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Stimulation Seeking and Intelligence: A Prospective Longitudinal Study

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The prediction that high stimulation seeking 3-year-olds would have higher IQs by 11 years old was tested in 1,795 children on whom behavioral measures of stimulation seeking were taken at 3 years, together with cognitive ability at 11 years. High 3-year-old stimulation seekers scored 12 points higher on total IQ at age 11 compared with low stimulation seekers and also had superior scholastic and reading ability. Results replicated across independent samples and were found for all gender and ethnic groups. Effect sizes for the relationship between age 3 stimulation seeking and age 11 IQ ranged from 0.52 to 0.87. Findings appear to be the first to show a prospective link between stimulation seeking and intelligence. It is hypothesized that young stimulation seekers create for themselves an enriched environment that stimulates cognitive development.

Despite increasing interest in the ways personality can contribute to intelligence in adults (Sternberg & Ruzgis, 1994), stimulation seeking in young children is greatly underresearched, and almost nothing is known about its relationship to later intelligence. One study has shown that preschoolers who are low on shyness have higher creativity scores (Kemple, David, & Wang, 1996), thus suggesting a possible link between increased sociability (a component of stimulation seeking) and a cognitive trait related to intelligence. Nevertheless, no link was found in this study between low shyness and increased scores on the Peabody Picture Vocabulary Test (Dunn, 1965), and there appear to be no published studies on behavioral stimulation seeking (as opposed to other traits of shyness or visual novelty preference in infants) and intelligence in early childhood.

More is known about the link between stimulation seeking and intelligence in nonpathological adolescent and adult populations, but the empirical data are sparse. Zuckerman (1994), in a review of research on intelligence, academic performance, and sensation seeking, reported findings from two unpublished studies of high school students. One of these studies (M. S. Buchsbaum & D. L. Murphy, personal communication to M. Zuckerman, 1974; cited in Zuckerman, 1994) showed a significant, positive relationship ($r = .22$) between total sensation-seeking scores and the Wechsler Adult Intelligence Scale (Wechsler, 1955) in 138 high school students. Another unpublished study (Pemberton, 1971) indicated a significant, positive correlation ($r = .19$) between stimulation-seeking scores and Scholastic Assessment Test scores in 200 male graduates and exactly the same correlation in 200 female undergraduates. These two unpublished findings are supported by positive correlations between stimulation seeking and arithmetic problem solving ($r = .21$) and arithmetic concepts ($r = .15$) in a study of 97 male and female junior high school students (Kish & Leahy, 1970), although the latter finding failed to reach statistical significance.

Findings from these studies on nonpathological groups are supported by similar findings of positive relationships between stimulation seeking and IQ in three samples of drug abusers (Carrol & Zuckerman, 1977), a sample of juvenile delinquents (L. Cohen, Dingemans, Lesnik-Oberstein, & van der Vlugt, 1983), 9–14-year-old boys with psychiatric disorders (Russo, Stokes, Lahey, & Christ, 1993), and hospitalized alcoholics (Kish & Busse, 1968). It is surprising that these wide-ranging studies of both pathological and normal populations have been unusually consistent in observing low-level but significant relationships between stimulation seeking and intelligence. Despite the potential significance of these findings, none of these studies has provided a conceptual or theoretical explanation for this relationship, and the empirical finding itself has virtually been ignored.

To our knowledge, there have been no prospective studies of any kind on the link between stimulation seeking in children—whether measured through questionnaires, parental ratings, or laboratory observational assessments—and later cognitive ability. Indeed, there appears to have been very little research of any kind

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on stimulation seeking in preschool children. Yet stimulation-seeking behaviors in which preschoolers physically explore their environment and engage in verbal and nonverbal stimulation with other children and adults are of significance in that they provide the basis for dimensions of stimulation seeking that have been found to characterize adults (Zuckerman, Eysenck, & Eysenck, 1978). Furthermore, physical exploration of the environment may in part be driven by curiosity, a cognitive trait that has been found to characterize highly intelligent children (A. W. Gottfried, Gottfried, Bathurst, & Guerin, 1994), whereas the confident, outgoing nature of stimulation seekers may help to provide such children with rich environmental experiences that stimulate cognitive development. The neglect of the link between intelligence and stimulation seeking in children is paralleled by its neglect in adults. For example, Sternberg and Ruzgis (1994) argued that some of the most interesting insights on intelligence are now being gained from research on personality, yet none of the 11 chapters in their edited volume even mentioned stimulation seeking.

The current study attempts to address this gap in the literature. Four competing hypotheses on the relationship between early stimulation seeking and later cognitive ability can be entertained. First, the null hypothesis is that although there may be a concurrent relationship between early stimulation seeking and cognitive ability, developmental changes in both temperament and cognitive ability result in no longitudinal relationship (zero effect size) over an 8-year period from preschool to late childhood. Second, the longitudinal relationship in children may mimic the concurrent relationship observed in adult studies both in direction and size of effect—that is, high stimulation seeking in preschoolers is weakly associated (i.e., positive correlation of approximately .20) with higher intelligence in later childhood. Third, if stimulation seeking in childhood but not in later adolescence and adulthood is important in shaping intelligence, then effect sizes based on early (age 3 years) assessments of stimulation seeking may be stronger than those observed in cross-sectional studies of adolescents and adults. A fourth hypothesis is that a negative relationship may exist between stimulation seeking and IQ because stimulation seeking could be expected to be associated with disinhibited behaviors, which could interfere with school performance and, hence, cognitive development (Zuckerman, 1994).

These four competing hypotheses are tested in the context of a longitudinal study of child health and human development on the island of Mauritius. A preschool analogue of stimulation seeking was taken when children were 3 years old, and cognitive ability was measured at ages 3 and 11 years. To assess whether relations between age 3 stimulation seeking and age 11 cognitive ability extend beyond IQ, we also assessed prospective relationships between age 3 stimulation seeking and later school achievement, reading ability, and performance on neuropsychological tests.

Method

Participants

The larger population from which the participants were drawn consisted of 1,795 children from the island of Mauritius (a country lying in the Indian Ocean between Africa and India). All children born in 1969–1970 in two towns on the island were recruited into the study between September 1972 and August 1973, when they were 3 years old. The two towns (Vacoas and Quatre Bornes) were chosen to be representative of the ethnic distribution of the whole island. Informed consent was obtained from the mothers of the participants.

The total sample consisted of both boys (51%) and girls (49%). Ethnic distribution was as follows: 69% Indian, 26% General Population, and 6% others (Chinese, English, French, and ethnically unidentified). The term *General Population* is the official government term used predominantly to characterize descendants from slaves brought over by the French between 1670 and 1810 from Madagascar (45%), the East African coast (primarily Mozambique, 40%), India (13%), and West Africa (2%; Barker, 1996; Filliot, 1974). This ethnic group is predominantly identified by its constituents as Creole and was described by Bowman (1991) as being constituted as follows: 85% African or Malagasy origin, 11% mixed origin, and 4% Franco-Mauritians. The Indian group are largely descendants of indentured laborers brought over by the English after slavery was abolished in 1835 and constitute Hindus (from Northern India, especially Bihar and Uttar Pradesh), Tamils (from Madras), and Muslims (from the Gangetic plain of North India and West India; Bowman, 1991). Census data for the island as a whole indicated 66% Indian, 29% Creole, and 5% other, indicating that the study largely achieved its goal of sampling a population that was representative in gender and ethnicity.

Intelligence and Cognitive Ability at Ages 3 and 11 Years

Age 3. Measures of verbal and spatial cognitive ability were derived from subtests of the Boehm Test of Basic Concepts—Preschool Version (Boehm, 1986). These tests were used to assess basic verbal and cognitive abilities at age 3 and took approximately 30 min (range 20–45) to administer. Although testing the children at age 11 posed few difficulties, pilot testing of the Boehm Test of Basic Concepts on 3-year olds indicated that some changes in format were necessary for age 3 testing. In addition to pilot tests in the laboratory, visits were made to the homes of pilot test children to observe them in a more natural context. This pilot testing led to minor modifications of the test for use with Mauritian children. For example, sugar cane sticks were used for judgments of length (Mauritius had a predominantly sugar cane economy in 1972), local rocks were used for judgments of size, pictures of Mauritian children were used for identification of body parts of children, and a tea set was used to assess ability to follow directions (tea drinking is ubiquitous in Mauritius).

The modified test had six components: (a) block assembly (making constructions from blocks; e.g., bridge, circle, tower), (b) copying shapes (copying circle, triangle, and square), (c) information (identifying body parts, pictures of boys and girls), (d) number, size, and length concepts (simple numeric ability, size and length discriminations), (e) color concepts (naming and pointing to different colors), and (f) classification (making discriminations between same and different objects).

Many of these abilities parallel cognitive skills found in the Wechsler Preschool and Primary Scale of Intelligence (WPPSI; Wechsler, 1967; e.g., labeling is similar to the WPPSI Information subscale, similar and different discriminations are similar to the Similarities subscale, copying shapes is similar to Geometric Design, number, size, and length concepts are similar to Arithmetic). Consequently, scale construction initially followed a face validity approach to form indices of verbal and spatial ability. The researchers first normalized each scale by transforming the raw scores to percentiles and then finding the standard score for each percentile (Allen & Yen, 1979). Scales were then standardized to have a mean of 10 and standard deviation of 3.

Two of the scales (block assembly and copying shapes) were spatial–constructional in nature and were similar in nature to the Block Design and Geometric Design spatial tests of the WPPSI. These two tests correlated significantly with age 11 spatial IQ (range = .22–.25, $p < .0001$). These tests were summated and further standardized to a mean of 100 and standard deviation of 15 to form an index of age 3 spatial ability. Coefficient alpha for this spatial scale was .46.

The remaining scales were verbal in nature. Some involved a verbal response (e.g., picture content, numbers), whereas others required verbal comprehension and knowledge of the names of objects (information). All of these subtests correlated significantly with age 11 verbal IQ (range = .19–.27, $p < .0001$). Several of the Boehm Test of Basic Concepts verbal tests had parallels with WPPSI verbal tests (e.g., information was similar to the Information subscale, classification was similar to Similarities, number, size, and length were similar to Arithmetic). These subscales were summated and standardized in the same way as were the spatial tests to form an index of age 3 verbal ability. Coefficient alpha for the verbal scale was .76. Age 3 verbal ability correlated significantly with age 3 spatial ability ($r = .41$, $n = 1{,}387$, $p < .0001$). Data were available on 1,387 of the sample.

Age 11. Estimates of verbal and spatial IQ were assessed at age 11 years using six subtests of the Wechsler Intelligence Scale for Children—Revised (WISC–R; Wechsler, 1974). Raw scores on the WISC–R subscales were normalized and standardized in the same way as were the age 3 scales. The Similarities and Digit Span subscales formed an estimate of verbal IQ, whereas the Block Design, Object Assembly, Coding, Mazes, and Picture Completion subscales formed an estimate of spatial IQ. Data were available on 1,261 of the sample.

Reliability and Validity of the Age 3 and Age 11 Cognitive Measures

The two subcomponents of the age 3 spatial measure correlated significantly with age 11 spatial IQ (range = .22–.25, $p < .0001$). Similarly, all subcomponents of the age 3 verbal measure correlated significantly with age 11 verbal IQ (range = .19–.27, $p < .0001$). Age 3 verbal ability correlated significantly with age 3 spatial ability ($r = .41$, $n = 1{,}387$, $p < .0001$). The age 3 spatial measure correlated .24 ($p < .0001$) with the age 11 spatial IQ measure, whereas the age 3 verbal measure correlated .25 ($p < .0001$) with the age 11 verbal IQ measure. Age 3 verbal ability correlated significantly ($r = .25$, $p < .0001$) with age 11 reading ability. Both verbal ($r = .29$, $p < .0001$) and spatial ability ($r = .25$, $p < .0001$) measures taken at age 3 predicted scholastic ability at age 11. Age 3 verbal ability correlated significantly ($r = .31$, $p < .0001$) with a rating of the amount of verbalizations the child made to the experimenter at age 3 (Raine, Reynolds, Venables, Mednick, & Farrington, 1998), whereas age 3 spatial ability correlated significantly with a measure of motor ability (e.g., jumping, hopping, balancing on one foot) at age 3 ($r = .23$, $p < .0001$). Data from 73 participants who were given the Reynell Developmental Language Scale (Reynell & Huntley, 1972) at age 6 showed a .36 correlation ($p < .002$) with the age 3 verbal ability measure, compared with a .25 correlation ($p < .005$) with the age 3 spatial measure ($p < .025$); although the difference between these two correlations is not statistically significant because of the modest sample size, the age 3 verbal measure predicted twice the amount of variance in age 6 language than did the age 3 spatial measure. The intercorrelation between age 3 total cognitive score (verbal + spatial) and age 11 estimated total IQ was .30 ($n = 969$, $p < .0001$). This latter correlation is modest but in keeping with the facts that (a) IQ does not stabilize until later childhood, and correlations between early cognitive ability and later IQ are relatively small (A. W. Gottfried et al., 1994), (b) different cognitive measures were used in the age 3 and age 11 test sessions, and (c) internal reliabilities for the age 3 measures are not high.

Confirmatory factor analysis was used to assess whether the two-factor (verbal–spatial) model was a significantly better fit than the one factor model. A one-factor solution resulted in a significant misfit, $\Delta\chi^2(20, N = 1{,}386) = 817.94$, $p < .0001$, root-mean-square error of approximation (RMSEA) = .17. However, the two-factor model (spatial, verbal) resulted in a significant improvement in fit compared with the one-factor model, $\Delta\chi^2(1, N = 1{,}386) = 34.79$, $p < .0001$. Coefficient alpha at the subtest level was .76 for the verbal scale and .46 for the spatial scale.

School Attainment and Reading Ability at Age 11

Reading ability was assessed at age 11 using the Holborn Reading Scale (Pumfrey, 1985). This word recognition test consists of 33 sentences of increasing difficulty. Total scores (number of sentences correctly read) were standardized into reading quotients and were available for 1,264 of the sample.

The measure of scholastic ability was based on scores on four standardized academic tests (Certificates of Primary Education) that were given to all 11-year-old children throughout the country: English, French, Mathematics, and Environmental Studies. Scores on these tests (graded 0 through 5) were summated to form an overall index of school attainment and were available for 1,415 of the sample. The correlation between school attainment and reading ability was .69 ($n = 1{,}094$, $p < .0001$).

Trails A and B at Age 11

One neuropsychological measure, the Trail Making Test (Reitan, 1958), was administered to the children at age 11. The two components of this task (Trails A and B) assess visuomotor tracking, motor speed, and attention, and Trail B also contains a working memory component (Lezak, 1983). The task requires the participant to draw lines to connect consecutively numbered circles (Trail A) and to connect consecutively numbered and lettered circles (Trail B). Participants were instructed to go as quickly as they could without lifting the pencil off the paper, and time-to-completion scores for each component were corrected for age by residualization. Data were available on 1,157 and 1,239 of the sample, respectively.

Stimulation Seeking and Sociability

Full details of the creation of the age 3 index of stimulation seeking and sociability are given in Raine et al. (1998). Briefly, four putative indices of stimulation seeking and sociability were taken at age 3 as follows:

1. The child's *physical exploration* away from the mother toward new toys was assessed in a laboratory room by a research assistant. Exploratory behavior was rated on a 4-point scale as follows: 1 = *passive, clings to mother, withdrawn;* 2 = *shows interest, examines toys but stays close to mother;* 3 = *leaves mother, mild independent exploration, comes and goes to mother;* and 4 = *active independent exploration.* This behavior was rated on four occasions during the entire testing session (soon after arrival, before psychophysiological testing, between tests, and after completion of tests). Scores for the four ratings were summated to obtain an overall index of physical exploration.
2. Extent of *verbalizations* to the research assistant during cognitive testing was rated on a 4-point scale ranging from 1 (*very reluctant to speak*) to 4 (*many spontaneous comments*).
3. *Friendliness* with the research assistant during cognitive testing was rated on a 4-point scale ranging from 1 (*fearful*) to 4 (*immediately friendly*).
4. Active *social play* with other children during free play in a sandbox was rated by a research assistant on a 5-point scale ranging from 1 (*solitary*) to 5 (*cooperative relationship with role reciprocity*).

Confirmatory factor analysis using LISREL 8 (Jöreskog & Sörbom, 1993) confirmed that these items all loaded together on the same factor (Raine et al., 1998). Virtually identical findings were obtained for boys and girls and for Indians and Creoles (see Raine et al., 1998, for full details). The four items from this factor all intercorrelated from .25 to .68 ($M = .43$). Item–total correlations for this scale ranged from .48 to .59 ($M = .53$). Coefficient alpha for the scale was .75. These items were z transformed and summated into a scale of Stimulation Seeking, with high scores indicating increased stimulation seeking. Data were available on 1,772 of the sample.

Parental Education and Social Class

Demographic measures were recorded in an interview with the mother when the child was age 3. Parental occupation was rated on an 8-point rating scale that ranged from 1 (*part-time laborer*) to 8 (*academic or head of business with 50 or more employees*), whereas parental education was scored as the number of years in full-time education. Data were available on 1,795 and 1,785 of the sample, respectively.

Results

Stimulation Seeking and Cognitive Ability at Ages 3 and 11

IQ. Means and standard deviations of all variables are given in Table 1. The sample was randomly divided into two subsamples to assess replicability of findings. Intercorrelations between stimulation seeking at age 3 and cognitive ability at ages 3 and 11 for these two samples, together with the total sample, are given in Table 2. All correlations for the two replication samples were statistically significant and in a positive direction (i.e., high stimulation seeking was associated with high cognitive ability), with relatively little variability in the absolute magnitude of the correlations from one sample to another. The effect size for the correlation of stimulation seeking and the age 3 total cognitive score ($r = .36$) was calculated as $d = 0.77$ (J. Cohen, 1988), whereas for the correlation of age 3 stimulation seeking and age 11 total IQ ($r = .25$), the effect size was 0.52.

As a comparison, we calculated intercorrelations between age 3 and age 11 measures of cognitive ability as follows: verbal, $r = .25$, $n = 971$, $p < .0001$; spatial, $r = .24$, $n = 1{,}025$, $p < .0001$; and total, $r = .30$, $n = 969$, $p < .0001$. Consequently, the relation between age 3 stimulation seeking and age 11 spatial ability ($r = .24$) was as high as the correlation between age 3 spatial ability and age 11 spatial ability ($r = .24$).

Age 11 reading, school achievement, and performance on Trail Making Test. Intercorrelations between age 3 stimulation seeking and age 11 scholastic ability (reading and school achievement scores) are given in Table 2. Again, findings replicated from one sample to the other, with correlations statistically significant and in the predicted direction but somewhat lower in magnitude than for cognitive ability and IQ. For the total sample, correlations of .15 (reading) and .17 (school achievement) were observed. Effect sizes were calculated as 0.30 for reading and 0.35 for school achievement.

Similarly sized and replicable correlations were obtained for neuropsychological test performance (Trails A and B), with negative correlations indicating faster completion times for high stimulation-seeking scorers. Effect size for both measures were calculated as 0.30.

Stimulation Seeking in the Context of g

To obtain the purest estimate of the size of the relationship between stimulation seeking and general cognitive ability, we entered stimulation seeking at age 3 into the principal-components analysis with the six age 3 cognitive subtest measures and also with the six age 11 IQ subtest measures. The loadings of cognitive and stimulation-seeking measures on the first principal component for these two analyses are given in Table 3. It can be seen that for age 3 cognitive measures, stimulation seeking loaded .55 ($d = 1.32$) on the first principal component and that on age 11 cognitive measures it loaded .35 ($d = 0.75$).

Extremes in Stimulation Seeking and Cognitive Ability

Extremes of stimulation seeking have been associated in the adult and child literatures with drug and alcohol abuse and antisocial behavior (Cloninger, Sigvardsson, & Bohman, 1988; Raine et al., 1998; Zuckerman, 1994), behaviors that, in turn, have been associated with lower, not higher, cognitive functioning (Lynam, Moffitt, & Stouthamer-Loeber, 1993; Moffitt & Silva, 1988; Tarter, Jacob, & Laird, 1993). It is possible that individuals at the end of the stimulation-seeking continuum do not show enhanced cognitive ability. To test this possibility, we compared the top 15% of scorers on stimulation seeking ($n = 193$–270) at age 3 years with those falling as close as possible to the bottom 15% cut off ($n = 80$–204)[1] on age 3 and age 11 cognitive, school, and neuropsychological measures. This same 15% cut off was used in the one other previous study of stimulation seeking with this population (Raine et al., 1998). Comparisons for these groups are shown in Table 4.

High stimulation seekers had significantly higher scores on all 10 measures at both ages. The effect size for age 3 total cognitive ability was 1.41, and there was an effect size of 0.87 for age 11 IQ. Consequently, the positive association between stimulation seeking and cognitive ability that was observed for the entire population also held for extreme stimulation seekers.

Gender and Ethnicity

To assess whether the stimulation seeking–cognitive ability relationship was the same in both boys and girls, we computed intercorrelations separately for the two sexes. Results are given in Table 2. Intercorrelations in boys were again positive and statistically significant, ranging from .18 to .34. These relationships were replicated in girls, with correlations ranging from .23 to .38. On average, there was a difference of .033 between boys and girls in the size of the sensation seeking–cognitive ability correlation, favoring girls. Similar findings were obtained for scholastic ability and neuropsychological test performance.

The sample was then divided into Indians and Creoles to test cross-ethnic replicability of findings. Correlations for Indians were positive and statistically significant, ranging from .20 to .33. Correlations for Creoles similarly ranged from .18 to .42. On average, there was a difference of .032 between Indians and Creoles, favoring Creoles. Similar findings were obtained for scholastic ability and neuropsychological test performance.

Components of Stimulation Seeking and Cognitive Ability

It is possible that the link between stimulation seeking at age 3 and IQ at age 11 is driven only by the verbal component of stimulation seeking, with no contribution made by nonverbal, behavioral aspects. For example, it is conceivable that a child who makes more spontaneous verbalizations at age 3 is more verbally skilled and that it is this specific component of age 3 stimulation seeking that relates to later IQ

[1] The smaller sample of low relative to high sensation seekers at age 3 reflects the fact that 19% of the sample was untestable on cognitive tasks at this age, with a disproportionate number of low stimulation seekers falling into this category. In contrast, very few high stimulation seekers were untestable. All children were testable at age 11.

Table 1
Means, Standard Deviations, and Sample Sizes for Stimulation Seeking, Age 3 and Age 11 Cognitive Measures, and Parental Education and Occupation for the Total Sample and Gender and Ethnic Subgroups

Variable and statistic	Total sample	Boys	Girls	Indians	Creoles
Age 3					
Sensation seeking					
M	0.00	−0.03	−0.06	0.06	−0.07
SD	0.71	0.67	0.69	0.66	0.68
n	1,772	919	852	490	1,213
Verbal					
M	100.00	99.52	100.56	100.96	99.53
SD	15.00	15.25	14.83	14.53	15.28
n	1,387	724	664	400	937
Spatial					
M	100.00	99.00	100.90	100.40	99.81
SD	15.00	14.97	15.13	15.00	15.12
n	1,452	752	701	419	980
Total					
M	100.00	99.24	100.87	100.84	99.63
SD	15.00	15.00	14.94	14.61	15.29
n	1,384	722	663	399	935
g					
M	0.03	−0.05	0.06	0.06	−0.03
SD	1.00	1.01	1.03	0.98	1.00
n	1,384	722	663	399	935
Age 11					
Verbal					
M	100.00	100.57	99.18	101.42	99.44
SD	15.00	15.52	14.58	15.02	15.03
n	1,261	636	622	331	875
Spatial					
M	100.00	103.33	96.48	101.75	99.36
SD	15.00	14.69	14.56	14.94	15.06
n	1,261	636	622	331	875
Total					
M	100.00	102.81	97.00	101.82	99.39
SD	15.00	14.93	14.57	15.11	15.00
n	1,261	636	622	331	875
g					
M	−0.02	0.17	−0.17	0.12	−0.05
SD	1.00	0.99	0.98	1.00	0.99
n	1,261	636	622	331	875
Reading					
M	91.13	86.45	95.63	86.96	91.45
SD	55.92	57.66	53.78	58.24	54.93
n	1,264	637	624	331	878
Achievement					
M	9.81	9.66	9.97	9.73	9.70
SD	7.07	7.18	7.07	7.18	7.06
n	1,415	720	691	366	991
Trails A					
M	0.00	−0.13	0.13	−0.03	0.02
SD	1.00	0.89	1.14	0.94	1.02
n	1,239	627	609	323	863
Trails B					
M	0.00	−0.07	0.08	−0.06	0.03
SD	1.00	0.98	1.01	1.02	1.01
n	1,157	586	568	303	804
Parent					
Occupation					
M	3.87	3.90	3.82	4.03	3.82
SD	1.45	1.44	1.44	1.54	1.40
n	1,785	929	856	491	1,227
Education					
M	4.55	4.67	4.41	4.79	4.45
SD	3.58	3.65	3.48	3.65	3.54
n	1,795	930	865	495	1,232

Note. g = general intelligence.

Table 2
Intercorrelations Between Stimulation Seeking and Cognitive Ability at Age 3 and IQ, Reading, School Achievement, and Neuropsychological Performance at Age 11

Variable and statistic	Total	Sample 1	Sample 2	Boys	Girls	Indian	Creole
Age 3							
Verbal	.36	.36	.36	.34	.38	.33	.42
n	1,366	718	669	714	652	919	396
Spatial	.22	.24	.20	.21	.23	.20	.25
n	1,429	750	702	741	658	961	414
Total	.36	.36	.35	.35	.38	.33	.43
n	1,363	716	668	712	651	917	395
g	.37	.37	.36	.36	.38	.33	.44
n	1,363	716	668	712	651	917	395
Age 11							
Verbal	.20	.18	.21	.18	.23	.21	.18
n	1,255	651	610	629	615	861	331
Spatial	.24	.22	.26	.22	.26	.24	.24
n	1,244	651	610	629	615	861	331
Total	.25	.23	.27	.23	.27	.26	.24
n	1,244	651	610	629	615	861	331
g	.25	.24	.27	.23	.26	.24	.26
n	1,244	651	610	629	615	861	331
Scholastic ability							
Reading	.15	.17	.13	.13	.18	.14	.19
n	1,247	651	613	630	617	864	331
Achievement	.17	.18	.15	.15	.19	.17	.19
n	1,391	726	689	711	680	775	362
Neuropsychological functioning							
Trails A	−.15	−.14	−.15	−.14	−.16	−.15	−.16
n	1,222	633	606	620	602	849	323
Trails B	−.15	−.19	−.11	−.15	−.15	−.15	−.17
n	1,153	595	562	580	561	791	303

Note. All correlations are significant at $p < .05$. g = general intelligence.

rather than the nonverbal components such as exploration of the environment. We tested this possibility by relating the individual subcomponents of age 3 stimulation seeking with age 3 and age 11 cognitive ability and calculating confidence intervals for correlation coefficients using the structural equation modeling program Mx 1.5 (Neale, Boker, Xie, & Maes, 1999).

Table 3
Factor Loadings of Stimulation Seeking on First Principal Component of Cognitive Measures at Age 3 and Age 11

Measure/scale	Factor loading
Age 3	
Stimulation seeking	.55
Information	.76
Similarities	.62
Color	.62
Arithmetic	.60
Geometry	.60
Block	.50
Age 11	
Stimulation seeking	.35
Block Design	.79
Object Assembly	.74
Mazes	.70
Coding	.68
Digit Span	.68
Similarities	.67

Results are shown in Table 5. It can be seen that all correlations were statistically significant and in the direction of high sensation seeking being associated with better performance. Exploration was the component of stimulation seeking most highly associated with cognitive ability, with a correlation with age 11 total IQ of .24 (d = 0.50), compared with a correlation of .15 (d = 0.30) for the verbalization component. Although confidence intervals overlapped (see Table 5), it is clear that the age 11 stimulation seeking–intelligence relationship cannot be attributed solely to the verbal component of stimulation seeking. For the age 3 sensation-seeking components, gregariousness was the component most strongly linked to cognition. The 95% confidence interval for the correlations associated with gregariousness did not overlap with those for the other three components, indicating that the cognition relations with gregariousness were significantly higher than were all other sensation-seeking components (see Table 5).

Role of Parental Education and Occupation

It is conceivable that the link between stimulation seeking and later IQ is mediated by parental education and occupation. For example, parents of higher educational and occupational status may provide both genetic and environmental contributions to their child's intellectual ability and also may encourage exploratory, socially stimulating behaviors. In support of this possibility, we

Table 4
Extremes of Sensation Seeking at Age 3 and Cognitive Functioning at Ages 3 and 11

	Stimulation seeking									
	High			Low						
Variable and statistic	*M*	*SD*	*n*	*M*	*SD*	*n*	*t*	*df*	*p*	*d*
Age 3										
Verbal	105.9	13.7	256	85.4	13.6	80	11.7	334	.0001	1.50
Spatial	103.2	14.7	270	90.7	13.3	83	7.0	351	.0001	0.91
Total	105.7	13.4	256	85.1	12.9	80	12.1	334	.0001	1.57
g	0.39	0.89	256	−1.01	0.86	80	12.4	334	.0001	1.61
Age 11										
Verbal	104.3	13.9	197	93.9	15.7	177	6.8	372	.0001	0.71
Spatial	104.0	14.0	197	93.1	15.5	177	7.2	372	.0001	0.74
Total	104.5	13.8	197	92.7	15.6	177	7.8	372	.0001	0.81
g	0.30	0.94	197	−0.49	1.01	177	7.8	372	.0001	0.81
Scholastic ability										
Reading	104.6	55.4	198	75.9	60.9	177	4.8	373	.0001	0.50
Achievement	11.4	7.0	212	8.6	7.0	204	4.1	414	.0001	0.40
Neuropsychological functioning										
Trails A	−0.25	0.74	195	0.28	1.20	169	5.1	362	.0001	0.56
Trails B	−0.20	0.83	193	0.29	0.97	148	5.0	339	.0001	0.55

Note. g = general intelligence.

observed significant correlations between parental education and stimulation seeking ($r = .14$, $p < .0001$), age 3 cognitive ability, $r(1385) = .21$, $p < .0001$, and age 11 total IQ, $r(1258) = .31$, $p < .0001$, and between parental occupation and stimulation seeking ($r = .14$, $p < .0001$), age 3 cognitive ability, $r(1378) = .18$, $p < .0001$, and age 11 IQ, $r(1251) = .30$, $p < .0001$. Parental education and occupation intercorrelated at $r(1785) = .45$, $p < .0001$. We tested the potential mediating role of parental education and occupation by computing partial correlations for the total sample between stimulation seeking and age 11 total IQ, controlling for these two factors individually and also in combination. Results are given in Table 6. The sensation seeking–age 11 IQ relationship remained significant after we partialed out these effects, with little change in the absolute size of the correlations, as compared with Table 2.

Discussion

The key finding from this study is that increased stimulation seeking at age 3 years is associated with increased cognitive, scholastic, and neuropsychological test performance at age 11 years. It is important to note that the results replicated across independent samples, were found in both boys and girls, applied to both Indians and Creoles, and were not mediated by parental education and occupation. The effect size for the relationship between age 3 stimulation seeking and age 11 IQ was not small, with d medium to large in size (J. Cohen, 1988) and ranging from 0.52 (correlational analysis) through 0.75 (principal-components analysis) to 0.87 (extreme group analysis). These longitudinal effect sizes are, if anything, higher than the cross-sectional effect sizes found for normal adults; pooling the four studies on school children reported above results in an average effect size of 0.40 based on a combined sample of 732. The strength of the relation between age 3 stimulation seeking and age 11 spatial ability ($r = .24$) can be gauged by the fact that it was as high as the correlation between age 3 spatial ability and age 11 spatial ability ($r = .24$). Furthermore, the relationship was not lost in more extreme stimulation-seeking groups who have been viewed as pathological, with an effect size of 0.87 being observed. Consequently, results are strongly inconsistent with Hypothesis 4 (negative relationship), inconsistent with Hypothesis 1 (zero relationship), moderately consistent with Hypothesis 2 (small positive effect size), and most consistent with Hypothesis 3 (medium positive effect). To our knowledge, this is the first report of a prospective relationship between stimulation seeking in preschool children and enhanced cognitive ability in later childhood.

Previous studies in adults have not provided a theoretical account of why increased stimulation seeking might be associated with better cognitive ability later in life. We hypothesize an environmental enrichment explanation of the stimulation seeking–IQ relationship, which argues that young children who physically explore their environment, engage socially with other children, and verbally interact with adults create for themselves an enriched, stimulating, varied, and challenging environment. This environmental enrichment in turn is hypothesized to result in enhanced cognitive ability and better school performance. This environmental enrichment hypothesis is broadly consistent with the seminal research of Bell (1968), which showed that children affect their own environment, and also with the triarchic theory of experience developed by Scarr (1992), which argues that individuals both create their own environments and select environments that are correlated with their interests and personality characteristics. Provision of an educationally enriched environment is known to result in short-term but generally not long-term increases in IQ (Neisser et al., 1996), and it is conceivable that early stimulation seeking is associated with more substantive, longer term increases in IQ, because stimulation seeking provides a continuous (not short-term) enrichment of the environment. Nevertheless, this is only one of a number of possible explanations for the significant longitudinal

Table 5
Correlations and Their 95% Confidence Intervals for Relationships Between the Four Subcomponents of Sensation Seeking and Cognitive Ability

Measure and CI	*n*	Verbalizations	Play	Gregarious	Explore
		Age 3			
Verbal	1,366	**.31**	**.08**	**.42**	**.24**
Lower CI		.27	.03	.37	.19
Upper CI		.36	.14	.46	.29
Spatial	1,429	**.17**	**.10**	**.24**	**.12**
Lower CI		.12	.05	.19	.07
Upper CI		.22	.16	.29	.17
Total	1,363	**.30**	**.10**	**.42**	**.23**
Lower CI		.25	.05	.37	.18
Upper CI		.35	.16	.46	.28
g	1,363	**.31**	**.10**	**.43**	**.24**
Lower CI		.26	.05	.38	.18
Upper CI		.36	.16	.47	.28
		Age 11			
Verbal	1,243	**.13**	**.12**	**.17**	**.19**
Lower CI		.08	.06	.11	.14
Upper CI		.19	.17	.22	.24
Spatial	1,243	**.15**	**.14**	**.19**	**.24**
Lower CI		.09	.09	.13	.18
Upper CI		.20	.20	.24	.29
Total	1,243	**.16**	**.15**	**.20**	**.24**
Lower CI		.10	.09	.14	.19
Upper CI		.21	.20	.25	.30
g	1,243	**.15**	**.15**	**.19**	**.24**
Lower CI		.10	.09	.14	.19
Upper CI		.21	.20	.24	.29
Reading	1,246	**.09**	**.08**	**.14**	**.14**
Lower CI		.03	.03	.08	.09
Upper CI		.14	.14	.19	.20
Achievement	1,390	**.10**	**.08**	**.15**	**.16**
Lower CI		.05	.03	.10	.11
Upper CI		.15	.14	.20	.21
Trails A	1,221	**−.06**	**−.10**	**−.11**	**−.17**
Lower CI		−.11	−.15	−.16	−.22
Upper CI		.00	−.04	−.05	−.11
Trails B	1,140	**−.10**	**−.09**	**−.11**	**−.15**
Lower CI		−.15	−.15	−.17	−.21
Upper CI		−.04	−.03	−.05	−.10

Note. All correlations in boldface are statistically significant at $p < .05$, two-tailed. CI = confidence interval; g = general intelligence.

relationship that exists between early stimulation seeking and later increased intelligence.

A competing explanation is suggested by the fact that the component of age 3 stimulation seeking that was most predictive in absolute terms of later intelligence at age 11 was behavioral exploration. Specifically, the correlation between age 3 behavioral exploration and age 11 total IQ was nonsignificantly higher than the other three components of stimulation seeking (see Table 5). It is conceivable that sensation-seeking children are more intelligent because they are more physically active and that it is physical activity per se rather than the creation of an enriched environment that results in increased cognitive ability. Studies that experimentally manipulated physical activity in rats have shown that physical exercise and environmental enrichment result in the growth of new neurons in the hippocampus (van Praag, Kempermann, & Gage, 1999), a brain area of importance in both attention and memory (Burgess, Jeffery, & O'Keefe, 1999; Newman & Grace, 1999). In humans, there is increasing evidence that exercise can be beneficial to both cognitive functioning (Thomas, Landers, Salazar, & Etnier, 1994) and psychophysiological measures of information processing and arousal (Lardon & Polich, 1996; Raine et al., 2001). It is also known that environmental enrichment increases novelty seeking in rats (Fernandez-Teruel, Escorihuela, Casetellano, Gonzalez, & Tobena, 1997). As such, the link between stimulation seeking and intelligence could be mediated at least in part by the increase in exercise that is a byproduct of stimulation-seeking activities.

The physical activity explanation of the intelligence–stimulation seeking relationship is seemingly inconsistent with some studies on activity levels in children. For example, Halverson and Waldrop (1976) found that vigorous, high-activity behavior in pre-

Table 6
Partial Correlations Between Age 3 Stimulation Seeking and Cognitive Ability at Age 3 and IQ, Reading, School Achievement, and Neuropsychological Performance at Age 11

Variable and statistic	Controlled for: Education	Occupation	Education and occupation
Age 3			
Verbal	.34	.35	.34
n	1,363	1,356	1,355
Spatial	.21	.21	.21
n	1,426	1,418	1,417
Total	.34	.35	.34
n	1,360	1,351	1,352
g	.35	.35	.34
n	1,360	1,351	1,352
Age 11			
Verbal	.18	.18	.17
n	1,241	1,234	1,233
Spatial	.21	.21	.20
n	1,241	1,234	1,233
Total	.22	.22	.21
n	1,241	1,234	1,236
g	.21	.22	.20
n	1,241	1,234	1,236
Scholastic ability			
Reading	.12	.12	.11
n	1,244	1,237	1,236
Achievement	.13	.14	.12
n	1,388	1,381	1,380
Neuropsychological functioning			
Trails A	−.15	−.13	−.12
n	1,219	1,212	1,211
Trails B	−.14	−.13	−.13
n	1,138	1,131	1,130

Note. All correlations are statistically significant at $p < .001$. g = general intelligence.

schoolers was associated with poorer, not better, intellectual ability at age 7.5 years. It is likely that the precise nature of physical activity is of central importance with respect to intellectual outcome. In the current study, a high level of active social play was defined in terms of expressing cooperative social relationships with other children with full role reciprocity. Similarly, Halverson and Waldrop (1976) found that social participation in preschoolers that was equally as vigorous and intense as high-activity behaviors was indeed associated with higher intelligence in later childhood. High-activity behaviors that are unstructured and independent of social reciprocity are more likely to be markers of hyperactivity and inattention, whereas highly active social play and goal-directed exploration of the environment (both of which contributed to the stimulation-seeking measure in this study) may better facilitate or reflect superior cognitive functioning. Consequently, despite recent evidence from animal studies, high levels of physical activity per se may not necessarily facilitate or reflect superior intellectual performance in young children, and social involvement with others may be particularly important. In support of this possibility, the gregarious component of sensation seeking was significantly more highly related to age 3 cognition than were all other sensation-seeking components, indicating the potential importance of the social components of sensation seeking in facilitating superior cognitive abilities.

Behavioral exploration may also be a marker for curiosity, which in turn motivates learning and task persistence. A. W. Gottfried et al. (1994) have reviewed evidence showing that gifted children and adolescents have higher levels of curiosity than do controls, and A. E. Gottfried (1990) argued that “academic intrinsic motivation” (p. 525) may be an important factor that contributes to intellectual giftedness. Similarly, novelty preference in children (which may parallel the stimulation-seeking component of boredom susceptibility in adults) has been related to higher achievement scores in second- and fifth-grade children (Cahill-Solis & Witryol, 1994). Visual novelty preference and habituation in infants has also been found to relate to increased intellectual functioning in later childhood (Fagan, 1984; McCall & Garriger, 1993), although it is clear that measures of infant novelty preference may be better construed as measures of information processing rather than of temperament and personality (Rose & Tamis-LeMonda, 1999). Furthermore, positive associations have been found in 6–10-year-old children between increased stimulation seeking and increased preference for complex puzzles and pictures (Kafry, 1982). Consequently, curiosity may result in both stimulation-seeking behavior and increased intelligence rather than stimulation seeking itself causing increased intelligence through environmental enrichment.

Genetic explanations of the stimulation seeking–intelligence link are as plausible as the above environmental explanations and represent an uncontrolled third factor. On the basis of 1,591 twin pairs ranging from 12 to 24 years old, 48% to 63% of the variability in stimulation seeking is accounted for by genetic factors, with heritability levels being equal in both males and females (Koopmans, Boomsma, Heath, van Doornen, & Lorenz, 1995). Childhood intelligence is also known to show significant heritability, though not as strong as adult intelligence (Neisser et al., 1996), and it is conceivable that the same set of genes may influence both intelligence and stimulation seeking. At this level, stimulation seeking could be viewed as an integral component of the wider construct of intelligence rather than being a separate construct. In addition, it is possible that inherent brain differences may contribute to both stimulation seeking and cognitive ability rather than stimulation-seeking experiences themselves causing increased cognitive ability. Although human studies are lacking, studies of rats have shown that normal rats with an increase in volume of the cerebellar molecular layer show increased exploratory behavior (Anderson, 1994), and there is increasing evidence that the cerebellum plays a significant role in complex cognitive functions (Schmahmann & Sherman, 1998). Furthermore, rat strains that are almost totally lacking in Purkinje and granule cells in the cerebellar cortex both show low levels of exploration of novel environments and have spatial deficits, compared with other rat strains (Caston, Chianale, Delhaye-Bouchaud, & Mariani, 1998). Consequently, the cerebellar cortex may represent one brain area that mediates both cognitive ability and stimulus-seeking behavior. Future twin studies that assess stimulation seeking, intelligence, and cerebellar structure and function are needed to further test this possibility of a genetic correlation between stimulation seeking and intelligence.

Stimulation seeking as measured behaviorally in this study in children and sensation seeking as assessed through self-report questionnaires in adults are conceptualized as related although not entirely identical constructs. Sensation seeking in adults is particularly related to the impulsivity component of extraversion (Zuckerman, Kuhlman, Joireman, Teta, & Kraft, 1993), whereas sensation seeking and neuroticism have been found to load on separate factors (Glickshon & Abulafia, 1998; Zuckerman, 1991). In the context of the Big Five, sensation seeking has been most clearly related to Openness to Experience (Rawlings, Twomey, Burns, & Morris, 1998; Zuckerman, 1972). Stimulation seeking as measured behaviorally in this study is conceptualized as lying at the interface of exploration, curiosity, experience seeking, and sociability and is anticipated as predisposing one to have a sensation-seeking personality as an adult. It remains to be seen, therefore, whether stimulation seekers at age 3 are more likely to develop sensation-seeking personalities in adulthood.

The prospective, longitudinal nature of the findings showing associations between stimulation seeking at age 3 and cognitive ability at age 11 is consistent with but does not prove the hypothesis that stimulation-seeking behavior leads to enhanced cognitive ability. Future studies need to replicate the nature of this longitudinal relationship in Western societies to assess cross-cultural generalizability, although the consistency of the current findings with cross-sectional findings from the United States suggests that the findings should generalize. More critically, experimental manipulations that encourage appropriate stimulation seeking in infants and preschoolers compared with controls are needed to demonstrate a casual relationship between stimulation seeking and cognitive ability. If such causality can be demonstrated in future studies, results could have significant theoretical implications for the development of intelligence, practical implications on how intelligence can be increased (Detterman & Sternberg, 1982), and clinical implications for behavioral conditions such as antisocial behavior that are linked to low intelligence (Moffitt & Silva, 1988). Provision of an educationally enriched head start to children is known to result in short-term increases in IQ that disappear by age 11 (Neisser et al., 1996). Findings of this study suggest that stimulation-seeking children may provide for themselves a more potent and continuous environmental enrichment than traditional educational enrichment can provide, and in contrast to such enrichment programs, can produce long-term IQ changes that last throughout childhood.

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(*Appendix follows*)

Appendix

Cross-Trait, Cross-Age Correlation Matrix

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Verbalizns	—															
2. Play	.47	—														
3. Gregarious	.77	.44	—													
4. Explore	.39	.49	.48	—												
Age 3																
5. Verbal	.31	.08	.42	.24	—											
6. Spatial	.17	.10	.24	.12	.41	—										
7. Total	.30	.10	.42	.23	.92	.73	—									
8. *g*	.31	.10	.43	.24	.94	.70	1.00	—								
Age 11																
9. Verbal	.13	.12	.17	.19	.25	.13	.24	.24	—							
10. Spatial	.15	.14	.19	.24	.23	.24	.28	.28	.60	—						
11. Total	.16	.15	.20	.24	.26	.23	.30	.30	.80	.96	—					
12. *g*	.15	.15	.19	.24	.26	.23	.30	.30	.80	.94	.98	—				
13. Read	.09	.08	.14	.14	.25	.16	.25	.25	.54	.48	.55	.55	—			
14. Achieve	.10	.08	.15	.16	.28	.25	.32	.32	.58	.59	.65	.66	.69	—		
15. Trails A	−.06	−.10	−.11	−.17	−.13	−.14	−.16	−.16	−.40	−.56	−.56	−.56	−.41	−.39	—	
16. Trails B	−.10	−.09	−.11	−.15	−.15	−.16	−.17	−.17	−.39	−.50	−.53	−.54	−.37	−.43	.48	—

Note. All values are significant at $p < .05$. $N = 899–1,795$. Verbalizns = verbalizations; *g* = general intelligence.

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