Preterm Toddlers' Inhibitory Control Abilities Predict Attention Regulation and Academic Achievement at Age 8 Years

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Objective To determine if adverse effects of preterm birth on attention and academic abilities at age 8 years are mediated by children's inhibitory control abilities.

Study design Five hundred fifty-eight children born at 26-41 weeks gestation were studied as part of a prospective geographically defined longitudinal investigation in Germany. Toddlers' inhibitory control abilities were observed at age 20 months. At 8 years, attention and academic abilities were assessed.

Results Preterm birth negatively affected children's inhibitory control abilities (B = .25, 95% CI [.11, .39], $P < .001$) and directly predicted subsequent low attention regulation (B = .23, 95% CI [.07, .38], $P < .001$) and academic achievement (B = .10, 95% CI [.03, .17], $P < .001$), after adjusting for other factors. Higher ability to inhibit unwanted behaviors predicted better later attention regulation (B = .24, 95% CI [.07, .41], $P < .001$) and academic achievement (B = .10, 95% CI [.03, .17], $P < .001$).

Conclusions The lower a child's gestational age, the lower the inhibitory control and the more likely that the child had poor attention regulation and low academic achievement. Adverse effects of preterm birth on attention and academic outcomes are partially mediated by toddlers' inhibitory control abilities. These findings provide new information about the mechanisms linking preterm birth with long-term attention difficulties and academic underachievement. *(J Pediatr 2016;169:87-92)*.

Preterm birth increases the risk of attention difficulties[1-4] as well as long-term academic underachievement.[3,5,6] Studies have suggested that early self-control abilities (eg, inhibitory or effortful control) may mediate effects of preterm birth on cognitive outcomes[7,8] and later achievement.[9,10] Inhibitory control predicts the development of the executive attention network[11] and is related to children's executive functions, high-level cognitive abilities that allow humans to show adaptive, goal-directed behavior in complex situations.[12] In an ever-changing and unpredictable environment, executive functions and self-control in particular, are not only vital to master real-life situations but also predictive of long-term academic achievement.[13-15]

One highly reliable indicator of early self-control is an individual's ability to inhibit undesirable behaviors (eg, wait for a treat instead of instantly grabbing it).[16] The inhibition of such behaviors that are driven by emotions has been coined "hot" effortful control. Children's performance in such emotionally valenced inhibitory task assessment has been shown to predict life-long academic attainment and achievement outcomes, even after controlling for cognitive ability and socioeconomic status (SES).[17-19]

Few studies on preterm children have specifically addressed potential links between low gestational age (GA) at birth, early self-control, and long-term outcomes.[20] A recent study suggested that inhibitory control might predict learning and attention regulation abilities at age 6 years in preterm children.[21] Other investigations have shown that very preterm children have problems with inhibitory control[8] and that these may be associated with delay of frustration, as well as attention and behavior problems in preadolescence.[22] Unknown is whether there is a dose-response effect of low GA at birth on inhibitory control in toddlers. If this is the case, inhibitory control abilities may be a functional indicator of the effects of preterm birth on the pathway to later attention and academic outcomes.

The aim of the current study was to test in a large sample of children born across the whole spectrum of gestation whether: (1) there are differences in early inhibitory control according to GA at birth; and (2) whether adverse effects of preterm birth on attention regulation and academic achievement at age 8 years are mediated by children's inhibitory control abilities using structural equation modeling (SEM). We hypothesized that: (1) GA at birth would directly and positively predict inhibitory control at corrected age 20 months and attention regulation and academic achievement abilities at age 8 years; (2) inhibitory

GA	Gestational age
SEM	Structural equation modeling
SES	Socioeconomic status

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control would also directly and positively predict attention regulation and academic achievement; and (3) the impact of GA at birth on later outcomes would be mediated by children's ability to inhibit undesirable behaviors, after statistically adjusting for potential confounders (ie, child sex, neonatal medical risk, and family SES at birth).

Methods

Data were collected as part of the prospective Bavarian Longitudinal Study.[23] The Bavarian Longitudinal Study is a geographically defined, entire population sample of neonatal at-risk children born in Southern Bavaria, Germany, between January 1985 and March 1986 who required admission to a children's hospital within the first 10 days of life (N = 7505; 10.6% of all live births). In addition, 916 healthy term control infants (normal postnatal care) were identified at birth from the same hospitals in Bavaria during the same period. From the initial samples, 393 children born between 25 and 38 weeks of gestation (randomly drawn within the stratification factors sex, socioeconomic background, and degree of neonatal risk) and 165 healthy full-term (39-41 weeks GA) control children were assessed at corrected age 20 months and again at age 8 years. Full details of the sampling criteria and dropout rates are provided elsewhere.[23] Table I shows the descriptive characteristics of the final sample according to their GA group status (N = 558).

Participating parents were approached within 48 hours of the infant's hospital admission and were included in the study once they had given written consent for their child to participate. Toddlers' inhibitory control abilities were assessed at 20 months of age corrected for prematurity. At age 8 years, participating children and their mothers were assessed by an interdisciplinary study team for 1 entire day including neurologic assessments (conducted by pediatricians), parent interviews (conducted by psychologists), cognitive assessments, and behavior ratings (administered by psychological assistants and the whole team). All raters and assessors were blinded to preterm birth status of participating children. Ethical permission for the study was granted by the ethics committee of the University of Munich Children's Hospital and the Bavarian Health Council (Landesärztekammer Bayern).

GA at birth was determined from maternal reports of the last menstrual period and serial ultrasounds during pregnancy. Children were summarized into 5 GA groups (very preterm: <32 weeks GA; moderately preterm: 32-33 weeks GA; late preterm: 34-36 weeks GA; early term: 37-38 weeks GA; full-term 39-41 weeks GA) in order to make findings comparable with other studies.[24,25]

Infant postnatal complications were assessed using a comprehensive optimality index including 21 items (eg, intubation, severe anemia, cerebral hemorrhage).[26]

Family SES at birth information was collected through structured parental interviews and computed as a weighted composite score derived from the occupation of the self-identified head of each family (usually the father) together with the highest educational qualification held by either parent[27] into 3 predefined categories of low, medium, and high SES.

At corrected age 20 months, children's inhibitory control abilities were assessed with a standardized behavioral observation task. At the start of the raisin game, toddlers were presented with a raisin that was placed under an opaque cup within easy reach. After 3 training runs during which eating the raisin was allowed after short but increasing time intervals (instant eating, then 5 and 10 seconds waiting time) the

Table I. Descriptive sample characteristics according to GA groups

	<32 wk GA	32-33 wk GA	34-36 wk GA	37-38 wk GA	39-41 wk GA
	n = 104	n = 51	n = 126	n = 112	n = 165
GA at birth	29.74 (1.53)	32.49 (0.51)	35.07 (0.76)	37.56 (0.50)	40.07 (0.66)
Birth weight	1391 (353)	1649 (398)	2269 (566)	2796 (495)	3776 (447)
Child sex (male)	55.8%	39.2%	47.6%	44.6%	47.9%
Neonatal medical risk score	9.40 (2.57)	8.02 (2.67)	5.25 (2.79)	3.28 (2.74)	0.31 (0.56)
Cognitive abilities (20 mo)	101.65 (7.90)	104.84 (8.10)	105.65 (7.66)	106.88 (5.76)	107.55 (6.42)
Family SES					
Low	29.8%	27.5%	31.7%	33.0%	26.7%
Medium	41.3%	43.1%	26.2%	27.7%	44.8%
High	28.8%	29.4%	42.1%	39.3%	28.5%
Inhibitory control (waiting time in s) at age 20 mo					
Did not wait/waited ≤10 s	58.7%	41.2%	34.1%	34.8%	24.2%
Waited 11-59 s	30.8%	31.4%	36.5%	40.2%	48.5%
Waited 60 s	10.6%	27.5%	29.4%	25.0%	27.3%
Attention and achievement outcomes at age 8 y					
CBCL attention problems	2.78 (2.38)	2.24 (2.23)	1.76 (2.05)	2.18 (2.09)	2.01 (2.09)
Testers' attention rating	6.56 (1.23)	6.59 (1.18)	6.94 (1.08)	6.86 (1.17)	7.23 (1.05)
Mathematic test	−0.41 (0.69)	−0.31 (0.79)	−0.01 (0.67)	0.02 (0.67)	0.03 (0.66)
Reading test	−0.21 (1.38)	−0.36 (1.58)	0.24 (0.82)	0.07 (0.75)	0.14 (0.69)
Spelling/writing test	−0.39 (1.08)	−0.17 (1.05)	0.16 (0.96)	−0.07 (1.06)	0.06 (0.94)

CBCL, Child Behavior Checklist.
Descriptive sample characteristics according to GA groups.
Data is presented as mean (SD) for continuous variables and percentages (%) for categorical variables.