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Cognitive Functioning of Akwesasne Mohawk Adolescents Exposed to PCBs

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Cover Page Footnote
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In 1995 the Mohawk Adolescent Wellbeing Study, referred to as MAWBS, was commenced in partnership with the Akwesasne Mohawk Nation, investigating human health effects of exposure to polychlorinated biphenyls (PCBs), an industrial effluent that had entered their environment and food chain (Schell et al., 2003). A national Priority Superfund Site (General Motors Central Foundry Division) and two New York State Superfund Sites (Reynolds Metal Company and Aluminum Company of America) were located upstream of Mohawk territory along the St. Lawrence River at the juncture of Quebec, Ontario and New York. Compliance with fish advisories published in the 1980s caused disruption to many aspects of the traditional lifestyle of the Mohawks.

One focus of MAWBS concerned the cognitive functioning of the adolescents. Results have been published elsewhere (Newman et al., 2006; Newman et al., 2009) and will be integrated here. In the cognitive studies, 269 adolescents (131 males and 140 females) and their mothers volunteered their time and blood to examine any relationship between the adolescents' body burdens of PCBs and their cognitive functioning. Although most published studies investigating neurotoxic effects of PCBs report on infants and children, adolescence is an appropriate age to study as it is a period marked by considerable endocrine activity and brain maturation (Casey, Geidd, Thomas, 2000; Spear, 2000).

The adolescents completed three cognitive tests in the research office on the reservation. These were administered individually by members of the Akwesasne community who were trained in testing at the University at Albany, and who were also certified phlebotomists. Mothers provided information about family factors, breastfeeding and their children's diet, and their own smoking and alcohol consumption during pregnancy. Fasting blood draws of 15 mL were taken first thing in the morning from the adolescents in their homes.

Blood was analyzed for 101 PCB congeners, but only those 16 congeners detected in at least 50% of the participants were included in analyses. A summary measure of total PCB body burden for each participant was created from these 16 congeners. Details of PCB laboratory procedures have been described elsewhere (DeCaprio et al., 2000). In a second statistical analysis, we categorized the PCB congeners onto those that were more or less persistent in the environment, and those that had a dioxin-like structure or not. Persistent congeners may have been accumulated at any time in the adolescent's life span including prenatally, whereas low-persistent congeners reflect more recent and/or ongoing exposure. Previous researchers have examined the differential effects of congeners of different structures, but results of animal (Holene et al., 1998) and human (Huisman et al., 1995) studies have been inconclusive and in need of further research (Rice 2005; Schantz, Widholm & Rice, 2003).

The cognitive tests administered were the Woodcock Johnson- Revised Tests of Cognitive Ability, Standard and Supplemental Batteries (WJR), Test of Memory and Learning (TOMAL) and Ravens Progressive Matrices. The WJR provides an overall cognitive score as well as information about seven specific domains of cognition (Long Term Retrieval, Short Term Memory, Processing Speed, Auditory Processing, Visual Processing, Comprehension - Knowledge, and Fluid Reasoning). The TOMAL yields scores on Verbal Memory, Non-verbal Memory, Delayed Recall as well as a Composite Memory Index. The Ravens is a non-verbal test of the ability to identify patterns in complex visual stimuli. It is considered 'culturally fair' because it does not require language in either the test itself or

administration. Mothers were also given the WJR test (although just the shorter Standard Battery) to allow the influence of their cognitive level on their children's scores to be controlled statistically. Average scores of the North American standardization sample on the WJR and TOMAL are 100; average score of the standardization sample on the Ravens is 50. Table 1 shows the average scores gained by the Akwesasne adolescents on all subtests of the three cognitive tests.

Table 1

Adolescent average scores on cognitive tests

Cognitive Test		n	Average	Standard Deviation
WJR				
	Long Term Retrieval	269	106.2	12.7
	Short Term Memory	266	99.0	13.0
	Processing Speed	268	100.4	14.8
	Auditory Processing	263	95.6	12.2
	Visual Processing	269	114.7	13.1
	Comprehension-Knowledge	250	95.3	12.0
	Fluid Reasoning	258	102.8	13.1
	Broad Cognitive Ability	236	100.7	12.4
TOMAL				
	Verbal Memory	269	99.2	11.6
	Nonverbal Memory	269	101.1	12.0
	Delayed Recall	269	99.7	8.4
	Composite Memory	269	100.3	10.4
Ravens		268	54.2	26.5

All statistical analyses examined and, where necessary, took into account the contribution of variables other than PCB exposure that might influence adolescent cognitive functioning. Such factors included other toxicants, lipids, thyroid measures, BMI, maternal cigarette and alcohol consumption in pregnancy, breast feeding, SES, social problems, pregnancy order, sex, age, and maternal cognitive scores.

Among the Akwesasne adolescent participants, the range of body burdens of PCBs was from 0.31 *ppb* to 2.70 *ppb*, with the average being 0.731 *ppb* (SD = 0.3666). Whereas in many other studies the PCB measure was gained prenatally, in the present study PCBs were measured concurrently with cognitive test performance.

Results of the Akwesasne adolescents on all three cognitive tests showed that they scored as a group in the average range for adolescents of the same age in the North American comparison group. The exception was in Visual Processing where the Akwesasne adolescents scored above average.

The combination of tests used in the study enabled us to detect subtle, more specific effects than are provided by general measures (such as overall intellectual functioning) that have been used in many previous human studies. To test if the total PCB measure was related to the adolescents' scores on the various cognitive measures, regression analyses were carried out. These statistical tests showed that total PCB levels were significantly and negatively related to scores on three of the cognitive subtests; Delayed Recall (TOMAL), Long Term Retrieval (WJR), and Comprehension-knowledge (WJR). Adolescents who had higher levels of total PCBs scored more poorly on these measures. Total PCB levels were not related to scores on the Ravens, nor to the remaining subtests of the WJR and TOMAL.

It should be noted that Delayed Recall and Long Term Retrieval measure very similar skills - the ability to hold in memory and recall visual and verbal information that was presented from 5 to 30 minutes earlier. Comprehension-knowledge measures the recall of information acquired over the lifetime. All three subtests rely on memory and were negatively related to total PCB level. The size of the negative effect was small, but statistically significant. Nevertheless, not all memory tests showed the same pattern. Some other specific memory scores (Verbal Memory, Non-verbal Memory, Short Term Memory) and the general memory score (Composite Memory) of the adolescents in the study did not show the same negative association with total PCB body burden as the two specific long-term memory skills.

We conducted further analyses of our data according to the persistence of the PCB congeners. These showed that Auditory Processing was associated (negatively) only with congeners in the persistent category. On the other hand, Delayed Recall, Long Term Retrieval and Comprehension-Knowledge were the only subtests related (negatively) to low-persistent congeners, suggesting that scores of the adolescents on these measures were influenced by recent or ongoing exposure to PCBs. However, Delayed Recall and Long Term Retrieval were related also to persistent congeners, indicating that the robust negative associations did not result only from recent exposure. Persistent congeners could have had effects on cognitive development prenatally, in infancy, childhood, or currently, whereas low-persistent congeners were likely to reflect recent and ongoing exposure.

Our analyses contributed to the small amount of literature about the role of the structure of PCB congeners on human cognitive functioning. Delayed Recall and Long Term Retrieval were related to both dioxin-like and non dioxin- like congeners, but strongest effect sizes on these two subtests were from non-dioxin like congeners. By contrast, the Ravens test was associated (negatively) with only congeners that had structures that were dioxin-like.

Some previous studies have found a variety of memory deficits in children associated with PCB exposure. Studies of children exposed to Lake Michigan fish found continuing memory deficits (of different types) during repeated testing from infancy (Jacobson, Fein, Jacobson, Schwartz, Dowler, 1985), preschool (Jacobson, Jacobson, Humphrey, 1990), and pre-adolescence (Jacobson, & Jacobson, 1996). By contrast, children eating fish from Lake Ontario had deficits in memory only in infancy (Darvill, Lonky, Reihman, Stewart, Pagano, 2000) and not as preschoolers (Stewart, Reihman, Lonky, Darvill, Pagano, 2003. Cognitive deficits, where found in these studies, were attributed to prenatal PCB exposure. We did not have data about prenatal and early childhood PCB levels. Our finding that three

cognitive measures (Delayed Recall, Long Term Retrieval, Comprehension-knowledge) gained at adolescence were associated with exposure to low-persistent congeners indicates the need for research into continuing exposure at Akwesasne. Recent findings about airborne transmission of PCBs (Carpenter, 2015), including among Akwesasne residents (DeCaprio et al., 2005), confirm this need.

In conclusion, the results of our study with the Akwesasne adolescents show evidence that some of their cognitive abilities (particularly those associated with memory) have been negatively influenced by PCB exposure over more than one age period and by more than one congener type. Although these effects are small or moderate, they are of justified concern to members of the Akwesasne community who have suffered significant disruption to their traditional lifestyle to accommodate environmental risk.

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