

Neurocognitive Correlates of Problem Behavior in Environmentally At-Risk Adolescents

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ABSTRACT: *Objective:* This study prospectively examines the correlation between neurocognitive (NC) functioning and problem behavior in early adolescence. *Methods:* As part of a longitudinal study, African American urban youths of lower socioeconomic status, mean age 12.1 years (SD = 1.2, n = 111), were administered a battery of 16 NC tasks assessing eight NC systems (two tasks per system) including four systems primarily associated with frontal cortex and four primarily associated with nonfrontal cortex. The former systems included (1) executive cognitive functioning (ECF), (2) cognitive control, (3) working memory, and (4) reward processing. The latter systems included (5) receptive language, (6) spatial cognition, (7) visual cognition, and (8) memory. The Teacher's Report Form of the Achenbach System of Empirically Based Assessment was performed approximately at the same age that the NC assessments were performed. Bivariate correlations were calculated between the eight NC system composite scores and the externalizing scores. *Results:* Significant negative relationships were found between ECF and receptive language ability and externalizing behavior. Further analyses, using linear regression, showed that receptive language was more predictive of externalizing behavior than ECF. *Conclusion:* Based on these results we conclude that (1) NC functioning, specifically in ECF and in receptive language systems, was associated with adolescent problem behavior and (2) receptive language was more strongly associated with problem behavior than ECF.

(*J Dev Behav Pediatr* 28:376–385, 2007) **Index terms:** neurocognitive function, language, adolescents, conduct problems.

Many factors have been examined as predictors of problem behavior in children including: poverty,¹ lead exposure,² gestational tobacco exposure,³ peer affiliation,⁴ family history of antisocial behavior,⁵ nutrition,⁶ nurturance,⁷ and numerous other biological and environmental factors. In recent years, there has been particular focus on neurocognitive (NC) function and its relationship to problem behavior in children, particularly as neuroimaging methods have called our attention to the existence of diverse and anatomically separate systems underlying behavior.^{8,9} Here, NC systems refer to systems of the brain that can be distinguished by both functional criteria and anatomical criteria. In general, these two types of criteria strengthen the rationale for parsing psychological function into separate systems. However, the boundaries between systems are inexact and the brain localizations are more complex than a single anatomical label can convey. For example, processes such as decision making, delay of gratification, and other components

of executive functioning are primarily dependent on frontal regions of the brain, although they involve subcortical and posterior cortical areas to varying degrees as well.^{8,10,11} Similarly, such processes as memory, language, and visual and spatial abilities are primarily associated with temporal, parietal, and occipital brain regions, but also engage frontal regions.^{8,12}

Which NC systems play a role in promoting and preventing problem behavior? One source of evidence comes from the studies of incarcerated and/or antisocial individuals. Hare^{13–15} has explored the relationship between cognitive function and antisocial behavior, specifically psychopathic personality. Studies of incarcerated individuals showed that greater frontal cognitive deficits correlated with higher psychopathy scores.¹⁴ Deficits in semantic and affective processing in psychopathic individuals also have been demonstrated using cognitive tasks and imaging techniques.^{16,17}

Raine¹⁸ has studied antisocial personality and its relationship to a wide range of brain characteristics, including volume of prefrontal gray matter,¹⁹ hippocampal structure,²⁰ and structure and function of the corpus callosum.²¹ He has also studied NC functioning in antisocial adolescents and adults.²² Recent studies of antisocial adolescents found that these adolescents exhibited ongoing impairments in spatial memory that were specific to their persistent antisocial behavior.²³ For some of these individuals, both cognitive and behavioral problems persisted over the life course.

Likewise, Giancola²⁴ has examined the relationship between executive cognitive functioning (ECF) and antisocial behavior in several groups of adolescents. In stud-

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ies of adolescent boys, there was a consistent inverse relationship of ECF to measures of antisocial behavior.²⁵ Similar findings were reported among groups of antisocial and conduct disordered girls.²⁶ Cauffman et al²⁷ reported that deficits in ECF and spatial working memory were found in incarcerated, compared to nonincarcerated, adolescent boys.

Other longitudinal studies have examined antisocial behavior across several ages. For example, Moffitt^{28,29} has studied the life-course development of antisocial behavior in children and adolescents, particularly antisocial development as limited to adolescence, or antisocial development with lifetime persistence into adulthood. Further, Moffitt and colleagues have explored many correlates of antisocial behavior in adolescents including environment,³⁰ impulsivity,³¹ IQ,³² and lower performance on NC tasks.³³ NC deficits, such as in ECF, spatial, and verbal abilities, were shown to be strongly linked to antisocial behavior that begins in childhood and is sustained throughout childhood.

There appears to be an array of NC abilities that are compromised in antisocial adolescents. Yet, the most consistent finding of the NC studies cited above is the association of deficits of ECF with antisocial behavior. Several other areas also have been shown to be related to antisocial behavior, particularly pertaining to verbal, spatial, and memory functions. Most prospective studies have focused on predominantly white samples. Further, studies that have focused on nonwhite adolescents at risk of delinquency have examined NC factors associated with delinquent behavior *after* adolescents have been diagnosed with conduct disorder or adjudicated.

OBJECTIVE

Most studies examine NC function and its relationship to problem behavior concurrently or retrospectively. Also, most studies use predominantly white samples that may not be directly generalized to African American urban youths. To address the dearth of studies on African American youths, this study prospectively examines the association of NC function with problem behavior in nonadjudicated African American adolescents.

METHODS

Participants

Participants were originally recruited at birth, over a 3-year period, from a northeastern metropolitan hospital as part of a National Institute on Drug Abuse study of developmental outcomes in participants with and without gestational cocaine exposure.^{34,35} The project was given approval by Albert Einstein Medical Center and The Children's Hospital of Philadelphia Institutional Review Boards. Consent to participate in this study was obtained from the primary legal guardian of each participant, and each participant gave assent to be included. The entire cohort consists of 120 participants, half of whom had gestational cocaine exposure (COC), and half of whom did not (CON). The participants are African American, urban, and of low socioeconomic status. They were born

at or near term and were nonasphyxiated.³⁶ The cohort has been followed for the past 16 years, with annual evaluation of a variety of psychological processes including cognitive, academic, and social emotional functioning.³⁷ Data used in this study include 111 participants for whom there are both NC assessments and evaluation of problem behavior.

NC Measures

NC functioning was evaluated using a battery of tasks designed to assess eight key NC systems in contrast to standardized intelligence tests.²⁷ This task battery provides an assessment of specific abilities that correspond more closely to the underlying NC systems, specifically (1) ECF, (2) cognitive control, (3) working memory, and (4) reward processing, (5) receptive language, (6) spatial cognition, (7) visual cognition, and (8) memory. Of course, the entire brain is engaged when participants perform these tasks. Nonetheless, the tasks for this study disproportionately tax the particular systems of interest, particularly in the mature brain.³⁸⁻⁴⁰ Less is known about their localization in child and adolescent brains, although younger subjects are generally more likely to recruit more widely distributed regions of cortex during cognitive tasks. We selected two representative tasks per system that could be carried out in a single testing session.

ECF

ECF involves complex cognitive skills mediated by the frontal cortex. These skills include planning and problem solving.

Stockings of Cambridge (SOC)⁴¹

The SOC is a subtest of the Cambridge Neuropsychological Test Automated Battery (CANTAB). The participant is shown how to move the balls within the test portion of the touch screen, and rules for movement of the balls are explained and demonstrated according to standardized procedures. Scores reflect the ability to develop and monitor a problem-solving strategy at various levels of difficulty. Performance is measured as the number of problems solved in the minimum number of moves.^{42,43}

Wechsler Mazes

The Mazes subtest of the Wechsler Intelligence Scale for Children-Third Edition was also administered to measure planning ability. The child must complete each maze within a given time limit.⁴⁴ The score is computed by subtracting points from the maximum score of 28 for errors such as going into a blind alley or crossing through the lines of the maze.⁴²

Cognitive control

These tasks tap the ability to inhibit inappropriate behavioral responses, in particular the more potent response tendency.

Go/No-Go

In this task, single numbers are presented one after another on the computer screen.⁴⁵ The child must press the space bar on the keyboard after the appearance of each number except the number "4." Total correct responses are recorded. This task has been shown in imag-

ing studies to activate the anterior cingulate cortex in both children and adults.^{46,47}

Counting Stroop⁴⁸

There are two conditions for this test: (1) in the congruent condition, the child must sort cards into piles according to the number or numbers written on each card, and (2) in the incongruent condition, the child must sort according to how many numbers are written on each card. Subject performance is timed for the two conditions and the difference in time between the congruent and incongruent condition is recorded. Functional neuroimaging studies have shown that the incongruent condition of the task activates a network of prefrontal and parietal regions that includes the anterior cingulate cortex.⁴⁹

Working memory

Working memory involves information storage that is temporary and limited in capacity and requires continual rehearsal and updating. Working memory is required to hold the present context or goals of a complex task in the mind.

Two-back

This task involves monitoring a series of letters for a repeat of the letter “two-back.” Single letters are presented one at a time on a computer screen. Participants must continually update their working memory in order to compare the current letter to the one presented two letters back. Total correct responses are recorded. Imaging studies in adults and children find lateral prefrontal activation with this task.⁵⁰

Spatial working memory

This self-ordered searching task, a subset of the CANTAB,⁴¹ measures working memory for spatial stimuli. The participant must keep track of locations visited in a sequence. The test moves through three difficulty levels with four trials of each. Within each trial, the subject is told not to return to any box in which a token has been found. Between-search errors were recorded. Functional imaging studies using spatial working memory tasks show reliable activation in the dorsolateral prefrontal cortex in pediatric populations.⁵¹

Reward processing

This system involves behaviors and associative learning mechanisms necessary to motivate action and pair behaviors with outcomes. Reward processing relates to the processing of emotionally salient information such as positive and negative feedback. These tasks tap the ability to resist the pull of reward stimuli.

Intradimensional/extradimensional shift task

This CANTAB⁴¹ task tests the participant’s reversal learning or the ability to “unlearn” the association between a stimulus and a reward and then reassociate the stimulus with a punishment. Two patterns are displayed on the computer screen and the participant must select the correct stimulus according to the rule to be learned. The computer signals whether the participant is right or wrong, and, after a number of correct responses, the rule changes (shifts), and the participant must learn the new rule. Of particular interest is Total Errors, which is a measure of the participant’s efficiency in figuring out the

rule. Reversal learning is shown to be impaired after damage to the ventromedial prefrontal cortex.⁵²

Delay task

This task, part of the Gordon Diagnostic System,^{53,54} is a visual computerized test measuring impulsivity and sustained attention. The participant’s goal is to win points by pressing a button, while inhibiting his or her response for an appropriate amount of time, and then pressing the button again. If the button is pressed too soon, no points are given. The efficiency ratio score is calculated by dividing the total correct by total responses. In animals, this type of task is a sensitive measure of ventromedial prefrontal function.⁵⁵

Receptive language

Receptive language refers to the ability to attend to, process, comprehend, retain, or integrate spoken language. Selected tasks are of a receptive nature and target lexical-semantic processing and syntactic abilities.

Peabody Picture Vocabulary Test, Third Edition

This is a standardized test that measures the size of a participant’s receptive vocabulary.⁵⁶ On each trial, the participant hears a word and must select the correct meaning of the word as depicted on one of the four picture choices. This tests the lexical-semantic aspect of language. The total correct raw score is recorded. Similar word-picture matching tasks used in functional neuroimaging studies also implicate the left-perisylvian/frontotemporal area.⁵⁶

Test for reception of grammar

This is a sentence-picture matching task where the child hears a sentence and must choose the picture from a set of four that depicts the sentence.⁵⁷ Its lexical-semantic demands are negligible, as the vocabulary is simple and a pretest ensures that subjects know the meanings of the small set of words that occur in the test. The total correct raw score is recorded. The syntactic abilities tested here are localized to the perisylvian frontal and temporal cortex.^{58,59}

Visual cognition

This system includes such aspects of vision as perceptual organization; object, face, and scene recognition; visual attention and search; short-term and long-term visual memory; visual word recognition and reading; eye movement control and active vision; dynamic vision; and visual imagery.

Shape Detection

Adapted from Warrington’s Visual Object and Space Perception Battery,⁶⁰ the task requires detection of “X” in visual “noise.” A square filled with fuzz (looks like “snow” on a television set) flashes quickly on the computer screen. The participant’s task is to determine whether there is an “X” in the picture. The total correct score is recorded. Agnosic patients with damage to the visual association cortices in the occipital and inferior regions have difficulty with this task.⁶¹

Mooney Faces

The participant is shown pictures on a computer screen that are largely black in color.⁶² Some pictures contain the suggestion of a face. The participants are told to say “yes” if they see a face in the upright position and

“no” for everything else. The total correct score is recorded. The ability to perceive Mooney Faces is particularly compromised in visual agnosia following occipitotemporal damage.⁶³

Spatial cognition

Spatial cognition is concerned with the acquisition, organization, utilization, and revision of knowledge about spatial environments. These capabilities enable humans to manage basic and high-level cognitive tasks in everyday life.

Eckstrom Mental Rotation

A computer presents pairs of geometric figures from the Eckstrom kit of factor reference tests, and the subject's task is to determine whether they are the same despite orientation differences.⁶⁴ The total correct score is recorded. Mental rotation is strongly linked to posterior parietal lobes in children and adults.⁶⁵

Benton Judgment of Line Orientation

Three lines flash quickly on the computer screen; one line is on the left side of the screen and two on the right. The participant must decide whether their orientation matches, i.e., if one of the lines on the right is slanted to the same degree and in the same direction as the one on the left. The total correct score is recorded. Lesions to the parietal cortex in humans compromise spatial recognition.⁶⁶

Memory

These tasks use incidental learning tests. In order to obtain a relatively pure measure of learning ability, the participants do not know when the “to-be-remembered” stimuli are presented, thus eliminating differences in memory performance due to the use of mnemonic strategies.

Incidental word learning

The participant views pairs of pictures, one pair presented per page, and must point to the picture of the word being spoken by the experimenter. During the “test” phase, the child listens to a list of words and must decide which items were viewed earlier. The total correct score is recorded. Patients with medial temporal damage do poorly on incidental word learning.⁶⁷ Functional neuroimaging studies support this localization.⁶⁸

Incidental Face Learning

This task is analogous to the task with words, except that the learning set stimuli is 25 faces presented individually. The exposure to the initial set takes place while participants judge the faces to be older or younger than 30 years. During the “test” phase, the subject must decide whether the faces were viewed earlier. The total correct score is recorded. Medial temporal damage also impairs incidental learning of visual materials, including faces.⁶⁹ Face learning is known to activate medial temporal regions of the brain in normal humans.⁷⁰

Adolescent Problem Behavior

For the purposes of this study, problem behavior is defined as aggressive behavior, rule breaking, or social and personal disturbance that is often highly correlated with antisocial behavior later in life.^{28,71,72} Adolescent problem behavior was assessed here using the Achen-

bach System of Empirically Based Assessment Teacher's Report Form (TRF), a well-known structured reporting form. Its use, validity, and reliability are well documented.^{73,74} The TRF was chosen because it is one of the most widely used clinical tools for assessing children for behavioral problems. TRF studies have shown that teachers are more reliable when reporting on externalizing behaviors than the parents or the children themselves.⁷³ The Externalizing score on the TRF well characterizes aggressive problem behavior because the items comprise “problems that mainly involve conflicts with other people and expectations for the child.”⁷⁵ Included are such behaviors as lack of guilt, stealing, arguing, and fighting. The Externalizing scale of the TRF is a composite of two subscales, Rule Breaking and Aggressive Behavior. For the purposes of this study, the term externalizing refers to problem behavior.

TRFs were collected annually for cohort participants from the first through eighth grades. We selected the TRF that corresponded most closely to the time of the NC assessment. For example, if the NC assessment was given at age 11 years, we used the TRF scored at the age closest to 11 years. This allowed us to match the TRF evaluation for each child with the corresponding age of his or her NC battery. The TRF scores corresponding to those obtained 1 year after NC testing (when the participant was 1 year older) were termed TRF-2. Assessments at TRF-2 allowed for the examination of the reliability of the relationship between NC scores and externalizing over time. That is, we examined TRF scores 1 year later to confirm that our correlation at one age point was not a spurious finding.

Intelligence

In addition to the measures for NC functioning and externalizing, we measured IQ for the participants at age 6 years using the Wechsler Preschool and Primary Scale of Intelligence-Revised. It was administered according to standard procedures by a licensed psychologist.

Statistical Analyses

Z scores were computed for each NC task score. For each of the eight systems, a composite score was calculated as the mean of the tasks given for each NC function. Use of composite scores for NC function is a commonly accepted method for examining the relationship of the NC function to outcome behaviors.⁷⁶⁻⁷⁸ The composite scores were then used to perform statistical analyses. For the TRF, *T* scores were computed from raw scores, using the Assessment Data Manager⁷⁹ and were used for analyses. Age in years, Full Scale IQ, NC composite scores, and TRF scores between the COC and CON groups were compared using independent *t*-tests.

Further analyses were conducted in two steps. First, the association of age, IQ, cocaine exposure status, and the eight NC systems with externalizing, as the outcome variable, was examined using Pearson correlations. The results of these correlations were used to select variables associated with externalizing behavior at $p < .25$ to be included in the multivariate analysis in step 2.⁸⁰ Addi-

tional variables, identified as related to problem behavior in previous studies,^{23,27} were also included in the multivariate analysis, whether or not they met the aforementioned criteria. These variables are IQ, receptive language, and spatial cognition. That is, selected variables for the multiple regression will be age, Full Scale IQ, cocaine exposure status, receptive language, spatial cognition, and any variable that meets the test for selection as correlating with externalizing at a significance level of $\leq .25$. A backward stepwise regression model selection was used to maximize the predictive relationship between externalizing and the selected independent variables.

RESULTS

Characteristics for the cohort are as follows: 59% ($n = 65$) were girls and 45% ($n = 50$) were of the cocaine-exposed (COC) group, with the entire cohort having a mean age of 12.1 years with an SD of 1.2 years (range, 10–15) at the time of neurocognitive testing (NC) testing;

11.8 years ($SD = 1.7$; range, 7–13 years) at the time of Teacher's Report Form at time 1 assessment (TRF-1); and age 12.7 years ($SD = 1.0$; range, 8–14 years) at TRF-2. The cohort had a Full Scale IQ mean of 82.4 with an SD of 13.1 and a mean TRF score of 58.9 with an SD of 11.3 (Table 1). The clinical range for the Externalizing scale of the TRF is a T score of ≥ 70 with 11% of the cohort falling in the clinical range. This proportion is higher than the 2% found in the normative sample, but T scores are found to be slightly higher for low socioeconomic status adolescents.⁷³ No differences were found between girls and boys for age, Full Scale IQ, cocaine exposure status, NC performance, and TRF scores. A difference was found between COC and not exposed to cocaine (CON) groups for memory ($t = 2.17, p = .03$), with the COC group having lower memory scores.

IQ was significantly correlated with six of the NC systems: the frontal systems of executive cognitive functioning (ECF), reward processing, and cognitive control,

Table 1. Correlations of Age, IQ, Cocaine Status, and Neurocognitive Tasks with Teacher's Report Form Externalizing Scores: Time 1 (TRF-1)

Variable	Mean	SD	Range	<i>r</i>	<i>p</i>
Participant characteristics					
Age at time of NC testing, yr	12.1	1.2	10–15	.123	.20
Age at time of TRF-1, yr	11.8	1.7	7–13	.083	.47
Age at time of TRF-2, yr	12.7	1.0	8–14	.18	.12
Full Scale IQ, age 6 yr	82.4	13.1		-.215	.03*
Cocaine exposure status				.002	.98
Neurocognitive function					
Task					
Executive cognitive function					
Stockings of Cambridge	6.7	1.8		-.236	.002**
Wechsler Mazes	18.9	4.6		-.157	.10
Reward processing					
IE/ED shift task	46.9	19.1		.173	.07
Working memory					
Two-Back	108.4	5.9		-.153	.11
Spatial working memory	47.6	16.5		.151	.12
Cognitive control					
Go/no-go	96.7	5.7		-.153	.11
Counting Stroop	28.8	17.4		.039	.69
Receptive language					
Peabody Picture Vocabulary	121.0	21.5		-.236	.01**
Test for Reception of Grammar	16.3	2.3		-.222	.02*
Spatial cognition					
Eckstrom Rotation	31.1	5.7		-.112	.25
Benton Line	30.4	3.1		-.100	.30
Visual cognition					
Mooney Faces	28.7	4.7		.093	.34
Memory					
Face learning	43.0	5.0		-.092	.35
Word learning	25.0	7.2		-.018	.85

NC, neurocognitive; IE/ED, intradimensional/extradimensional. * $p < .05$; ** $p < .01$.

and the nonfrontal systems of receptive language, spatial cognition, and memory ($p < .003$). IQ was not associated with working memory and visual cognition ($p \geq .15$) (Table 2).

Relationship of NC Functioning with TRF

Correlations between age, IQ, cocaine exposure status, and NC task means are displayed in Table 2. Given the very slight differences historically³⁷ shown between the COC and CON groups and by controlling for cocaine exposure for the remainder of our analyses, the groups are studied as one cohort. Composite scores were used to explore the relationship of the NC systems and externalizing (TRF-1, closest in time to the NC assessment and TRF-2, 1 year later) (Table 2). At TRF-1, ECF and receptive language were correlated with externalizing ($p = .004$ and $.005$, respectively). Adjustment for multiple comparisons was performed for the simultaneous testing for the eight systems, using a more conservative critical p value of $.006$ (test value of $p < .05$ divided by eight tests, Bonferroni correction). Using these more stringent criteria ECF and receptive language continued to be significantly negatively correlated with externalizing. Other systems were not found to be significant ($p > .07$). At 1-year post-NC assessment (TRF-2), ECF and receptive language continued to be associated with externalizing ($p < .04$), but not significantly after adjusting for multiple comparisons (Table 2). This finding was to be expected, given that TRFs at each age are highly correlated with one another. Nevertheless, it confirmed that (1) the correlation of NC with externalizing was stable at a point in the future and (2) the relationship was not spurious.

In post hoc analyses, the relationship between the NC systems and the two externalizing (TRF-1) components (Rule Breaking and Aggressive Behavior) also revealed significant negative correlations between ECF and Rule Breaking and Aggressive Behavior ($p < .05$), and between receptive language and Rule Breaking and Aggressive Behavior ($p < .01$) (data not shown). Using this more stringent criterion, ECF and receptive language continued to show a significant negative correlation with Rule Breaking and Aggressive Behavior. At TRF-2, ECF and receptive

Table 2. Neurocognitive Systems Correlated with Teacher's Report Form Externalizing Scores: Bivariate Correlations at Time 1 and Time 2

Function	TRF-1 (n = 111)		TRF-2 (n = 75)	
	r	p	R	p
Executive cognitive function	-.274	.004**	-.333	.003**
Reward processing	-.173	.07	-.067	.57
Working memory	-.001	1.0	-.057	.63
Cognitive control	-.122	.21	-.200	.09
Receptive language	-.263	.005**	-.236	.04
Spatial cognition	-.132	.17	-.131	.27
Visual cognition	.093	.34	.107	.36
Memory	-.074	.45	-.125	.030

* $p \leq .05$; ** $p \leq .01$.

language also remained correlated with the subscales Rule Breaking, but not Aggressive Behavior ($p < .05$) (data not shown).

So far, it has been demonstrated ECF and receptive language are associated with externalizing behavior. In order to test the predictive value of ECF and receptive language for externalizing behaviors in the context of other possible predictors, we performed further analyses. Thus, using backward, stepwise multiple regressions, the first model consisted of five selected NC scores based on the criteria set forth in the analysis plan. These predictor variables included ECF, cognitive control, reward processing, receptive language, and spatial cognition. Age, IQ and cocaine exposure status were also included as predictor variables. After backward selection, with threshold for variable removal at $p > .10$, three variables remained: age, ECF, and receptive language (Table 3).

To evaluate the robustness of this model, we also applied backward (removal if $p > .10$) and forward (entry if $p < .05$) variable selection, using all eight NC scores, age, IQ, and cocaine exposure status. This backward selection resulted in a different model yielding age ($B = 1.76$, $SE = 0.95$, $p = .07$), reward processing ($B = -2.37$, $SE = 1.15$, $p = .04$), and receptive language ($B = -3.41$, $SE = 1.35$, $p = .01$) as predictors of externalizing (TRF-1). The forward process selected only receptive language ($B = -3.47$, $SE = 1.29$, $p = .008$) as a predictor, after which age was not significant enough to enter at $p < .05$ (data not shown). Because age is an important factor in NC cognitive development and externalizing behaviors, we chose the first result (age, ECF, receptive language) as our final model.

ECF as a Mediating Variable

Deficiencies of ECF are often implicated in many types of behavior syndromes such as attention-deficit/hyperactivity disorder (ADHD). Theoretical models consider ECF to be a higher level system, drawing on several other NC systems. Also, for our cohort, ECF is highly correlated

Table 3. Stepwise, Backward Regression Age, IQ, and Neurocognitive Systems with Teacher's Report Scores at Time 1

Variables	B_a	SE_b	β_c	p
Step 1				
Age	2.44	1.09	0.25	.03*
Full Scale IQ	0.08	0.13	0.09	.56
Cocaine exposure group	-1.97	2.38	-0.08	.41
Executive cognitive function	-3.16	1.68	-0.22	.06
Cognitive control	-0.26	1.61	-0.02	.87
Reward processing	-2.27	1.27	-0.19	.08
Receptive language	-3.79	2.05	-0.29	.07
Spatial	1.38	1.90	0.10	.48
Step 6				
Age	1.95	0.95	0.20	.04*
Executive cognitive function	-3.20	1.57	-0.22	.05*
Receptive language	-2.75	1.48	-0.21	.07

* $p \leq .05$.

with receptive language ($r = .50, p < .001$). Thus, we tested whether ECF could be a mediator of the effect of language on externalizing behavior, all after adjusting for age.

A coefficient product test⁸¹ was calculated to determine whether there is an indirect effect (mediation) and to what degree ECF and receptive language covary. The coefficient product test computes the product of the estimated coefficient from one model (ECF on language) and the main model (externalizing on ECF) along with an estimate of SE using the estimated SEs of the coefficients. If the z score of the product is significantly different from 0 with a standard normal distribution as reference, then we infer that mediation is present. The difference between full and partial mediation comes from the degree to which the coefficient of language on externalizing reduces in significance when ECF is added to the model. We found ECF did mediate the effect of receptive language on externalizing ($p = .012$). Without ECF, and after adjusting for age, the effect of receptive language on externalizing was significantly stronger (coefficient = $-4.163, p = .001$) (data not shown).

DISCUSSION

Results of this study provide important information about the relationship between neurocognitive (NC) function and problem behavior in African American adolescents, a population that is underrepresented in the NC literature. We found that two systems, executive cognitive functioning (ECF) and receptive language, were associated with problem behavior. That is, lower cognitive functioning in these areas is associated with higher scores of behavioral problems as measured by the Teacher's Report Form (TRF).

Executive Functioning

The relationship between lower ECF function and more problem behavior is an expected finding. Impaired executive function has been well documented in psychology and criminology literature as associated with antisocial behavior.^{82,83} The working explanation holds that participants who have more difficulty completing a multistep task that requires integrating details at each step are more likely to engage in problem behaviors because they cannot consistently keep rules of conduct in mind when they interact with others. These findings suggest that adolescents with compromised ECF may exhibit externalizing behaviors for several reasons, such as (1) they have fewer NC resources from which to formulate a working plan of action to follow rules and (2) they have an impaired ability to plan adaptive responses while involved in complex situations.

In adolescence, the brain is undergoing later stages of development, physiologically and cognitively, that will result in the sophisticated NC processing needed to negotiate a complex world.^{84,85} These changes are occurring at a time when middle school and high school rules are becoming more complex and require more personal control and monitoring. Thus, adolescents who have compromised ECF may not be able to understand or

respond appropriately to expectations for behavior in complicated classroom situations. As a result, adolescents with compromised ECF may become frustrated and resort to "acting out" behaviors such as rule breaking and aggression. Siegel and Scovill⁸⁶ have described this combination of age and cognitive vulnerability as "the double symptom of adolescence." That is, vulnerable adolescents may exhibit behavioral problems not only related to general adolescent stages of development, but also due to their particular cognitive deficits. Likewise, as adolescents become older, we might expect to see more externalizing behavior as more responsibilities and social pressures are taken on, particularly in poor urban African American adolescents who tend to have less support to handle academic and societal demands.

Language Functioning

In this study, receptive language was correlated with externalizing behavior, an association with problem behavior that has been documented in the literature.^{87,88} However, language problems are most often incidentally found when evaluating other psychiatric diagnoses such as conduct disorder. For example, diagnoses of language dysfunction in violent offenders or children with externalizing behavior are most often made *after* youths have been incarcerated or referred for treatment. Rarely is language functioning considered as a predictor of problem behavior.

Our finding that lower receptive language abilities are a predictor of problem behavior may account, in part, for problems in the classroom because of (1) limited receptive language skills to use in processing and understanding the rules and (2) limited internal language skills to guide and control their behavior. Receptive language is the vehicle by which youths understand and incorporate classroom rules. Deficiencies in receptive language (as shown in this study) may affect comprehension and result in increased rule breaking. This suggestion has been supported by Dionne,⁸⁹ who states that, over time, language deficits can result in a "break down" in communication with others. For adolescents, this frustration in communication may result in acting out behavior and conduct problems.

Limitations of this study are several. The number of participants is small. Further, they are African American and of low socioeconomic status, which limits the generalizability of our findings to all adolescent populations. The outcome measure (TRF) used in this study is an observation checklist that is as objective as school discipline or court records, but is highly correlated with these measures. This notwithstanding, these findings pertaining to executive functioning are similar to those found in studies of antisocial behavior that included a more diverse sample of participants.^{22,90,91} Moreover, investigations in African Americans of lower socioeconomic status are quite important, as low socioeconomic status African Americans are disproportionately referred to the criminal justice system.^{92,93}

Summary

Historically, individuals with a low IQ have often been found to be antisocial, suggesting that “slow-witted delinquents have a greater susceptibility to detection by police.”²⁸ Likewise, children who have been referred for treatment for conduct problems are frequently found to have a preexisting language development disorder that may have led to the conduct problem. In this study, we find that receptive language may be a better predictor than IQ of externalizing behavior. As noted earlier, the correlation between ECF and problem behavior was an expected finding. What is surprising is that receptive language was more predictive of problem behavior than ECF. This may reflect the fact that ECF is a diffuse ability that does not fit neatly into any one system and draws on multiple abilities. Because receptive language is considered to involve a more distinct cognitive system than ECF, subsequent investigation of the relationship between language and predelinquent behavior deserves to be considered.

We know that language deficiencies can affect behavior, but results are varied and inconsistent in the literature regarding which specific mechanisms are involved.^{17,23,87-89} Yet, the language literature should not be ignored when examining language difficulties in an attempt to prevent and intervene in problem behavior. This study offers renewed attention to this body of literature as well as a new perspective. That is, there are specific mechanisms involved in the pathways of receptive language abilities leading to problem behavior in children and adolescents. These mechanisms include (1) children do not understand the rules and thus are involved in increased rule breaking, (2) communicating with others (e.g., teachers and peers) is a frustrating experience and results in increased problem behaviors, or (3) a combination of these two mechanisms is at work. Thus, this study suggests that renewed attention to a familiar problem would enhance understanding of specific mechanisms of language in relation to problem behavior and inform our effort to create workable interventions.

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