# Different Views

# Effect of Polybrominated Biphenyls (PBB) on Developmental Abilities in Young Children

EDWARD M. SCHWARTZ, PHD, AND WILLIAM A. RAE, PHD

**Abstract:** Eighteen children, ages 4 to 6 years, with known exposure to polybrominated biphenyls (PBB) in utero and/or through breast milk were administered developmental tests. These same children had exhibited low scores on a partial developmental assessment two years earlier. Current results were compared to normative test data. Findings showed: 1) PBB cohort children are within the normal range in all areas assessed; 2) An inverse relationship is noted between PBB fat level and scores on some developmental tasks. The importance of this finding for later development is unclear and, thus will bear future monitoring. (*Am J Public Health* 1983; 73:277–281.)

## *Introduction*

In Michigan during the summer of 1973 a fire retardant, Firemaster FFI, composed of polybrominated biphenyls (PBB), was inadvertently mixed with cattle feed. A year later the accidental introduction of PBB was detected. Exposed farms began to be quarantined, but PBB had already entered the Michigan food chain through dairy and beef cattle, poultry, pork, and eggs.[1] It has been estimated that virtually every resident of the lower peninsula of Michigan, from late 1973 to 1975, had some exposure to PBB and that people who bought food primarily from quarantined farms and/or from stores whose products had been contaminated may have been exposed to 10 to 100 times more PBB than the typical retail store customer.[2]

Since that time, numerous studies have been undertaken in order to ascertain the impact of PBB on health. To date, these studies show a lack of confirmed association between physical symptomatology or neurological functioning in humans and serum and/or adipose PBB levels.[3–7]

PBB has a chemical property which has been demonstrated to be biologically persistent and toxic to animals.[3] PBB, like its chemical cousin, PCB, concentrates in hepatic and adipose tissue and is poorly metabolized and slowly excreted. It is possible that PBB has lingering developmental effects and long-term neuropsychologic problems could result.[8–9] This has been the case with numerous other chemical contaminants.[10] Since these chemicals cross the placenta in animals and are excreted in human breast milk,[11] children who were in utero or being fed breast milk at the time of contamination may be particularly susceptible to PBB accumulation. This vulnerability and possible developmental sequelae was suggested within the data emerging from the State of Michigan's Muskegon Project.[12] The Project was designed to examine a group of children born between September 1, 1973 and December 31, 1975 to families living on farms that were quarantined as a result of known contamination with PBB. The 28-month time period was selected because it represented the interval when PBB contamination should have been the highest. The children of families consenting to participate in the project included only individuals exposed in utero or in early infancy or both. They represented about one third of the potential subjects available. Out of this group of 33 children, 19 (ranging in age from 2 years 5 months to 3 years 11 months) were selected for psychological evaluation since they were conceived, born, or nursing during the period of maximal exposure to

Address reprint requests to Edward M. Schwartz, PhD, Associate Professor of Psychology, Department of Pediatrics, Box 054, University of Michigan Medical Center, Ann Arbor, MI 48109. Dr. Rae, formerly with the Department of Pediatrics, Henry Ford Hospital, Detroit, is currently with the Scott and White Clinic, Temple, Texas. This paper, submitted to the Journal May 8, 1981, was revised and accepted for publication July 1, 1982.

**Editor's Note:** See also related articles in Different Views section, p 281, and p 286, and in Public Health Then and Now, p 302, this issue.

**TABLE 1—Ranking of PBB Cohort Children According to Fat Level of PPB in ppm, Lowest to Highest**

| Subject | PPB Parts per Million |
|---|---|
| 1 | .010 |
| 2 | .034 |
| 3 | .045 |
| 4 | .047 |
| 5 | .051 |
| 6 | .051 |
| 7 | .069 |
| 8 | .070 |
| 9 | .074 |
| 10 | .116 |
| 11 | .297 |
| 12 | .414 |
| 13 | .662 |
| 14 | .702 |
| 15 | 1.340 |
| 16 | 2.140 |
| 17 | 2.280 |
| 18 | 13.270 |
| 19 | 20.960 |

(Note: Subject No. 2 discontinued involvement in the study)

PBB. They were administered five of 18 subtests from the McCarthy Scales of Children's Abilities. The results showed significantly lower performance on four of the five subtests for the high PBB-exposed group compared to the low-exposed group. In addition, there was an inverse relationship found between body level of PBB and performance on four of these tests. Questions remained, however, as to whether the relationship would hold up if a complete developmental assessment were done and if the results were transitory given the young age of the subjects. The present study was undertaken with these questions in mind and to further explore the possibility of a relationship between PBB exposure and developmental abilities in children.

## *Materials and Methodology*

The PBB cohort was made up of the same children from the quarantined farms who were involved in Michigan's Muskegon Project. Since this group is not necessarily representative of the exposed sample of children in Michigan, it should be considered a "convenience" sample and all subsequent data to be reported from the sample should be interpreted with caution. Of the 19 families contacted in follow-up, only one refused to participate in the study. The subjects, all White, now ranged in age from 4 years and 1 month to 6 years and 1 month (mean of 5 years, 0 months; 11 girls and 7 boys). Since body burden of PBB is essentially unchanging over time, the same PBB levels measured through fat biopsy for the initial study two years earlier were used in this study as the index of exposure (Table 1).

An attempt was made to obtain a matched control group of 19 children, randomly selected from the same schools or school district as the PBB cohort, and not previously identified as PBB-exposed. They resided in the same rural areas as the PBB cohort. Parents in both groups either owned or worked on small farms or were involved in other small businesses or in semi-skilled and skilled labor. Following the testing, permission was obtained from parents to draw blood from all children (PBB cohort and comparison group) in order to determine comparative PBB levels. Results of the blood serum analysis, however, did not differentiate between subjects either within or between groups. Consequently, the comparison group could not be used as a control group. It was felt to be most appropriate to restrict the data analysis to the PBB cohort, using their known PBB levels from earlier fat biopsies, and to compare their test results against the age appropriate normative or expected mean scores from the standardization data from each test. Although the sample of children in the PBB cohort were from rural areas, it was felt that these comparisons were appropriate since the standardization data from both tests show no differences between rural and urban children in the overall and specific tests scores. Socioeconomic class was within the middle class for all families as well.

**TABLE 2—Mean Scores of PBB Exposed Children on WPPSI and MSCA**

| Test | Mean | SD | Range |
|---|---|---|---|
| WPPSI[1] | | | |
| Full IQ | 110.4 | 13.5 | 67–124 |
| Verbal IQ | 109.4 | 13.8 | 67–125 |
| Performance IQ | 110.4 | 13.0 | 73–130 |
| MSCA | | | |
| General Cognitive Index[2] | 107.2 | 17.9 | 55–134 |
| Verbal[3] | 56.5 | 11.8 | 27–72 |
| Perceptual | 53.2 | 11.1 | 31–77 |
| Quantitative | 49.7 | 10.7 | 22–64 |
| Memory | 51.8 | 8.8 | 30–63 |
| Motor | 48.6 | 11.1 | 25–78 |

[1]Standard scores for all WPPSI scales: Mean = 100; SD = 15
[2]Standard scores for GCI: Mean = 100; SD = 16
[3]Standard scores for all MSCA scales: Mean = 50; SD = 10

After obtaining written consent from parents to test their children, the McCarthy Scales of Children's Abilities (MSCA)[13] and the Wechsler Preschool and Primary Scale of Intelligence (WPPSI)[14] were administered individually to each child. The testing was done in the school attended or to be attended by the child with the exception of one case where the child was tested in the home. A total of seven psychologists tested the subjects. All test responses were reviewed by the two principal investigators in order to maximize consistency in scoring specific responses. The principal investigators were blind to the PBB values at the time of this review.

## *Results*

Cognitive indices and overall IQs as well as composite and subtest scores from the PBB cohort revealed means to be within the average or normal range in all areas (Table 2). There were no differences in scores between the PBB cohort and the norm group for both tests. Actually, in the majority

**TABLE 3—Mean Scores of PBB Exposed Children and Standard Normal Means on the MSCA Subtests (N=18)**

| | PBB Cohort | | Standard Normal | |
|---|---|---|---|---|
| Subtest | M | SD | M | SD |
| 1. Block Building | 9.5 | 0.8 | 9.3 | 1.2 |
| 2. Puzzle Solving | 12.8 | 7.3 | 10.7 | 6.8 |
| 3. Pictorial Memory | 3.8 | 1.3 | 3.6 | 1.2 |
| 4. Word Knowledge | 17.7 | 3.1 | 16.1 | 3.0 |
| 5. Number Knowledge | 4.3 | 1.9 | 4.4 | 1.4 |
| 6. Tapping Sequence | 4.1 | 1.7 | 3.5 | 1.6 |
| 7. Verbal Memory | 24.8 | 5.2 | 22.0 | 6.5 |
| 8. R-L Orientation | 5.5 | 3.5 | 6.1 | 3.2 |
| 9. Leg Coordination | 9.8 | 3.3 | 11.1 | 1.8 |
| 10. Arm Coordination | 6.8 | 4.2 | 8.3 | 4.0 |
| 11. Imitative Action | 3.8 | 0.4 | 3.8 | 0.4 |
| 12. Draw-A-Design | 7.3 | 3.8 | 6.7 | 3.0 |
| 13. Draw-A-Child | 9.7 | 4.4 | 9.1 | 3.7 |
| 14. Numerical Memory | 6.0 | 1.6 | 5.9 | 1.9 |
| 15. Verbal Fluency | 17.3 | 6.7 | 12.9 | 4.8* |
| 16. Counting and Sorting | 6.2 | 2.6 | 6.3 | 1.9 |
| 17. Opposite Analogies | 5.4 | 1.7 | 4.6 | 1.5 |
| 18. Conceptual Grouping | 7.7 | 2.2 | 7.6 | 2.4 |

*$p < .05$ for difference between means.

of areas assessed, the PBB cohort scored higher than expected from the standardization data.

Since the initial Muskegon study had revealed low scores for these same children on four of the five MSCA subtests administered, some direct comparisons of the current data with the earlier data are appropriate. A complete listing of PBB cohort scores on the MSCA is shown in Table 3. One significant difference was observed: the PBB cohort was found to score higher than expected (based on standardization data) on "verbal fluency". Table 4 shows the correlations of the natural logarithms of PBB fat levels and scores on the five MSCA subtests administered in the initial study. Since the PBB levels were of such a wide range, the fat values were transformed into their natural logarithms in order to make a linear analysis possible. The correlations did not approach significance.

In the initial study, the PBB cohort was divided into high and low exposure groups and a comparison of scores on the five MSCA subtests between groups was undertaken. This analysis was repeated for the current study using the same PBB level cut-off point. As shown in Table 5, the only difference found between the groups for the five MSCA subtests was on Puzzle Solving, with the high exposure

**TABLE 4—Pearson Product Moment Correlation Coefficients between the Natural Logarithm and PBB Fat levels and Five MSCA Subtest Scores (N=18)**

| Subtest | Correlation Coefficient (Natural log of Fat Level) |
|---|---|
| Block Building | −.03 |
| Puzzle Solving | .17 |
| Word Knowledge | −.03 |
| Draw-A-Design | .09 |
| Draw-A-Child | .09 |

**TABLE 5—Mean Scores of High and Low PBB Exposed Children on Five MSCA Subtests**

| | High Exposure (> .100 ppm) (N = 10) | | Low Exposure (< .100 ppm) (N = 8) | |
|---|---|---|---|---|
| Subtest | M | SD | M | SD |
| Block Building | 9.6 | 0.8 | 9.5 | 0.7 |
| Puzzle Solving | 7.6 | 3.4 | 4.9 | 3.2* |
| Word Knowledge | 18.2 | 3.2 | 17.1 | 2.7 |
| Draw-A-Design | 8.3 | 4.1 | 6.0 | 2.6 |
| Draw-A-Child | 10.7 | 4.4 | 8.4 | 3.7 |

*$.05 < p < .10$ for difference between means.

group performing more effectively on this task. A more complete comparison of cognitive and developmental skills between high and low exposure groups is shown in Table 6. Mean WPPSI and MSCA scores are generally found to be higher in the low exposure group compared to the high exposure group. This is most evident for the performance or perceptual scale of the WPPSI although neither this difference nor any of the others approach statistical significance. Several deviant scores were noted within the high exposure group and at both ends of test score ranges throughout the scales. The more consolidated performance of the children in the low exposure group is reflected within the differences in standard deviations between groups.

Pearson product moment correlation coefficients between natural logarithm transformations of PBB fat levels and WPPSI and MSCA scores are found in Table 7. The results show an inverse relationship of borderline statistical significance on the perceptual scales of both tests. Since two of the 18 subjects had PBB levels well above the others in the cohort, it was decided to determine the impact of these two subjects on the "effect" observed. The correlations are shown in Table 7. The inverse relationship between PBB levels and performance or perceptual scales is increased following removal of both subjects from the total PBB cohort. The "effect", in fact, reaches borderline statistical significance throughout the scales. Also included in Table 7

**TABLE 6—Mean WPPSI and MSCA Scores of High and Low PBB-Exposed Children**

| | High Exposure (> .100 ppm) N = 10 | | Low Exposure (< .100 ppm) N = 8 | |
|---|---|---|---|---|
| Test | Mean | SD | Mean | SD |
| WPPSI | | | | |
| Full IQ | 109.4 | 16.0 | 113.0 | 10.0 |
| Verbal IQ | 108.5 | 15.9 | 110.6 | 11.5 |
| Performance IQ | 106.3 | 14.4 | 115.6 | 9.4 |
| MSCA | | | | |
| GCI | 105.9 | 22.9 | 108.9 | 10.0 |
| Verbal | 56.2 | 15.7 | 56.9 | 4.5 |
| Perceptual | 51.8 | 13.2 | 55.0 | 8.2 |
| Quantitative | 48.5 | 11.1 | 51.1 | 10.8 |
| Memory | 51.3 | 10.1 | 52.5 | 7.5 |
| Motor | 48.3 | 15.5 | 48.2 | 3.0 |

**TABLE 7—Pearson Product Moment Correlation Coefficients Between Natural Logarithm Transformations of PBB Adipose Levels and WPPSI and MSCA Scores**

| Test | Coefficient N = 18 | Coefficient N = 16[1] | Coefficient Lower Educ. N = 10[2] | Coefficient Higher Educ. N = 8[3] |
|---|---|---|---|---|
| WPPSI | | | | |
| Full IQ | −.23 | −.40* | −.60** | −.28 |
| Verbal IQ | −.12 | −.26 | −.53* | .10 |
| Performance IQ | −.40* | −.56** | −.70** | −.45 |
| MSCA | | | | |
| General Cognitive Index | −.20 | −.40* | −.72** | .08 |
| Verbal | −.20 | −.25 | −.76*** | −.04 |
| Perceptual | −.35* | −.51** | −.46* | −.33 |
| Quantitative | −.02 | −.35* | −.64** | .49 |
| Memory | −.21 | −.24 | −.68** | −.13 |
| Motor | −.19 | −.37* | −.43 | .02 |

[1]Sample size is reduced by two, subjects 18 and 19.
[2]Parent education level (mother) is 11th or 12th year high school.
[3]Parent education level (mother) is 13 years and over.
*$0.05 < p < 0.10$
**$p < .05$
***$p < .01$

are the correlations between PBB level and test scores when parent (mothers) education level is taken in account. The magnitude and number of significant correlations increases within the lower parent education group (all inverse relationships) while correlations in the higher educated group are consistently non-significant. Interpretation of these results is difficult, not only because of small sample sizes, but also because of the distribution of PBB levels in each group. Table 8 shows that the variability in actual PBB values for the two groups is markedly different. Within the lower educated group, the range is highly restricted with the majority of scores barely differentiated. On the other hand, the distribution of PBB values in the higher educated group shows considerable variability. Thus, controlling for parent education within this small sample and narrow range of PBB values results, at best, in correlations of questionable meaning.

## *Discussion*

Results of the follow-up developmental assessment revealed that children in the PBB cohort, of preschool and kindergarten age at the time of testing, are functioning within the normal range in all cognitive areas. In addition, they were not observed nor reported to be exhibiting problems in behavior, activity level, or attention to tasks. Comparison scores between high and low PBB exposure groups as well as correlations between PBB fat levels and test scores suggest, however, that there may be a relationship between PBB exposure and performance on perceptual and perceptual-motor tasks. At this point, the "effect" appears to be not only specific but minimal. In view of the partial testing emerging from the Muskegon Project, it is not possible to determine if these findings relate to those earlier results or their "course" over time. Nor can it be determined at this time, and based on the limited sample size, if these findings will be of significance in the academic and developmental functioning of these children in future years. Consequently, these children will need continued monitoring. In the meantime, it is hoped that investigators researching the impact of similar chemical contaminants (e.g., PCB) will be able to utilize the data in more effectively controlled studies.

**TABLE 8—Distribution of Actual PBB Adipose Levels within Parent Education Groupings**

| Education Level 13+ years | | Education Level 11–12 years | |
|---|---|---|---|
| Subject No. | PBB Level (ppm) | Subject No. | PBB Level (ppm) |
| 19 | 20.960 | 16 | 2.140 |
| 18 | 13.270 | 14 | .702 |
| 17 | 2.280 | 11 | .297 |
| 15 | 1.340 | 10 | .116 |
| 13 | .662 | 9 | .074 |
| 12 | .414 | 8 | .070 |
| 6 | .051 | 7 | .069 |
| 1 | .010 | 5 | .051 |
| | | 4 | .047 |
| | | 3 | .045 |

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# Developmental Abilities of Children Exposed to Polybrominated Biphenyls (PBB)

ELIZABETH ANN WALKER SEAGULL, PHD

**Abstract:** To investigate whether ingestion of polybrominated biphenyls has an adverse effect on the neuropsychological development of young children exposed *in utero* and in infancy, five tests of the McCarthy Scales of Children's Abilities were administered to a group of 19 PBB-exposed Michigan children. When the data for the exposed group were analyzed according to body burden of PBB as determined by fat biopsy, correlations ranging from $-.5228$ to $-.3004$ were found between the natural logarithms of the children's fat PBB values and their standardized scores on the developmental scales. Four of the five correlations were significant at $p < .05$. Multivariate analysis of covariance confirmed the existence of a significant main effect for fat PBB level, with parental education held constant. Children with higher body burdens of PBB ($>$ .100 ppm) scored significantly lower than exposed children with lower body burdens on the same four tests, and on a composite score representing overall performance. These results suggest the existence of an inverse relationship between body levels of PBB and some developmental abilities in young children. (*Am J Public Health* 1983; 73:281–285.)

Address reprint requests to Elizabeth A. W. Seagull, PhD, Department of Pediatrics and Human Development, B240 Life Sciences, Michigan State University, East Lansing, MI 48824. This paper, submitted to the Journal July 15, 1981, was revised and accepted for publication July 1, 1982.

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## *Introduction*

From May 1973 to May 1974, Michigan residents unknowingly ingested polybrominated biphenyls (PBBs) through eggs, meat, and dairy products from animals whose feed had been inadvertently contaminated through the substitution of a fire retardant for a feed supplement in what has been called "one of the most costly agricultural accidents in the history of the United States."[1] The series of errors