhood Behavior Questionnaire (ECBQ; Putnam, Garstein, & Rothbart, 2006) was administered to establish a parent report of toddler IC. The ECBQ is a 201-item questionnaire designed to measure temperament in 1.5- to 3-year-old children. All ECBQ temperament subscales were collected, with the IC subscale of particular interest in the current study. This 12 item scale has high internal consistency (α = .89; Putnam et al., 2006) and contains questions regarding children's conflict IC (i.e., "When asked now to, how often did your child touch an attractive item (such as an ornament) anyway?"; reverse scored) as well as questions of delay IC (i.e., "when asked to wait for a desirable item (such as ice cream), how often did your child wait patiently?"). Mothers rated their agreement with how accurately each item described their child's behavior (1= extremely untrue; 7= extremely true) in the 2 weeks prior to the laboratory visit. The questionnaire was mailed to mothers shortly after they scheduled their laboratory appointment and was collected upon arrival at the laboratory.

Children's Behavior Questionnaire (3 and 4 years)—The Children's Behavior Questionnaire (CBQ; Rothbart, Ahadi, Hersey, & Fisher, 2001) was used to examine parent perceptions of child temperament. The CBQ is a 196-item questionnaire designed to measure general patterns of behavior in children of 3–7 years of age. Internal consistency data for this measure is not available for 3-year-olds, but the IC scale has high internal consistency (α = .88) in 4- and 5-year-olds (Rothbart et al., 2001). Like the CBQ, the ECBQ also contains questions of both conflict IC ("Is able to resist laughing or smiling when it isn't appropriate.") and delay IC ("Has difficulty waiting in line for something.", reverse scored). The questionnaire was mailed to the mothers shortly after they scheduled their laboratory appointment and was collected at the laboratory visit. All CBQ temperament scales were collected, with the IC scale of particular interest to this study.

Measures of Language

MacArthur-Bates Communicative Development Inventory (2 years)—The MacArthur-Bates Communicative Development Inventory (MCDI) "Words and Sentences" form (Fenson et al., 1992) was administered to examine toddler verbal ability. The MCDI, designed for use with 16- to 30-month-olds, is an inventory of common words and phrases. This inventory has high internal consistency (α = .96) and strong documented test-retest reliability (α > .90 for all ages tested during the toddler period; Fenson et al., 1992). Mothers indicated their toddler's production of the items on the inventory (words scale) and reported their toddler's early grammatical ability, specifically, the complexity of multi-word utterances. The measure of interest in the current study was toddlers' mean length utterance.

Peabody Picture Vocabulary Test (3 and 4 years)—Language ability in 3- and 4-year-olds was measured through the Peabody Picture Vocabulary Test (PPVT-III, L.Dunn & D. Dunn, 1997), a nationally standardized instrument that measures receptive vocabulary and verbal comprehension. During laboratory administration, each child is shown arrays of four pictures and must point to the picture that best describes a word. A standardized score was calculated based on the child's age and performance.

Results

Analyses were conducted for all available data. Data were not available for all children at all time points because of missed laboratory appointments, child noncompliance during task administration, and child failure to meet task inclusion requirements. This failure to meet task inclusion requirements affected the most children for the DCCS and Simon Says analyses at 2 years. However, it was critical that these analyses included correct-proportion data only from children who could correctly sort cards before the "switch" and respond to the "nice puppet" so as to more purely measure in in our analyses children's inhibition of the prepotent response to sort cards according to the first rule or to respond to the puppet with an action rather than measuring the child's understanding or misunderstanding of the most basic rules of the game. We chose not to use multiple imputation of missing data that were created from our inclusion requirements, because multiple imputation assumes that data are missing at random, which was not true of our data (He, 2010; Yuan, 2010). Children who lack IC are, by nature, more likely to struggle with slowing their responses enough to perform successfully on these pre-trials (Diamond, 2013). For this reason, scores were recorded as "0" for those children who could not demonstrate an understanding of task rules during pre-switch and "nice puppet" trials. We chose this method because a "0" score on these trials is indicative of their lack of ability but distinguishes them from children who did not participate in the task at all[1]. This is consistent with previous work in this area (Deng, 2008). All tables and figures report the number of children used in each of the analyses.

Table 1 displays the means, standard deviations, minimum and maximum values, and number of participants for all IC tasks, maternal reports of IC, and language assessments.

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[1]These analyses were also conducted by excluding the data of children who did not meet the inclusion requirements. Results of those analyses were similar to results revealed below, with the exception that conflict and delay IC at 2 years were marginally correlated with one another.

Paired samples *t*-tests were calculated to determine whether IC task performance improved with age. Crayon and Gift Delay task performance were compared using proportion scores calculated by dividing the total time that children were able to wait by the total amount of time that they were asked to wait. Task performance improved with age on all tasks (*t*s ≥ 2.97, *p*s ≤.005), with the exception of the Simon-Says/Bear-Dragon task ($t(22) = -1.57$, $p = .23$) and DCCS ($t(17) = -1.54$, $p = .14$) from 2 to 3 years of age and the Crayon/Gift Delay tasks from 3 to 4 years of age ($t(60) = .62$, $p = .54$).

Creation of IC Composite Scores

For the sake of parsimony, following research precedent, IC tasks were collapsed into six composite scores, based on a conceptual grouping of variables (Kochanska et al., 1997, 2000). One conflict composite and one delay composite were created for each age group. Conflict composites for each age group contained data from the Simon-Says and DCCS tasks. Delay composites contained data from the Goldfish task and the Crayon Delay task at 2 and 3 years of age and data from the Goldfish task and Gift Delay task at 4 years of age. Composites were formed by first standardizing task scores and then averaging these standardized scores into the appropriate composites for each age. Previous research included composite scores in analyses if data were available for at least 50% of the tasks in that composite (Kochanska et al., 1996). For this reason, when data were not available for one task, the composite score was based upon data from the remaining task in that composite.

Correlations among IC Composites, Temperament, and Language

Because we were interested in the size and direction of the relations among conflict IC and delay IC composites, temperament, and language, we calculated Pearson correlations among these variables. All correlations described below represent positive relations, with the exception of those relations involving the 2-year-old conflict IC composite, which, with the exception of the association with 4-year-old parental report of temperament, were predominately negative in sign.

Relations among conflict and delay composites—Pearson correlations were calculated between all conflict IC and delay IC composite scores (see Figure 1). Concurrent measures of conflict IC and delay IC were related to one another at 3 and 4 years, but were not related at 2 years of age. No relations were found between performance on conflict IC tasks at one age and performance on delay IC tasks at another age. Longitudinally, performance on delay IC tasks at 3 years was also related to performance on delay IC tasks at 2 years and 4 years. In contrast, no longitudinal relations were found between performance on conflict IC tasks at 2, 3, or 4 years of age.

Relations between IC, temperament, and language—Pearson correlations were also calculated between conflict IC and delay IC task performance, temperament-based IC, and language assessment scores at all ages. Results of these analyses are displayed in Table 2. Maternal report of temperament-based IC was related to conflict IC and delay IC across all ages and it showed some associations with language. Conflict IC and delay IC composites were also related to temperament IC and language, although relations varied with task type and with age. Notably, conflict IC at all ages was related or marginally related to language abilities at all ages, with only two exceptions, but delay IC related to language in only two instances, with one additional marginal association.

Examining the unique effects of temperament and language—In addition to examining Pearson correlations amongst IC, language, and temperament, we also conducted a series of multiple regression analyses in order to determine the unique effects of concurrent temperament and language on conflict and delay IC. Results of these analyses are displayed in Table 3. When temperament and language were examined together, temperament was not a significant predictor of conflict or delay IC at any age, and language was only a significant predictor of conflict IC at 3 years, though temperament was a marginal predictor of Delay IC at 2 years and language was a marginal predictor of Delay IC at 4 years.

Discussion

We provided a longitudinal examination of IC abilities throughout toddlerhood and the preschool years. Specifically, we focused on the interrelations of IC performance under conditions of conflict and delay, as well as the associations between IC performance and parental report of temperament-based IC and language abilities. It is important to have a more precise understanding of the developmental progression of children’s IC, as improvements in IC can lead to improvements in academic and social success (e.g., Diamond, 2012; Diamond 2012; McClelland et al., 2007). To our knowledge, this study is the first to longitudinally examine the correlates of conflict and delay IC from 2 to 4 years of age, therefore providing us with important information about the early childhood development of critical contributors to preschool success.

Our findings indicated that, at 3 and 4 years of age, performance on conflict IC tasks was related to concurrent performance on delay IC tasks. This corroborates previous findings demonstrating associations between conflict IC and delay IC tasks in early childhood (Carlson et al., 2004; Carlson & Moses, 2001). These findings are not unexpected, as such tasks share many common characteristics. Both, of course, were measured in the laboratory during this study and, may, therefore, have some shared method variance. Although more research is needed in which the two can be compared across settings (e.g., inside the laboratory versus outside, parental report versus observation), other research suggests that the association is more than an artifact of measurement. Both types of tasks, by definition, require either the inhibition of a dominant response or of thoughts and behaviors not relevant to the task at hand. Neurologically, this inhibition involves the use of the lateral prefrontal cortex and the anterior cingulate cortex (MacDonald, Cohen, Stenger, & Carter, 2000; Rothbart & Bates, 2006; Rueda, Posner, & Rothbart, 2005). Furthermore, performance on such tasks has been linked with common developmental outcomes in later academic performance and social skills (Fahie & Symons, 2003; Mischel, Shoda, & Peake, 1988; Rudasill & Konold, 2008; Waber, Gerber, Turcios, Wagner, & Forbes, 2006), which implies that IC tasks under conditions of conflict and delay measure similar abilities in 3- and 4-year-olds and that, at these ages, both are important to children’s success in a preschool classroom.

In contrast, in 2-year-olds, performance on conflict IC tasks was not related to concurrent performance on delay IC tasks. There is little cohesion in early executive function task performance (i.e., Miller & Marcovitch, 2015). Previous research demonstrates an increase in coherence among inhibitory abilities between 22 and 33 months of age (Kochanska et al., 2000), though two-factor solutions still best describe 3- to 4-year-old children's IC (Gandolfi, Viterbori, Traverso, & Usai, 2014). It is possible that the abilities underlying IC task performance under conditions of conflict and delay do not unify until the early childhood period (Morasch & Bell, 2011). Given the lack of association between performance on these two types of tasks at 2 years, but the subsequent correlations between these tasks at ages 3 and 4 years, it is possible that these abilities unify sometime in the third year. Therefore, it may be important to preschool readiness to individually support toddlers' developing conflict IC skills alongside their developing delay IC skills until these skills unify later in early childhood.

We also found that performance on tasks of delay IC was related over time. Children who performed well at 3 years of age had also performed well at 2 years and continued to perform well at 4 years. Previous research using other IC tasks demonstrates the longitudinal stability of IC battery performance from toddlerhood through early school age (Kochanska et al., 1996, 1997). Such stability indicates that, through these tasks, we were able to capture some enduring, trait-like IC quality. The ability to capture this quality longitudinally provides support for using these particular tasks to assess IC across toddlerhood and the preschool years. However, we did not find associations between delay IC at 2 and 4 years. For this reason, it is helpful to supplement laboratory measures of IC with parental-report measures, which exhibited longitudinal stability throughout this developmental period.

Performance on conflict IC tasks, however, was not related across ages. This finding was contrary to our hypothesis, as we expected conflict IC, like delay IC and parental report of temperament-based IC, to demonstrate longitudinal stability. This finding, however, is not necessarily in contrast to previous research. Earlier work, while showing stability in either performance on individual conflict IC tasks or on these tasks as part of a larger battery including other executive functioning tasks, has not examined longitudinal stability of composites composed only of conflict IC (e.g., Carlson et al., 2004; Hughes & Ensor, 2007; Kochanska et al., 1996, 1997). We suspect that the lack of stability found may be due to the different nature of conflict IC (versus delay IC) task demands. IC has been characterized both as a component of executive functioning and as an aspect of childhood temperament (e.g., Carlson et al., 2002; Diamond et al., 2007; Kochanska et al., 1996, 2000). We hypothesize that delay IC tasks, with their simple instructions, may draw upon more basic inhibitory processes than do conflict IC tasks. These basic inhibitory processes, as an aspect of a child's temperament, may be trait-like and stable over time (e.g., Kochanska et al., 1996, 1997; Rothbart et al., 2001). In contrast, children's conflict IC, while also drawing upon children's temperament, may be more state-like in their lack of stability. This could mean that educators may expect more stability in children's delay IC (i.e., waiting their turn) but may need to allow for more constant fluctuation in their conflict IC (i.e., raising their hand before speaking). More research is needed to examine the relative contributions of temperament-based and cognitively-based processes to conflict IC and delay IC performance.

We also examined the pattern of correlations among parental-report measures of temperament-based IC and between these measures and laboratory measures of IC. Again, parental-report temperament measures at all ages were moderately interrelated, corroborating previous reports of temperament stability in the toddler and preschool years (e.g., Gaertner, Spinrad, & Einsenberg, 2008; Kochanska et al., 1997; Putnam et al., 2006). Furthermore, parental-report of temperament in this age group exhibited a number of within-age and across-age relations to both conflict and delay IC, while not converging perfectly with any of these measures, indicating that it provides important additional IC information that our IC task batteries cannot provide, and that educators interested in the impact of IC should rely on laboratory *and* parental reports for the most comprehensive view of the subject.

There was also an interesting pattern of associations between language and IC task performance. Whereas conflict IC at all ages was related or marginally related to language abilities at all ages, with only two exceptions, delay IC rarely related to language. Perhaps the instructions to the conflict IC tasks were more difficult than those to the more basic delay IC tasks, requiring children to rely more heavily on their developing language abilities in order to complete conflict IC tasks. Interestingly, in our multiple regression analyses, language and temperament, individually, rarely predicted conflict and delay IC, implying that many of the associations amongst IC, temperament, and language, were impacted by the overlapping variance in temperament and language.

Another interesting pattern of findings is that of the negative associations between 2-year-old conflict IC and most other IC and language. We suspected at first that this was due to the nature of the Simon-Says task, in which toddlers demonstrate their inhibitory abilities by refusing to follow the instructions of a puppet. In this case, the measure could be confounding inhibitory abilities with toddler tendency to say “no”, a favorite word during the “terrible twos”. Still, our strict inclusion criteria required children to perform perfectly on all activation trials, trials that required children to obey, rather than refuse, the instructions of another puppet, or else be given a score of “0” for their performance. For these reasons, the surprising pattern of associations remains a mystery, and we may only conclude that there is some type of developmental shift between the toddler and preschool years in nature of conflict IC.

One final note considers our use of inclusion criteria, with children who could not pass activation/pre-switch trials being assigned a score of “0”, for the conflict IC tasks. It was important for us to establish these criteria in order to determine that task performance was due to inhibitory abilities under conditions of conflict rather than to an inability to understand or to comply with task rules. The use of inclusion criteria in such tasks has established precedence (e.g., Gerstadt et al., 1994; Jacques et al., 1999; Towse et al., 2000). In contrast, delay IC tasks do not typically include noninhibition trials, making it difficult to establish that children understand task rules and are performing as they do due to their IC abilities or their lack thereof. This establishes a two-fold problem: (1) a lack of confidence in the validity of delay IC task batteries and, (2) a lack of “true” data (data from children who were able to meet inclusion criteria) in conflict IC batteries in comparison to delay IC task batteries, particularly at young ages when conflict IC tasks are difficult for children and inclusion criteria remove a number of children from analyses. More research is needed to determine ways to establish that children's performance on delay IC tasks is reflective of their IC abilities.

These data represent the first attempt to longitudinally explore the development of IC under conditions of conflict and delay from 2 to 4 years of age. Care must be taken, however, when generalizing these results. Participants were recruited from a small area surrounding a research university, and were, thus, largely Caucasian with college-educated parents. Young lower-income children have disproportionately low executive function skills (Diamond et al., 2007). For this reason, we are currently testing a more diverse group of children on this same battery of tasks. Furthermore, research with children in this age group necessitates short experimental sessions, limiting the number of IC tasks that could be administered to the children. It would be helpful for future research to explore the longitudinal development of IC using a different variety of tasks in order to determine if other variations in task demands (physical demands, rather than verbal, for example) show the same pattern of relations we have found among IC, language, memory, and temperament. Likewise, it would be informative for future research to investigate the differential and shared contributions of performance on conflict and delay IC tasks to various academic and social outcomes in early childhood. Finally, though our research importantly provides evidence of divergence of conflict and delay IC in the early childhood years, more research is needed across the lifespan to determine the extent to which conflict and delay IC may be distinct theoretical constructs that may be predictive of different outcomes and that come from different neurological underpinnings.

Conclusions

Inhibitory control is an important ability involved in the inhibition of a dominant response or of thoughts and behaviors not relevant to the task at hand. IC performance under conditions of both conflict and delay is related concurrently in 3- and 4-year-olds, but is not related in 2-year-olds, perhaps indicating a unification of the abilities necessary for optimal conflict and delay IC task performance sometime in the third year. Additionally, the two types of IC exhibit different patterns of relations over time, with only performance on delay IC tasks showing longitudinal stability. Furthermore, conflict IC performance differs from delay IC performance in its relations to temperament, and language. These differences may be due to variation in the relative contributions of cognitive abilities and temperament to delay and conflict IC tasks over time. Such findings highlight important similarities and distinctions between conflict and delay IC abilities in their relation to one another and to temperament, and language, over time and imply that educators can use information from both delay IC tasks and conflict IC tasks to better understand their students' preschool classroom performance. Specifically, it appears that children's ability to delay a prepotent response (delay IC) may be trait-like, while their ability to override a prepotent response with a conflicting response (conflict IC) may be more state-like. Thus, educators can expect more fluctuation in classroom behaviors drawing upon children's conflict IC abilities, while they can expect those classroom behaviors drawing upon children's delay IC to remain more stable over time.

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Appendix

Table 1

Descriptive Statistics for Conflict and Delay Inhibitory Control Tasks from Ages 2–4 Years

Task Type	Task	2 Years					3 Years					4 Years			
		M	***SD***	**Min.**	**Max.**	***n***	***M***	***SD***	**Min.**	**Max.**	***n***	***M***	***SD***	**Min.**	**M**
Delay IC	Goldfish Task	.55	.41	.00	1.00	69	.70	.38	.00	1.00	62	.89	.24	.00	1
	Crayon/Gift Delay	23.46	24.89	.00	60.00	79	76.12	47.74	.00	120.00	69	104.94	73.42	.00	18
Conflict IC	Simon-Says	.16	.29	.00	1.00	50	.42	.33	.00	1.00	61	.67	.45	.00	1
	DCCS Post	.32	.29	.00	.83	25	.38	.43	.00	1.00	62	.82	.34	.00	1
Temp. IC	ECBQ/CBQ	4.06	.87	2.50	5.92	81	4.32	.68	2.82	5.69	69	4.52	.64	3.00	5
Language	MCDI/PPVT	4.84	2.10	1.00	11.00	78	107.26	12.63	67.00	133.00	68	108.56	15.58	69.00	13

Note: All IC task scores are based on proportion correct, with the exception of Crayon Delay (based on a score 0–60 s at 2 years and a score 0–120 s at 3 years) and Gift Delay (0–180 s at 4 years). "Temp. IC" is temperament-based maternal report of IC from the ECBQ IC subscale at 2 years and the CBQ IC subscale at 3 years. Language scores are MCDI Mean Length Utterance at 2 years and standardized scores from the PPVT at 3 and 4 years.

Table 2

Across-Age Correlations Between Conflict IC, Delay IC, and Temperament-based IC and Temperament, and Language

	2 Years			3 Years			4 Years		
Temperament	**Conflict 2**	**Delay 2**	**ECBQ IC 2**	**Conflict 3**	**Delay 3**	**CBQ IC 3**	**Conflict 4**	**Delay 4**	**CBQ IC 4**
ECBQ IC 2	−.08(53)	.25*(76)	--	.21+(62)	.29*(64)	.55**(62)	.08(56)	.02(58)	.42**(62)
CBQ IC 3	−.28*(45)	.30*(63)	.55**(62)	.06(65)	.19(67)	--	.01(58)	−.01(59)	.45**(61)
CBQ IC 4	.07(43)	.24+(61)	.42**(62)	−.15(61)	.21(62)	.45**(61)	.06(62)	.11(64)	--
Language	Conflict 2	Delay 2	ECBQ IC 2	Conflict 3	Delay 3	CBQ IC 3	Conflict 4	Delay 4	CBQ IC 4
MCDI MLU 2	−.19 (54)	.16(76)	.36**(77)	.39**(62)	.38**(64)	.18(62)	.32*(56)	.11(58)	.00(60)
PPVT 3	−.31*(45)	.06(64)	.27*(63)	.26*(66)	.14(68)	.12(66)	.27*(59)	.11(60)	−.09(61)
PPVT 4	−.28+(39)	.07(57)	.17(56)	.29*(58)	.26*(59)	.29*(58)	.19(60)	.24+(62)	−.03(62)

Note: Value in parentheses reflects number of subjects included in analysis; ECBQ IC 2 = Early Childhood Behavior Questionnaire Inhibitory Control scale at age 2; CBQ IC = Children's Behavior Questionnaire Inhibitory Control Scale at ages 3 and 4; MCDI MLU = MacArthur- Bates Communicative Development Inventory Mean Length Utterance measure; PPVT = Peabody Picture Vocabulary Test.

** $p<.01$.

* $p<.05$.

+ $p<.10$.

Table 3

Results of Multiple Regression Analyses Predicting Conflict and Delay IC from Concurrent Temperament and Language

	B	SE(B)	β	*t*	*p*	*sR*^{2}
Predicted: Conflict IC at 2 Years						
Temperament	−.02	.15	−.02	−.16	.876	.00
Language	−.07	.06	−.19	−1.30	.201	.04
$R^2 = .04$, $F(2, 50) = 1.00$, $p = .374$						
Predicted: Delay IC at 2 Years						
Temperament	.23	.12	.23	1.92	.059	.07
Language	..03	.05	.08	.67	.506	.09
$R^2 = .07$, $F(2, 72) = 2.85$, $p = .064$						
Predicted: Conflict IC at 3 Years						
Temperament	.02	.15	.02	.14	.890	.00
Language	.02	.01	.27	2.15	.036	.07
$R^2 = .07, F (2, 61) = 2.37, p = .102$						
Predicted: Delay IC at 3 Years						
Temperament	.20	.14	.17	1.37	.176	.03
Language	.01	.01	.10	.81	.423	.01
$R^2 = .04, F (2, 63) = 1.41, p = .251$						

	B	SE(B)	β	*t*	*p*	*sR*^{2}
Predicted: Conflict IC at 4 Years						
Temperament	−.08	.17	−.06	−.44	.660	.01
Language	.01	.01	.18	1.36	.178	.03
R^2 = .04, F (2, 57) = 1.16, p = .319						
Predicted: Delay IC at 4 Years						
Temperament	−.04	.14	−.03	−.25	.801	.01
Language	.01	.01	.24	1.89	.063	.05
R^2 = .06, F (2, 59) = 1.84, p = .168						

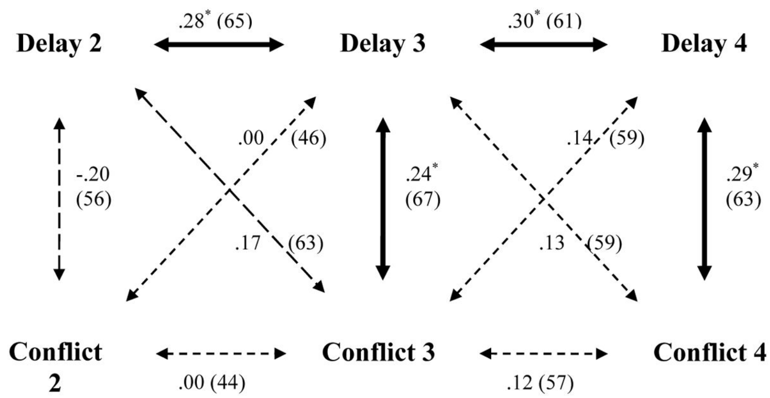

Figure 1.

Conflict and Delay IC Composite Intercorrelations from Ages 2–4 Years. Values in parentheses reflect number of subjects included in analyses. Concurrent measures of conflict IC and delay IC were related to one another at 3 and 4 years of age and were not related at 2 years of age. Performance on delay IC tasks at 3 years was related to performance at both 2 and 4 years, but there were no longitudinal relations among conflict IC tasks. *. $p < .05$