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Cognitive and Neuropsychological Characteristics of Physically Aggressive Boys

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Cognitive–neuropsychological tests were given to adolescent boys ($N = 177$) to investigate processes associated with physical aggression. Factor analysis yielded 4 factors representing verbal learning, incidental spatial learning, tactile–lateral ability, and executive functions. Physical aggression was assessed at ages 6, 10, 11, and 12, and 3 groups were created: stable aggressive, unstable aggressive, and nonaggressive. The authors found main effects for only the executive functions factor even when other factors were used as additional covariates in a step-down analysis; nonaggressive boys performed better than stable and unstable aggressive boys. The covariates family adversity and anxiety were both related only to the verbal learning factor. This study highlights the importance of deficits in executive function in the expression of physical aggression relative to other cognitive–neuropsychological functions.

The likelihood of expressing violent behavior is multifactorial (Raine, 1993) and probably interactive (Pennington & Bennetto, 1993), thus making the delineation of mechanisms of this complex behavior obscure. Attention has been given to social factors (Haapasalo & Tremblay, 1994; G. R. Patterson & Yoerger, 1992); personality in adolescence (Tremblay, 1992) and adulthood (Sigvardsson, Bohman, & Cloninger, 1987); psychophysiological profiles (Raine, Venables, & Williams, 1990); hormonal profiles (Dabbs, Jurkovic, & Frady, 1991); genetic background (Morell, 1993); and neuropsychological motivational processes (C. M. Patterson & Newman, 1993). Regarding the latter approach, deficits in cognitive–neuropsychological abilities early in life, the focus of this study, have been viewed as contributing to an impulsive behavioral style in a brain–environment interaction (Moffitt, 1993b) and to transactionally affect social maturity (Buikhuisen, 1987) and consequent likelihood of aggressive responding.

Both cognitive and behavioral similarities have been noted between individuals who have had frontal lobe damage, sometimes called the *pseudopsychopathic syndrome* (Moffitt, 1990; Stuss & Benson, 1984) or *acquired sociopathy* (Eslinger & Damasio, 1985), and those who show characteristics of antisocial behavior (Price, Daffner, Stowe, & Mesulam, 1990; Weiger & Bear, 1988). This observation has been a major impetus for the research of neuropsychological abnormalities in antisocial individuals. The authors of recent literature reviews (Buikhuisen, 1987; Kandel & Freed, 1989; Moffitt, 1990, 1993a; Pennington & Bennetto, 1993; see also reviews in J. S. Milner, 1991) and several other studies (e.g., Hurt & Naglieri, 1992; Lueger & Gill, 1990; Moffitt, Lynam, & Silva, 1994) unanimously conclude that impairments in cognitive functions are implicated in the regulation of aggressive behavior.

Three major classes of cognitive impairment seemingly associated with aggressive behavior are those affecting executive functions, verbal abilities, and abnormalities in cerebral dominance. *Executive functions* (also called *conative* or *control functions*) describe capacities for the initiation and maintenance of efficient attainment of goals (Lezak, 1985). They are typically derived from tests that assess primarily programming and planning of goal-oriented motor behavior skills, modulation of behavior in light of expected future consequences, anticipation of events in the regulation of behavior, learning of contingency rules and the ability to use feedback cues, inhibition of response set and flexibility (vs. perseveration), abstract reasoning, problem solving, sustained attention, and concentration. These abilities require active monitoring, operate within working memory (Petrides, Alivisatos, Evans, & Meyer, 1993), and have been associated with frontal lobe activity (Lezak, 1985; Welsh & Pennington, 1988). These important functions, historically overshadowed by a focus on more easily manageable abilities related to speech, perception, and memory, have been more extensively studied in the past 20 years (Benton, 1994).

Weaknesses in verbal skills affect language-based performance in areas such as receptive listening and reading, expressive speech and writing, and memory for verbal material

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When all selection criteria were applied, the selected sample consisted of 333 boys aged 13 ($M = 13.33$, $SD = 0.30$). Of them, 203 boys agreed to come to the laboratory. At age 14 ($M = 14.34$, $SD = 0.30$), 177 of those 203 returned to the laboratory for further testing. Participation on each visit entailed one full day of testing and experimentation in the summer or during a weekend in early fall. Written informed consent was obtained from the parents. Emphasis was placed on oversampling stable aggressive boys. Of the 177 boys who completed both years of testing, 63 were classified in the stable aggressive group, 59 in the nonaggressive group, and 55 in the unstable aggressive group. Note that 47 of the 59 nonaggressive boys had an average aggression score of 0. Among the stable aggressive boys, 28 were above the 70th percentile at all four assessments, whereas 35 were above at age 6 and two more assessments. Among the unstable aggressive boys, 2 were above the 70th percentile at ages 10, 11, and 12, four were twice above the 70th percentile, and 16 were once above the 70th percentile, whereas 18 were only aggressive at age 6 and 15 boys at age 6 and another time. There is thus no possible overlap between categories.

A preschool familial adversity composite index was compiled from the average of several variables collected from the mother when the boy was 6 years old. These variables were parental age at first child's birth, parental education level, family status (i.e., intact, nonintact), and SES of parent's occupations (Tremblay et al., 1991).

The laboratory sample ($N = 177$) was compared to the remainder of the 893 boys by group with 2 × 3 analyses of variance (ANOVAs). No Group × Sample interactions or sample main effects were found on ages 13 and 14 averages for SBQ measures of anxiety, inattention, and hyperactivity, and age 6 prosociality and familial adversity. The laboratory sample does not differ from the large sample on these parameters. Groups main effects were significant on all of these measures and average self-report delinquency (ages 13 and 14). Means for the stable aggressive boys were larger than the means for the unstable aggressive boys, which in turn were larger than the means for the nonaggressive boys. The direction of differences was reversed for SBQ prosociality ratings at age 6.

Materials and Procedure

Boys were given a different battery of cognitive–neuropsychological tests on two visits 1 year apart. At each visit the battery was administered over approximately 1 hr. Between 3 and 6 boys were tested every day. Because only 1 boy could be tested at a time, testing order was randomized. Experimenters were blind to hypotheses and group membership. All tests were administered in French.[2]

Dichhaptic Lateralization

This task assessed the somaesthetic modality, which is theoretically a right hemisphere ability specialized for the perception of nonlinguistic spatial tactual stimuli (Witelson, 1974). The task consisted in feeling two nonsense shapes, out of view, with the tips of two fingers, using both hands simultaneously, for 10 s. The boy then had to identify the two shapes from an array among six shapes, including the two correct answers. Simultaneous dichotomous presentation is believed to reduce interhemispheric communication that would allow the less competent hemisphere to assist the task. This task is therefore thought to measure cerebral dominance and has been found to be valid only for boys (Witelson, 1976). The task yields two indexes: correct answers right hand total (tactile laterality right) and correct answers left hand total (tactile laterality left).[3]

Digit Span

This test from the Wechsler Memory Scales (Wechsler, 1987) yields two subscores: digits forward and digits backwards. This test is thought to measure auditory attention and immediate auditory–verbal memory (Lezak, 1983) and is most sensitive to distractibility (Sattler, 1988).

Nonspatial Conditional Association

This is a task on which individuals with frontal lobe lesions perform poorly (Petrides, 1990). This task measures active monitoring in working memory and requires the maintenance and organization of recently acquired information. Boys had to associate a color with a hand signal. Positron emission tomography (PET) and magnetic resonance imaging (MRI) studies using a variant of this task with colors and abstract designs as pairs highlight the involvement of the left posterior dorsolateral frontal cortex of nonlesioned participants (Petrides, Alivisatos, Evans, & Meyer, 1993).

Paired Associates

This is a paired-word learning task from the Wechsler Memory Scales (Wechsler, 1987). Six of the pairs were easy to associate, and four were difficult.

Self-Ordered Pointing

The Self-Ordered Pointing task (B. Milner, Petrides, & Smith, 1985) measures active monitoring in working memory; it requires constant mental scanning of past selections in planning later choices. Boys were presented three times with 12 arrays that contained 12 different figures. The arrangement of figures changed on each page so that figures would change location on consecutive pages. The boy had to select a different figure on each page and could not choose the same location more than twice on consecutive pages. Abstract and concrete forms were administered. PET and MRI studies using a variant of this task with only abstract designs have shown that the task critically involves the right mid-dorsolateral frontal cortex with few peaks in the left mid-dorsolateral frontal cortex of nonlesioned participants (Petrides, Alivisatos, Evans, & Meyer, 1993).

Spatial Memory

Spatial memory was assessed using a task developed by M. L. Smith and Milner (1981, 1989). In the morning, 16 objects were presented on a board for each boy to name and examine. Board and objects were then covered, and he had 1 min to name them from memory. In the afternoon, he was presented with the same objects in a pile and was given 2 min to arrange them as he saw them in the morning. This task yielded three variables assessing incidental spatial learning: (a) delayed recall of 16 objects, (b) immediate recall of 16 objects, and (c) duration in seconds of delayed recall with a ceiling at 120 s. Finally, delay (in minutes) between exposure to stimuli and recall was measured as it varied from participant to participant due to scheduling contingencies. On delayed recall, patients with right temporal lobe lesions have shown marked deficits in remembering (not in encoding) as a factor of time alone, even under intentional learning conditions, whereas patients with left temporal lobe lesions were less affected.

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[2] Space considerations preclude a more thorough description of measures. Such information is available from the original sources or from Robert O. Pihl.

[3] Lateral preference was assessed with the Edinburgh Inventory (Oldfield, 1971). This variable was categorical and could not be included in the analyses. Small sample sizes in some cells precluded the use of chi-square statistics.

Strategic Problem Solving

On this task, developed by Becker, Butters, Rivoira, and Miliotis (1986), boys were shown three types of arrays of visual stimuli. One array consisted of drawings and was presented three times with a different predetermined target each time. The boys then had to find a target by asking questions to which the experimenter could answer only *yes* or *no*. The two other arrays consisted of digits and letters, respectively. In these arrays, there were no predetermined targets, although the boy was led to believe there was one. The rule was for the experimenter to always answer *yes* or *no* in order to leave unexplored the maximum number of remaining cells. Although this task has not been validated with either brain imaging techniques or lesion analysis, it theoretically assesses anterior cortical areas that mediate problem-solving abilities, and its authors have demonstrated that it requires abilities independent from IQ.

Subjective Ordering

This task required the boys to randomize numbers from a given range without creating any apparent sequence, repeating a digit, or using any apparent strategy (Wiegersma, van der Scheer, & Human, 1990). Only auditory cues could be used. Ranges of 4, 6, 8, and 10 digits between the numbers 1 to 10 were given verbally. A different starting digit from somewhere in the range was given for each trial. There were two trials per range, for a total of 8 trials. The test was terminated when boys responded incorrectly two consecutive times at the same range level. Total number of successful trials before failure was used as the dependent variable. This task measures active monitoring in working memory because it requires the maintenance and active organization of recently acquired information. PET and MRI studies using a 10-digit span have shown that this task critically involves the mid-dorsolateral frontal cortex bilaterally in nonlesioned participants (Petrides, Alivisatos, Meyer, & Evans, 1993).

Verbal Fluency

Letter fluency. This task required that the boys generate as many words starting with the letter *S* as they could think of in 5 min (unrestrained procedure) and that the boys generate as many four-letter words that started with the letter *P* in 4 min (restrained procedure; Lezak, 1983). The number of correct responses for both procedures were used as dependent variables.

Semantic fluency. Semantic fluency (a restrained procedure) was assessed with three category fluency procedures. Similar to letter fluency, semantic fluency requires the generation of as many words as possible in 1 min that belong to a given category (Lezak, 1983). Categories were *toys*, *flowers*, and *animals*. The number of correct responses in the three categories were used as dependent variables. These verbal fluency tasks involve left frontal and bilateral temporal cortices as measured in brain imaging studies with normal participants (Frith, Friston, Liddle, & Frackowiak, 1991; Parks et al., 1988; Randolph, Braun, Goldberg, & Chase, 1993). Dissociation studies suggest that the temporal cortices are involved in storage of words, whereas the left dorsolateral frontal cortex is involved in the retrieval mechanism (Frith et al., 1991; Randolph et al., 1993).

Results

Factor Analysis

Factor analysis was used to summarize the pattern of correlations among variables and to reduce the large number of variables. On the basis of the consistent findings in the literature (Moffitt, 1990), we expected that tests of executive function and tests involving verbal learning would load on separate but correlated factors. The correlation was expected because, for example, executive functions involve working memory processes that are dependent on the intactness of basic memory processes. Basic memory processes were assessed by verbal learning and spatial memory tests. A test of immediate recall of objects associated with the tests of spatial ability was expected to load mainly on a verbal learning factor because of its strong verbal component. Tests of delayed recall for spatial ability and of dichhaptic cerebral dominance were expected to form a third factor because of their strong reliance on right hemisphere processing.

Descriptive Statistics

Five missing test data points were replaced by sample means. To maintain a reasonable variables-to-participants ratio (Tabachnick & Fidell, 1989), we used aggregated scores for the following tests. These test scores are often used in aggregated form. For the Digit Span task, we used the sum total of both subscales as the dependent variable because they correlated significantly ($r = .53$, $p < .001$). For the Paired Associates task, the easy and difficult scores were summed and correlated ($r = .73$, $p < .001$). For the Self-Ordered Pointing task an index was computed from the sum of scores on the abstract and concrete subtests. These two variables were correlated ($r = .51$, $p < .001$). For the Strategic Problem Solving task, the variables describing types of questions were confounded and difficult to interpret, and only number of problems solved was used. The Letter Fluency task scores were summed and correlated ($r = .57$, $p < .001$). Semantic Fluency tasks were also summed. Correlations between categories were as follows: toys and flowers, $r = .35$, $p < .001$; toys and animals, $r = .64$, $p < .001$; flowers and animals, $r = .38$, $p < .001$.

Transformations

Prior to factor analysis we examined variables for multivariate outliers, univariate outliers, and normality. Outliers were first examined in relation to any medical conditions that may have affected the boys neurologically and consequently impaired their test performance. The boys' mothers had been asked retrospectively whether they had had any birth or pregnancy complications such as abnormal bleeding ($n = 15$), blood incompatibility ($n = 3$), preeclampsia ($n = 2$), rubella or syphilis ($n = 0$), premature rupture of membrane ($n = 8$), umbilical cord prolapse ($n = 8$), cesarian section complications ($n = 8$), use of forceps ($n = 23$), low birth weight (i.e., < 2.5 kg; $n = 11$), necessity to incubate child ($n = 26$), apparent physical anomalies ($n = 6$), and so on. The boys themselves were asked at ages 12 ($n = 9$), 13 ($n = 5$), and 14 ($n = 4$) whether they had had a serious illness in the past 12 months (and if so, what type) and whether they had ever been hospitalized (and if so, why; $n = 14$). Outliers were defined as cases at $\alpha < .001$. One of these affected boys had an outlying score due to poor performance on the semantic fluency tasks, whereas another had an outlying score on letter fluency due to very good performance. This suggests that these conditions did not impair test performance.

Table 1
Correlations Among Cognitive–Neuropsychological Tests

Test	SOP	NSP	NR	SPS	SFL	PASS	LFL	DS	SMDR	SMIR	SMTDR	TLR
NSP	.37***											
NR	.22**	.40***										
SPS	.21**	.30***	.20**									
SFL	.24***	.27***	.16*	.18*								
PASS	.20**	.31***	.27***	.33***	.44***							
LFL	.25***	.25***	.24***	.34***	.57***	.41***						
DS	.22**	.38***	.32***	.37***	.46***	.35***	.50***					
SMDR	.15*	.19**	.06	−.06	−.05	−.07	−.09	−.07				
SMIR	.12	.08	.10	−.03	.06	.07	.08	.004	.23**			
SMTDR	.14	.14	.17*	.03	.20**	.08	.06	.07	.20**	.24***		
TLR	.15*	.11	.11	.20**	.26***	.26***	.35***	.16*	.12	.09	−.03	
TLL	.15*	.14	.12	.21**	.09	.21**	.21**	.18*	.07	−.02	−.01	.47***

Note. Variables scored in the negative were transformed in the positive direction for ease of interpretation so that higher scores represent higher ability. The sign for time for delayed recall on the Spatial Memory task remains unchanged. SOP = Self-Ordered Pointing (square root); NSP = Non-Spatial Conditional Associate; NR = Number randomization; SPS = Strategic Problem Solving; SFL = semantic fluency; PASS = Paired Associates learning (reciprocal and logarithmic); LFL = Letter Fluency (square root); DS = Digit Span; SMDR = Smith and Milner (1981) Delayed Recall (logarithmic); SMIR = Smith and Milner (1981) Immediate Recall; SMTDR = Smith and Milner (1981) Time for Delayed Recall (logarithmic); TLL = Tactile Lateralization, left hand; TLR = Tactile Lateralization, right hand.
* $p < .05$. ** $p < .01$. *** $p < .001$.

We examined the effect of the delay between exposure to stimuli and recall of stimuli location for the spatial memory delayed-recall variable to see whether it would be necessary to control for this effect. The correlation ($r = -.07$) was found to be nonsignificant. This variable was dropped from further analyses.

No multivariate outliers were found. Variables were standardized for inspection, and those with univariate outlying cases at $\alpha < .001$ ($SD > 3.3$) were brought in next to the most extreme score where possible (Tabachnick & Fidell, 1989). Normality was assessed by examining skewness and kurtosis (criterion $\alpha < .001$). Appropriate action was taken to correct the distributions for Self-Ordered Pointing tasks (square root), letter fluency total (square root), spatial memory delayed recall (logarithmic), spatial memory time for delayed recall (logarithmic), and Paired Associates task (reciprocal and logarithmic).

Correlations

Correlations between variables prior to factor analysis are presented in Table 1.

Extraction and Rotation

Principal components extraction was followed by oblique rotation because of the expected correlation between hypothetical factors. After rotation, four factors accounting for 58% of the variance and with an eigenvalue greater than 1 were retained. Variables with loadings greater than .45 (i.e., greater than 20% variance overlap between variable and factor) in absolute value were retained for interpretation. With an oblique rotation, factors are interpreted from the loadings of the pattern matrix shown in Table 2. Factor 1 contains variables that reflect verbal learning. Factor 2 represents the Spatial Incidental Learning assessed with the spatial memory tasks. Factor 3 represents Tactile Laterality, and Factor 4 is comprised of variables associated with Executive Functions.[4] Table 2 also contains communalities, reliability statistics (alphas), and correlations between factors.

An examination of the between-factors correlations suggested that oblique rotation was warranted due to factor overlap ($r = .31$; > 9% of the variance) between Factors 1 and 4 (Verbal and Executive).

Conclusion

The structure of the factors was consistent with the hypotheses except for the Tactile Laterality factor, which had not been predicted. The Spatial Learning factor was not quite as expected but may be interpreted as a basic memory factor. Estimation of factor scores using the regression method were obtained for each of the four factors discussed earlier so that they may serve as dependent variables. This method of deriving scores is consistent with the oblique rotation of the factor analysis because it respects the correlations between empirical factors.

MANCOVA

With the expectation of establishing a clear distinction between specific and basic memory processes, we hypothesized that the Executive Functions factor would have the strongest association with physical aggression, over and above the effects of family adversity, Verbal Learning, and Incidental Spatial Learning factors. We did not make predictions about the relation between physical aggression and cerebral dominance as

[4] The stability of the solution was supported by the application of a Varimax rotation, which yielded the same variable groupings in factors.

Table 2
Factor Pattern Matrix

Variable	VL	ISL	TLL	EF	Communalities
	Factor				
		Factor loadings			
SFL	.84*	.22	−.002	−.04	.72
LFL	.76*	.04	.19	.04	.68
PASS	.55*	−.01	.13	.21	.47
DS	.55*	−.12	−.04	.39	.58
SMIR	.09	.74*	.07	−.08	.54
SMTDR	.17	.66*	−.21	.13	.51
SMDR	−.43	.55*	.26	.28	.61
TLR	.22	.09	.83*	−.14	.76
TLL	−.04	−.12	.80*	.10	.69
NSP	.01	.03	−.05	.82*	.66
NR	.02	.01	−.06	.69*	.47
SOP	.02	.16	.08	.55*	.39
SPS	.21	−.30	.14	.46*	.44
		Factor variances and reliabilities			
Variance[a]	2.21	1.49	1.53	1.99	
% variance	17.0	11.5	11.8	15.0	
α	.76	.46	.64	.61	
Factor		Correlations between factors			
ISL	−.03	—			
TL	.16	.03	—		
EF	.31	.12	.22	—	

Note. SFL = Semantic Fluency; LFL = Letter Fluency; PASS = Paired Associates learning; DS = Digit Span; SMIR = Smith and Milner (1981) Immediate Recall; SMTDR = Smith and Milner (1981) Time for Delayed Recall; SMDR = Smith and (1981) Milner Delayed Recall; TLR = Tactile Lateralization Right Hand; TLL = Tactile Lateralization Left Hand; NSP = Nonspatial Conditioned Associate; NR = Number Randomization; SOP = Self-Ordered Pointing; SPS = Strategic Problem Solving; ISL = Incidental Spatial Learning; TL = Tactile Lateralization; EF = Executive Functions; VL = Verbal Learning.
[a] Variance with an oblique rotation is computed by summing the squared loadings from the pattern matrix.
* Loadings ≥ .45.

represented by the Tactile Laterality factor because its defining components did not form the predicted factor.

Covariates

To control for the importance of social disadvantage, we used the familial adversity composite index as a covariate. This composite set of variables was found to be predictive of stability of externalizing disorders in a sample of over 3,000 French-speaking children (Vitaro, Tremblay, & Gagnon, 1992). To control for possible sampling bias caused by the use of anxiety as a selection criterion, we also covaried out concurrent (average of age 13 and age 14) teacher-rated anxiety scores. A family adversity score was missing for 1 boy from the unstable aggressive group and was replaced by the group mean. Anxiety data were missing for 3 boys and replaced with the ages 6 and 10 to 12 anxiety average. Anxiety was normalized with a square-root transformation. The between-groups homogeneity of the slopes of the covariates were examined for both covariates; Wilks's lambdas were nonsignificant.

Transformations

A 1 × 3 between-subjects MANCOVA was performed on the four factors while controlling for familial adversity and anxiety. Prior to applying the MANCOVA to the data, we examined factor scores and the covariates for multivariate outliers and factor scores for univariate outliers and normality within each group. No multivariate outliers were found at $\alpha < .001$. All distributions were normal as determined by examination for skewness and kurtosis (criterion < .001) and by examination of normal and detrended-normal probability plots. Two univariate outliers on the Incidental Spatial Learning factor ($SD > 3.3$; $p < .001$) were brought in toward the next most extreme score in the distribution by $^1/_{10}$ of a standard deviation (Tabachnick & Fidell, 1989). Evaluation of the assumption of homogeneity of variance–covariance matrixes was satisfactory.

Effect of the Covariates

We found the multivariate effect of the covariates to be significant, Hotelling's $T^2 = .13$, approximate $F(8, 336) = 2.80$, p

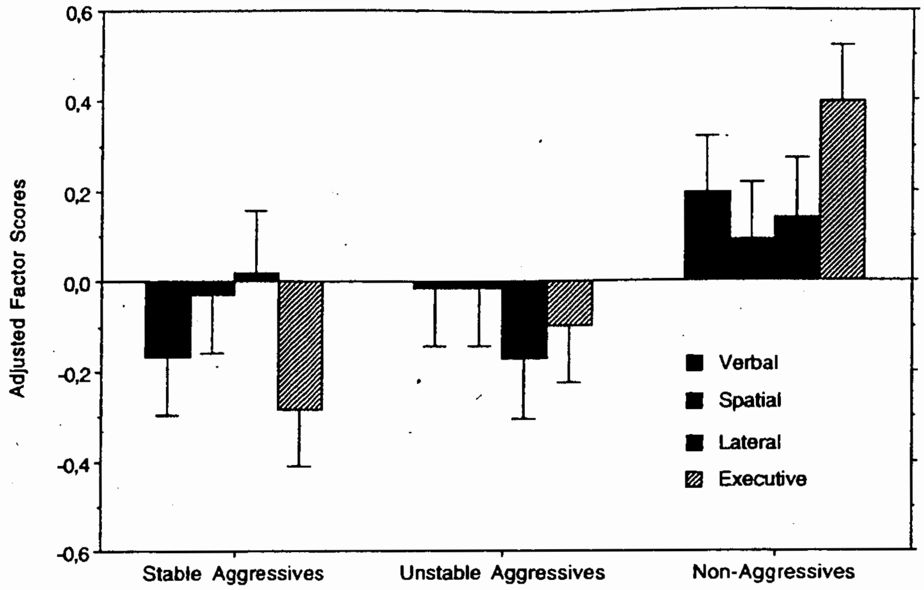

Figure 1. Adjusted means and standard errors for regression factor scores by aggression group.

< .006, power = .94. To investigate the effect of the covariates on the dependent variables, we ran multiple regressions for each dependent variable. Familial adversity and anxiety provided significant adjustment only to the verbal factor, $F(2, 172) = 9.39$, $p < .001$. The beta values were significantly different from zero: for familial adversity, $\beta = -.23$, $t(172) = -3.23$, $p < .002$, power = .89; for anxiety, $\beta = -.19$, $t(172) = -2.75$, $p < .008$, power = .78.

Effect of MANCOVA

Stepdown procedures have been used a priori to address factor overlap. A hierarchical order was derived theoretically. Incidental Spatial Learning and Tactile Laterality were entered in the model before Verbal Learning. This was to test the hypothesis that deficits in Verbal Learning were associated with physical aggression over and above deficits in spatial learning or cerebral dominance. Executive Functions were entered last to test the hypothesis that deficits in executive functioning were related to physical aggression, over and above all other cognitive–neuropsychological abilities.

The overall MANCOVA was found to be significant, Hotelling's $T^2 = .11$, approximate $F(8, 336) = 2.30$, $p = .020$, power = .98. Roy-Bargman stepdown F tests of the effect of the groups on the dependent variables after adjustment for the covariates followed. Significant main effects were found on the Executive Functions factor only, $F(2, 169) = 5.56$, $p = .005$. Adjusted means and standard errors for factor scores are presented in Figure 1. All means varied in the expected directions; the stable aggressive boys always performed more poorly, except on the Tactile Laterality factor. Univariate homogeneity of variance was found to be satisfactory. Planned contrasts were performed comparing stable aggressive boys and nonaggressive boys and unstable aggressive boys with nonaggressive boys. For the Executive Functions factor the comparison between stable aggressive boys and nonaggressive boys was significant, $t(120) = -3.76$, $p < .0003$, power = .96, as was the comparison between unstable aggressive boys and nonaggressive boys, $t(112) = -2.78$, $p < .007$, power = .79.[5]

Discussion

We draw four major conclusions from the results of this study. First, in this multivariate context, tests of executive functions had the strongest association with physically aggressive behavior, over and above tests of verbal learning, cerebral dominance, and incidental spatial learning. Second, even when controlling for social factors, stable physically aggressive boys displayed difficulties in executive functions. Third, social factors were related significantly to verbal learning only. Fourth, impairments in cognitive executive functions, which have been associated in previous studies with delinquency (Moffitt, 1990) and adult antisocial behaviour (Buikhuisen, 1987; Kandel & Freed, 1989), are also associated with physical aggression in a community sample.

In this study, the multivariate context illustrates the relative

[5] Analyses were rerun without anxiety as a covariate. It was found that familial adversity remained associated with the Verbal Learning factor. Stepdown procedures revealed that Executive Functions were significant over and above all other factors. Verbal Learning and Executive Functions factors were both significant in the MANCOVA itself, but Verbal Learning was not significant over and above Executive Functions in a second stepdown analysis. These results held also when adversity was not controlled for. Whether or not anxiety was controlled for did not affect the conclusions about Executive Functions, but controlling for it affected Verbal Learning. The study of the relationship between anxiety and performance on tests of Verbal Learning could then constitute a separate question, provided it is not a sampling artifact.

strengths of verbal, executive, spatial, and cerebral dominance[6] dimensions in their association with aggressive behavior.[7] Poor performance on several verbal abilities described by Moffitt (1993b), such as reasoning, planning, and problem solving in the verbal modality (which are associated with antisocial behavior), theoretically rely as much on executive abilities as nonverbal executive tests. Although the executive functions construct requires more definition (Benton, 1994; Block, 1995), the executive functions tests used in the present study required active formation of representations in working memory that needed to be temporarily stored, accessible, and free of interference as they were continually monitored and scanned according to a goal and rules. The representations thus formed were not accessible through external stimuli (i.e., written, visuospatial, or tactile). It was also important to contrast verbal and executive abilities, and this distinction may be better expressed in terms of a dissociation between memory processing subsystems. The tasks loading on the Verbal Learning factor required less active processing, storing, and retrieval of information. However, the basic memory abilities required for the Verbal or the Spatial Learning factors are prerequisites for the working memory abilities measured by the Executive Functions factor. It was important to show either an absence of differences in Verbal and Spatial Learning or Executive Functions differences over and above those in Verbal or Spatial Learning. Otherwise, differences in Executive Functions could have been confounded by differences for Verbal or Spatial Learning.

That the impairments were not generalized to all cognitive functions or to SES supports the hypothesis that the higher cognitive functions theoretically subserved by the frontal lobes are affected (Buikhuisen, 1987; de Bruin, 1990; Elliott, 1987; Gorenstein, 1982; Hare, 1984; Hoffman, Hall, & Bartsch, 1987; Kandel & Freed, 1989; Lapierre, Braun, & Hodgins, 1995; Lueger & Gill, 1990; Moffitt & Henry, 1989; Raine et al., 1994; S. S. Smith, Arnett, & Newman, 1992; Weiger & Bear, 1988). Although early clearcut frontal damage leads to comportmental difficulties in childhood and adulthood, the present impairments in executive functions may be undetectable neuroanatomically and may be solely at a neurochemical or physiological level (Price et al., 1990). Poor performance does not necessarily imply a brain lesion or neurodevelopmental delay (Lueger & Gill, 1990; Moffitt, 1990). Interestingly, there is some evidence supporting the hypothesis that subclinical levels of neurological impairment and associated mild cognitive deficits may cause difficult temperament and lead to child-rearing difficulties (for reviews, see Moffitt 1993a, 1993b; Pennington & Bennetto, 1993). In such a circumstance, an association between history of aggressive behavior and impairment in executive functions most probably reflects an inability to organize several parameters simultaneously, uncover complex rules, anticipate consequences of choices and actions, and reflect abstractly (verbally or otherwise) in order to solve interpersonal and social problems. The capacity to reflect in impaired individuals may quickly be overwhelmed or their abilities poorly activated when they are in a motivational situation that calls for a more adaptive social response (C. M. Patterson & Newman, 1993). This temperamental predisposition may then result in impulsivity, which in turn has been associated with impairments in executive functions (Block, 1995; Lapierre et al., 1995; Miller, 1992; Moffitt & Silva, 1988; Price et al., 1990; White et al., 1994; for a different point of view, see Raine & Scerbo, 1991). Furthermore, this impulsivity appears to have a strong biological basis (Fowles, 1987, 1993; Miller, 1992; Pihl & Peterson, 1993; Schachar & Logan, 1990) and plays an important role in aggressive behavior (Farrington, Loeber, & Van Kammen, 1990; Hurt & Naglieri, 1992; Moffitt & Henry, 1989). Alternative hypotheses evaluating the contribution of other motivational or learning factors, associated or not with executive functioning, must also be considered but could not be addressed with the present data.

The finding that difficulties in executive functions were associated with stable aggressive behavior over and above SES is consistent with other studies that have found that despite a significant relation between social class and cognitive variables, the relation between cognitive variables and self-report delinquency still held when social class was entered as a covariate (Lynam et al., 1993). It may appear surprising that SES was related to Verbal Learning but not to Executive Functioning. Executive Functions may be less susceptible to environmental influences of a social nature than may be Verbal Learning. This does not imply that executive functions are unaffected by learning. Although cultural opportunities affecting verbal abilities may be lacking for low SES persons (Fischbein, 1980), executive functions may be applied in other domains.

Deficits in executive functioning have also been associated with hyperactivity (Lou, Henriksen, & Bruhn, 1984; Shue & Douglas, 1992), with adolescent and adult nonalcoholic sons of alcoholic men (Giancola, Peterson, & Pihl, 1993; Harden & Pihl, 1995; Peterson, Finn, & Pihl, 1992), and with alcohol intoxication and concomitant increases in aggression (Pihl, Peterson, & Lau, 1993). Hyperactivity has been associated with aggressive behavior (Hinshaw, 1987; Lilienfeld & Waldman, 1990); sons of alcoholic men have been characterized as hyperactive and conduct disordered (Pihl & Peterson, 1991; Pihl, Peterson, & Finn, 1990).

The finding of decreased executive functions in boys with a history of physical aggression is consistent with studies of delinquency, psychopathy, and other types of aggressive behaviors (Moffitt & Silva, 1988). Of course, it is unlikely that all physi-

[6] The multivariate combination of hand dominance and proficiency may have resulted in the loss of interpretability. To replicate more closely the mixed dominance effect found with dichotic listening tests in psychopaths (e.g., Hare & McPherson, 1984; Raine, O'Brien, Smiley, Scerbo, & Chan, 1990), correct number of responses for left and right hands were used as dependent variables in a repeated measures ANOVA with physical aggression groups as the independent variable. No group main effect or interaction were found even when we removed the 12% of left handers in the sample. A significant hand effect was found, with higher accuracy for left hand (right hemisphere dominance). The main effect for hand demonstrates validity of the test. The lack of interaction may be because we brought our participants to the same baseline functioning to ensure they understood the task well. Alternatively, the failure to replicate earlier studies, but this time in the tactile modality, may be because there is no hemispheric problem for that modality in aggressive boys and any hemispheric problem may be restricted to the verbal or visual modalities, as other studies have shown.

[7] The multivariate context may well explain why tests of verbal fluency, often associated with executive functions and frontal lobe functioning, loaded poorly on the Executive Functions factor.

cally aggressive boys in this sample will engage in adult violent behavior, although the sample selected for this study represents a higher proportion of aggressive boys than expected in the general population. Those who will commit violent crimes might be those who show greater impairments of executive function. It would appear that with both a stable pattern of physically aggressive behavior and deficits in executive functioning, these boys are at particular risk for a persistent pattern of antisocial behavior (Moffitt et al., 1994).

Finally, although perinatal factors and self-report medical conditions that could have affected test performance were controlled for, we have not specifically investigated the boys for head trauma or for circumstances surrounding head trauma. Further studies would benefit from this control in order to determine more definitely whether head trauma is preceded by, followed by, or unrelated to an aggressive lifestyle. However, in support of the latter possibility, frontal lobe metabolism was found to be lower in violent offenders even when controlling for head trauma (Raine et al., 1994).

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