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PCBs and Measures of Attention and Impulsivity on a Continuous Performance Task of Young Adults

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Abstract

The present study examines the relationship between current body burden of persistent PCBs and attention and impulsivity in 140 Akwesasne Mohawk young adults aged 17 to 21 whose environment has been contaminated by industrial effluent. Attention and impulsivity were measured by errors of omission, errors of commission, and patterns of reaction time responses on the Conners Continuous Performance Test. The PCB measure was the sum of those persistent PCB congeners detected in 50% of the participants. After adjusting for multiple covariates, regression analyses showed a significant positive relationship between PCB levels and omission scores, but only for males.

Keywords

Polychlorinated biphenyls (PCBs); Conners Continuous Performance Test (CPT); Mohawk; Attention; Impulsivity; Young Adults

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1. Introduction

The present study is one of a series of investigations carried out with members of the Akwesasne Mohawk Nation, located along the St. Lawrence River between upstate New York, Ontario and Quebec. The residents have concerns about health and human developmental effects of PCBs and other contaminants that have entered their food chain and ecology from industrial effluent from a National Priority Superfund site and two New York State Superfund sites located upstream of the community (Akwesasne Task Force on the Environment, 1997; DeCaprio et al., 2005). The adolescents of the community, whose mothers were likely to have been exposed to PCBs by eating local contaminated food before and during their pregnancy, had participated in the Mohawk Adolescent Well-Being Study (MAWBS) that investigated physical, health, and cognitive outcomes of PCB exposure. The PCB levels of the adolescents in MAWBS (ages 10-16.9) were found to be negatively related to long-term memory (Newman et al., 2006, 2009) but were not found to be related to parent and teacher behavioral ratings of ADHD (Newman et al., 2014). A sample of the participants later took part in the Young Adult Well-Being Study (YAWBS) which included the current investigation using computerized measures of inattention and impulsiveness to examine links between PCBs and aspects of ADHD.

1.1. PCBs

Concerns over PCBs' toxicity and bioaccumulation resulted in PCB bans in many industrialized nations since the late 1970s. However, communities are still at risk today because of the persistent nature of the chemical, the improper disposal mainly by industries, contaminated food (Erickson, 2001) and air (Carpenter, 2015). Mothers can also transfer PCBs to their infants from their adipose tissue both prenatally through the placenta and postnatally through breastfeeding (Winneke et al., 2005).

1.2. ADHD

Attention Deficit Hyperactivity Disorder (ADHD) is a multifaceted construct composed of behavioral and attentional characteristics (American Psychiatric Association [APA], 2013). Two important components are poor sustained attention and impulsivity.

Sustained attention or vigilance is the ability to maintain attention “for infrequent but critical events over sustained periods of time” (Corkum & Siegel, 1993, p. 1218). Impulsivity is shown by difficulty in inhibiting or interrupting a response. Sustained attention and impulsivity are related to a number of disorders such as the attention deficit hyperactivity disorder (ADHD) or learning disabilities (APA, 2013). They have a negative impact on school functioning, as shown by such indices as suspension, expulsion, and dropout (Barkley, 2006; Murphy & Barkley, 1996).

1.3. PCBs and ADHD-like behaviors

Animal studies of prenatal and postnatal exposures to PCBs show a relationship between PCBs and motor activity and hyperactivity (Agrawal et al., 1981; Carpenter et al., 2002; Daly et al., 1998; Holene et al., 1998; Schantz et al., 1997). Other behaviors similar to aspects of ADHD appear to be associated with PCB exposure in animals. In particular,

inability to inhibit responses has been associated with PCB exposure in several animal studies (Berger et al., 2001; Rice, 1997; Sable & Schantz, 2006). Rice (2000) also noted some similarities between behavioral impairment in monkeys exposed to PCBs and some of the characteristics of attention deficit hyperactivity disorder (ADHD) found in children, such as the inability to learn from the consequences of past actions. In a cross-species comparison of the different effects of PCB exposure on various rodents and primates including humans, Tilson et al. (1990) found that PCB exposure altered activity level and caused behavioral problems. However, the outcomes were not always consistent among the different species.

Few studies have investigated the relationship between PCBs and behavioral activity measures in humans. This is in contrast to the large body of research looking at the cognitive effects of PCB exposure (Darvill et al., 2000; Jacobson & Jacobson, 1996; Koopman-Esseboom et al., 1996; Newman et al., 2006; Stewart et al., 2003b; Winneke et al., 1998). The early studies of children accidentally exposed to massive doses of PCBs (Chen et al., 1994; Harada, 1976) did note effects on children's activity levels, however the nature of the effects varied. The offspring of Japanese women who had ingested contaminated rice oils were hypotonic (Harada, 1976) while the exposed Taiwanese children were more active and had more behavioral problems than an unexposed control group (Chen et al., 1994). In a more recent study of children in Massachusetts, Sagiv et al. (2010) found that those children who had higher PCB levels at birth were rated by their teachers as having more behavior problems indicative of ADHD. By contrast, Newman et al. (2014), using the MAWBS Akwesasne sample, found no indication that concurrent PCB levels were related to problematic behavior ratings completed by teachers and parents. In addition, Neugebauer et al. (2015) found that prenatal PCB exposure was negatively associated with ADHD-like behavior reported by parents.

1.4. PCB studies using computerized behavioral measures

Hyperactivity can be diagnosed and measured by behavior rating scales, but its component behaviors are more objectively assessed by computerized measures that allow the researcher to assess an individual's actual behavior (Riccio et al., 2001). Several studies using a variety of computerized measures have investigated links between PCB exposure and ADHD-like behaviors. Reaction time is one method that has been used to assess an individual's executive control of attention. Using a modified version of a Simple Reaction Time Test, Vreugdenhil et al. (2004), related children's prenatal PCB exposure to their attention. Similarly, Grandjean et al. (2001) found that the umbilical cord PCB level of children in the Faroe Islands was related to their attention as measured by reaction time at age 7.

Sustained attention and impulsivity are often measured by ‘continuous performance tests’ such as the NES2 (Letz, 1998) or the Conners CPT (2000) which provide measures of various aspects of attention and vigilance. Continuous performance tests measure a person's ability to identify and respond to specific infrequent stimuli at random intervals while inhibiting responses to non-target stimuli. Errors of commission on these tests are considered indicators of impulsivity whereas errors of omission and inconsistency in response time are considered indicative of lapses of sustained attention. They have also been used to investigate effects on attention and impulsivity resulting from prenatal substance

exposure (Leech et al., 1999; Noland et al., 2005; Streissguth et al., 1984, 1986). In addition, continuous performance tests have been used to look at neurobehavioral effects of occupational exposure to neurotoxic chemicals (Estrin et al., 1987; Tsai & Chen, 1996). In these studies, performance was adversely affected by chemical exposure. The Conners CPT has been used to assess both children and adults with ADHD (Barkley, 2006) and evaluate medication effects (Earle-Boyer et al., 1991; Levin et al., 1996). In their review of neuropsychological effects of PCB exposure, Boucher et al. (2009) concluded that the Conners CPT was a sensitive instrument, and recommended that it should be used in future studies of the effects of exposure to organochlorine compounds.

The Conners CPT and other continuous performance tests have been used to assess children's functioning after exposure to PCBs. Using the NES5 continuous performance test, Stewart et al. (2003a) found that 4.5 year olds who were more highly exposed to PCBs prenatally had significant increases in their commission scores (impulsivity). Similar results were found for the same group of children at 8 and 9.5 years of age (Stewart et al., 2005). Jacobson and Jacobson (2003) found more errors of commission (impulsivity) in children aged 11 years, but only among those who had not been breast fed. However in an earlier study using the same cohort Jacobson et al. (1992) found no relationship between prenatal PCB exposure and 4-year old children's sustained attention to a ‘catch the cat’ task. On the other hand, prenatal PCB exposure was related to poorer sustained attention (measured by higher omission errors on the KITAP) of school-aged children in Germany (Neugebauer et al., 2015). Using the NES2 continuous performance test, Sagiv et al. (2012a) also found a negative relationship between PCBs and sustained attention but only for boys. Boucher et al. (2012) found that current PCB levels (but not prenatal measures) of 11-year old Inuit children were associated with slower reaction times, and with brain activity that suggested reduced error monitoring, on a task requiring selective inhibition of responses to visual stimuli.

The inconsistencies in the human data regarding links between PCB exposure and ADHD like behavior in studies using both behavior ratings and the computerized measures and the fact that very few studies have looked at the adverse effects of postnatal PCB exposure indicates a need for more research in this area.

1.5. The present study

A previous study (Newman et al., 2014) with many of the same individuals when they were adolescent participants of MAWBS (mean age of 13.62) found no relationship between behavior ratings of ADHD and then concurrent PCB levels. However, some other studies (reviewed above) have found relationships when using computerized measures of attention. These studies have related measures of prenatal PCB exposure to later performance on the attention measures. In contrast, the present study does not use measures of prenatal PCBs; it investigates associations between computerized measures of attention and measures of PCB exposure gained concurrently in a group of young adults. However, some persistent PCB congeners are sufficiently long-lived (some are 20+ years) that levels of them evident in our young adult participants reflect some prenatal exposure. Attention and impulsivity are measured by the omission, commission and reaction time scores on the Conners CPT.

2. Methods

2.1. Participants and procedures

The participants were young adults (aged 17 to 21) who participated in the YAWBS conducted at Akwesasne from 2000 to 2006, and who had earlier participated in MAWBS (when they were aged between 10 and 16.99 years). Children had been disqualified from participation in MAWBS (and hence from YAWBS) if they had Fetal Alcohol Syndrome or Fetal Alcohol Effects, if they were a twin, if they had been hospitalized for brain injury, or if they had a serious organic or psychological pathology (Newman et al., 2006), as all of these conditions could mask the effects of PCBs. Only one qualified child per family was accepted in the MAWBS phase of the study. All participants lived on or near the reserve.

At the commencement of the YAWBS in 2000, Akwesasne research team members attempted to recontact all MAWBS participants, and asked them to take part in the follow-up YAWBS phase of the study unless they were 22 or older, were pregnant, had a child or had lactated in the past 6 months (Schell et al., 2009). All data gathering for both projects was done by individuals who were members of the Akwesasne community. Data collectors were trained and supervised by researchers at the University at Albany and had no knowledge about the participants' PCBs exposure levels.

Of the original 269 participants in the MAWBS, 142 participated in this part of the YAWBS follow-up study which focused on performance on a computerized measure (CPT) of attention and impulsivity. Valid CPT scores were available for 140 of them (51 males and 89 females). Of the 140 participants, one reported taking ADHD medication. The mean age of the YAWBS participants was 18.11 years (SD = 1.10 years, range 16.97-21.36 years). The retained participants were comparable to those lost to follow-up on PCB levels, height, weight, socioeconomic index, maternal education, maternal cognitive scores, and breast feeding duration. Retained participants were different only in age (being significantly older) and birth order (being more likely to be second born than first born).

Some participants were born to mothers who were likely to have consumed local fish before advisories were announced in the mid-1980 and may have transferred more persistent PCBs to their infants who thus would have had higher persistent PCB body burdens (Gallo, et al., 2011). As a result, the participants in this study could have been exposed to PCBs prenatally through the placenta and postnatally through breastfeeding (Fitzgerald et al., 1998) as infants, as well as through their own local food consumption as children, adolescents and young adults (Fitzgerald et al., 2004) or from exposure to volatile PCBs that were persistent in their environment (Carpenter, 2015).

2.2. Independent variable: PCB body burden

PCBs and attention measures were taken at the same time period, when the participants were young adults (aged 17 to 21). For 90% of the participants, these two measures were gained either the same day or within a few days of each other. For the remainder (n=12), the CPT was administered on average 2.5 months after the blood draw. In every case, a fasting blood sample was taken from the young adults at first rising either at the participant's home or at the project office located on the Akwesasne Reserve by a trained Mohawk staff member. The

participants were asked not to eat any local food for three days before giving blood. They also could not eat or drink after 10 PM the night before blood collection. By venipuncture, 20 mL of blood were collected for PCBs analysis and the samples were periodically transferred to the University at Albany's Exposure Assessment Laboratory for analysis. Detailed descriptions of venipuncture and analytic procedures are given in previous publications (DeCaprio et al., 2000, 2005; Gallo et al., 2015; Schell & Gallo, 2010; Schell et al., 2003, 2009).

Eighty-three individual congeners of PCBs and 18 more PCB congeners as pairs or triplets were analyzed (Schell & Gallo, 2010; Schell et al., 2003, 2009), for a total of 101 individual congeners. However, congeners for which all values were below the minimum detection level (MDL) were excluded. Only congeners which were detected in at least 50 % of participants and considered persistent were included in this analysis. This resulted in inclusion of the higher frequency congeners which made the analyses comparable to those of other cohorts in which fewer ‘marker’ congeners are included (e.g. Grandjean et al., 2001; Neugebauer et al., 2015; Vreugdenhil et al., 2004).

Congeners included in the persistent PCB measure were International Union for Pure and Applied Chemistry (IUPAC) congener numbers 28, 74, 99, 105, 118, 138, 153, 180, and 187. Of these congeners that had values for a particular individual below the MDL, the midpoint value between zero and the MDL was used (MDL/2). The mean of persistent PCBs level was .36 ppb. in the 140 participants (SD = .24, minimum .11, maximum 1.91). A previous publication (Gallo et al., 2011) provides a summary of the specific congener levels for these Akwesasne young adults and allows comparison of their PCB congener levels with CDC national data. This comparison showed that mean congener concentrations of the Akwesasne youth were substantially higher than for the CDC general population of adolescents (Centers for Disease Control [CDC], 2009); indeed the average of the levels in the Akwesasne youth was equivalent to the 90th centile of the CDC reference values.

2.3. Dependent variables: Conners CPT omission, commission, hit RT SE, and hit RT block change scores

The standard version of the Conners CPT II called the X-type CPT (version 3.1 for Windows) was employed in the present study to measure aspects of attention and impulsivity. The Conners CPT II is a computerized measure of attention and impulsivity for ages 6 years and up and takes 14 mi to complete (Conners, 2000). The CPT II test was administered in accordance with the guidelines provided in the Conners CPT II computer program version 3.0 users' manual by a trained member of the Akwesasne research team. Before taking the scored test, the participants were asked to take the standard practice test. The actual items are administered in six time blocks. The test was given on a Texas Instrument EXTENSA 560CD laptop with a 10.5 i. monitor in a quiet room in the participant's house, or in a room in the research office. The examiner remained in the room for both the standard practice test and the actual test.

The Conners CPT II requires participants to press the space bar when any letter except the target letter X appeared on the screen. The test (Conners, 2000) yields two measures of response accuracy - errors of omission and errors of commission. Errors of omission are

missed targets. That is, a response is not given after a non-X letter appears on the screen. Errors of commission occur when a response is given to the letter X. Two other indices of inattentiveness selected from the measures generated by the Conners CPT II are variability in reaction time (Hit RT standard error), and slower reaction time as the test progresses (Hit RT block change). These two measures of reaction time maintenance were considered better indicators of attentiveness than the mean reaction time over all trials.

The Conners CPT was normed on a sample of individuals diagnosed with ADHD and other neurological impairments, as well as individuals from the general population, all from geographically diverse locations. Satisfactory reliability of the Conners CPT is reported (Conners, 2000) with split-half reliabilities of .94 for errors of omission, .83 for errors of commission, and .87 for reaction time standard error. Test–retest reliability for a small sample was reported to be .84 for errors of omission, .65 for errors of commission, and .65 for reaction time standard error.

Discriminant and concurrent validity has been examined and was satisfactory. According to the test manual, the Conners CPT can discriminate between clinical and non-clinical groups (Conners, 2000). Furthermore, the test allows effectiveness of treatments and medications to be monitored. For example, in one study, children's performance on the Conners CPT improved after taking methylphenidate, a central nervous system stimulant (Aman et al., 1993). The test has also been validated as a sensitive assessment tool for ADHD in adults (Barkley et al., 1996).

The scoring program converts the omission and commission error scores and the reaction time scores to T-scores which provide the data in the current analysis. T-scores compare the respondent to the same-aged normative group (aged 16-17, or 18-34) and gender. T-scores have a standard deviation of 10, and a T-score of 50 is the average for the normative group. High T-scores indicate a problem (Conners, 2000).

Descriptive statistics for the dependent variables are presented in Table 1. In general, participants' performances on the Conners CPT fell within the average range on all scores.

2.4. Control for other variables

Data from both the MAWBS and the YAWBS provided many potential covariates. Descriptive data for the covariates are presented in Table 2.

Bivariate correlations were carried out between all potential covariates and each outcome measure (see Table 3). Only variables that correlated with the outcome measure at $p < .20$ (set in bold) were used in the analysis of that particular outcome measure. This objective method resulted in omission of many possible covariates from regression analyses but included those with a demonstrable, if slight, contribution to the Conners CPT scores. This is an objective and a liberal inclusion method that allows even “marginalized variables” to be included (Stewart et al., 2004, p. 650) so that their role may be corrected for.

2.5. Data Screening

The dataset was screened for outliers, skewness, and multicollinearity. Two participants' protocols were invalidated because of their atypical error patterns and dropped from analyses. After examining each variable's distribution, probability plots and histogram, the following variables were log transformed: Persistent PCBs, HCB, *p,p′*-DDE, total fat and protein intake, cholesterol levels, and breastfeeding duration. The distribution of commission scores, hit RT SE scores, and hit RT block change scores were relatively normal. The distribution of omission scores, although slightly skewed, did not warrant transformation. Diagnostics showed no multicollinearity among the variables included in the regression model.

2.6. Statistical Analyses

Statistical analysis was conducted with SPSS 23. Four simultaneous multiple regressions were performed investigating each dependent variable separately (Cohen & Cohen, 1983), as has been the practice in many publications in this field (e.g., Grandjean et al., 2001; Koopman-Esseboom et al., 1996; Winneke et al., 1998).

3. Results

3.1. PCBs and Conners CPT measures of attention

Multiple regressions examined the relationships between persistent PCB levels and each attention measure, controlling for those variables that qualified as covariates for that outcome by our stated criterion. The result of the multiple regression (see Table 4) examining the relationship between persistent PCB levels and errors of omission, controlling for sex, video games in household, *p,p′*-DDE, and maternal smoking during pregnancy was not significant. There was no relationship between persistent PCB levels and errors of commission, controlling for age, computer, and video games in the household. No significant relationship was found between hit RT SE scores and persistent PCB levels controlling for sex, Ravens, TOMAL, WJ-R: BCAE, video games in household, SES, and maternal smoking during pregnancy. There was also no significant relationship between hit RT block change scores and PCB levels controlling for age, sex, BMI, total fat, total protein, Ravens, TOMAL, *p,p′*-DDE, maternal cognitive ability, birth order, and maternal smoking during pregnancy. Supplemental analyses repeated the multiple regressions excluding the three cognitive measures as covariates. This was to check if the results might have been influenced by an effect of the PCBs on cognitive functioning. The results of the analyses did not change because of this modification.

3.2. Sex differences

Table 5 shows results when the multiple regression was repeated separately for males (n = 51) and females (n = 89). Persistent PCBs were related to omission scores in males only (see Table 5), and the relationship was positive. Males also, but not females, had a tendency towards increased inconsistency in the speed of their correct responses (Hit RT SE scores) associated with PCB levels. There was no significant relationship between persistent PCBs

and commission scores for either males or females, although there was a tendency towards this relationship for females.

4. Discussion

4.1. Overview of results

The body burden of persistent PCBs was not related to the attentional vigilance (measured by errors of omission and reaction time response patterns) or impulsivity (measured by errors of commission) of the young adult participants as a group. However, when the analysis was conducted separately for males and females, persistent PCBs were found to be significantly related to the vigilance of the male participants. Males who had greater body burdens of persistent PCBs demonstrated more errors of omission on the Conners CPT. They also showed a greater tendency towards fluctuating attention resulting in inconsistent response times. There was no evidence of these associations for females, but there was a tendency for females with more persistent PCBs to have more commission scores which can indicate impulsivity.

4.2. Comparison with results of other studies using computerized measures

It is difficult to compare the results of the current study to some past studies because of the differences in the type of computerized measures employed, the timing of exposure (prenatal vs. postnatal), the particular PCB congeners analyzed, and the age of the participants. Nonetheless, the results of this study using an objective measure of attention support those of others who have found that aspects of attention are related to levels of PCB exposure (Boucher et al., 2012; Neugebauer et al., 2015; Sagiv et al., 2010; Stewart et al., 2005).

Moreover, our sex-specific results are similar to those of Sagiv et al. (2012a) who also used a continuous performance task as a measure of attention, and found the relationships only in omission (vigilance) errors in males. These researchers used measures of prenatal PCBs however. Other researchers who have recently reported a positive relationship between prenatal PCB exposure and children's inattention to computer-based tasks did not find it differentiated by sex. This was the situation for Neugebauer et al. (2015) who found a positive association between prenatal PCB levels and omission errors using the game-like KITAP. Similarly, Boucher et al. (2012) did not report sex differences in the observed associations between current PCB exposure and error monitoring of school-aged children on a computerized response choice task. Further, an earlier study by Jacobson et al. (1992) found no relationship between PCBs and sustained attention using a computerized vigilance task and PCBs in 4-year olds, and did not report sex differences. Thus the research findings on sex differences in the relationship between PCB exposure and sustained attention are inconsistent at this time.

Our results did not show a significant relationship between PCBs and errors of commission (an indication of impulsivity) for males or females, although there was a tendency towards this result for females. By contrast, Stewart et al. (2003a) found this relationship in 4.5 year olds. These results remained stable at 8 and 9.5 years of age for these children (Stewart et al., 2005). On the other hand, Jacobson and Jacobson (2003) found more errors of

commission at 11 years of age but only in the highly exposed children. These findings were not limited to boys.

Other studies have looked at children's reaction times to investigate attention. Reaction time could be influenced by both vigilance and impulsivity. In the Rotterdam cohort, PCB effects were found in 9 year olds as measured by an increase in the children's reaction time (Vreugdenhil et al., 2004). Similarly, in the Faroe Islands, umbilical cord PCB level was related to slower reaction time at age 7 (Grandjean et al., 2001). Moreover, the current PCB levels of Inuit 11-year olds were found to be associated with their reaction times (Boucher et al., 2012). Sex differences were not reported in these studies.

4.3. Comparison of our measures with behavioral measures of ADHD

It should be noted that the current study focused on specific aspects of attention and not more molar aspects of ADHD such as activity level or problem behavior. Results of previous studies have been mixed on whether exposure to PCBs is related to ADHD-like behaviors. Animal studies (e. g., Carpenter et al., 2002; Rice, 2000) and some studies of children (e. g., Chen et al., 1994; Sagiv et al., 2010) have found a relationship. In a previous study including the same and other participants from Akwesasne as adolescents, PCB body burdens were not related to problematic behavior ratings of the participants (Newman et al., 2014).

Nevertheless, the ability to direct, sustain and control attention is an important part of executive functioning and its weakness contributes to problematic behavior. In such settings as schools, this ability can have a great influence on learning and achievement. Our study has shown that some adolescents (males) may be particularly vulnerable to the effects of PCBs in this regard.

4.4. Sex differences and vulnerability

Many sources conclude that there are sex differences in ADHD (Arnett et al., 2015; Barkley, 2006; Davies, 2014; Ramtekkar et al., 2010). However, such behavioral syndromes are multiply determined by factors originating in various levels of the child's ecosystem (Bronfenbrenner & Morris, 2006). More specific attention and impulsivity responses may well originate in genetic predispositions (Trent & Davies, 2012) that influence differential susceptibility to exogenous factors. Findings about sex differences in deficits in particular component behaviors are less common and less consistent than differences in ADHD itself (Trent & Davies, 2012).

In our young adult sample, there was a negative relationship between PCB levels and Conners CPT attentional vigilance scores in males but not females. As discussed earlier, these findings have limited and inconsistent support in the PCB literature. Our findings are, however, consistent with the conclusions of DiPietro and Voegtline (2015) who comprehensively reviewed human evidence that sex moderates susceptibility to environmental toxicants and concluded that, in most instances, males are more vulnerable. However, their conclusions were based mostly on exposure to lead, methylmercury and organophosphates, with little mention of PCBs that were the focus of the current study.

To understand vulnerability to environmental substances (including PCBs), it is necessary to identify mechanisms that link exposure to the outcome of interest. When vulnerability is sex dimorphic, different pathways for the two sexes must be evident. A review by Davies (2014) suggests that endocrinological pathways may be one mediating mechanism, including the possibility that exogenous factors such as maternal smoking during pregnancy or other toxicants might affect the in utero hormonal milieu which in turn has sex specific influences. This is also consistent with our finding of the sex specific negative role of PCBs, although we are not able to ascertain the timing of the PCB effect. It is not possible to determine from our data if the increased male vulnerability was experienced prenatally, postnatally or during both periods.

Although much remains to be explained in regard to sex differentiated effects of PCBs on attention, it is important to make known our findings (Mergler, 2012). This is a necessary step before any mediating mechanisms of vulnerability can be identified.

4.5. Study design strengths

The current study has several methodological strengths. Care was taken to control for variables originating in both environmental (i.e., SES) and genetic sources (i.e., maternal cognitive level). In fact, according to Cicchetti et al. (2004), it is important to control for parents' IQ when studying attention in order to control for the cognitive contribution to outcome measures including sustained attention. The study also controlled for prenatal factors such as maternal smoking during pregnancy. By using a computerized vigilance test in order to obtain an objective measure of the outcome variables instead of using rating scales which are more subjective, the current study addresses some of the limitations of Newman et al. (2014) study and other studies relying on behavior ratings of ADHD-like behavior (Marks et al., 2010; Neugebauer et al., 2015; Sagiv et al., 2010).

Although measures of prenatal exposure were not available, the participants had been selected to include those born to mothers who may have consumed contaminated fish before advisories at Akwesasne went into place, and who therefore would have transmitted PCBs to their offspring prenatally and perhaps through breastfeeding. As young adults, the participants were likely to have been exposed to ongoing sources of PCBs in their diet and through the environment.

4.6. Limitations and suggestions for future studies

There are some limitations that must be considered. These suggest directions for future research. First, despite the advantage of having available measures of PCB body burden that were taken at the time of the attention measures, outcomes of prenatal exposure to PCBs have more often been studied (Darvill et al., 2000; Fein et al., 1984; Jacobson & Jacobson, 1996; Lai et al., 2002; Verner et al., 2015), specifically in studies using continuous performance tasks (Jacobson & Jacobson, 2003; Stewart et al., 2003a, 2005). Therefore, it is important for future studies to also obtain prenatal PCB exposure levels to investigate effects on the development of sustained attention. Also, some of the information collected (i.e., breastfeeding history, and cigarette smoking while pregnant) was gained by maternal recall and could be biased or inaccurate. Measures recorded during pregnancy would increase

accuracy. Furthermore, in studies of this kind there are many variables having potential impact on children's behavior. Among these are characteristics of the parents that could contribute to the child's outcome scores such as parental attention, impulsivity and ADHD (Davies, 2014), maternal diet (Mill & Petronis, 2008), ingestion of caffeinated drinks (Atik et al., 2017) or substances such as legal and illegal drugs during pregnancy (Johnson et al., 1984), or measures of other toxicants such as methylmercury (Sagiv et al., 2012b).

5. Conclusions

The Akwesasne community is concerned about the impact of environmental pollution on the environment and its people. Their concern has merit because their PCB levels have been related to some negative health and cognitive outcomes (e.g., Newman et al., 2006, 2009; Schell et al., 2004, 2009). The current study adds to this by finding a positive relationship between persistent PCB body burdens and problems with attentional vigilance in males.

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Highlights

- Akwesasne Mohawks are concerned about effects of PCB environmental pollution.
- Attention and impulsivity in young Mohawk adults were measured with Conners CPT.
- Overall, scores were not related to concurrent persistent PCB levels.
- For boys only, higher PCBs were related to poorer sustained attention.

Table 1

Descriptive Data for Conners CPT T-scores

Dependent variables	n	M	SD	Minimum	Maximum
Omission scores	140	47.30	5.36	40.86	69.35
Commission scores	140	53.40	9.94	32.64	79.89
Hit RT SE scores	140	48.19	7.15	33.79	77.41
Hit RT block change scores	140	49.06	7.16	31.91	70.17

Note. T-score mean is 50 and *SD* is 10 in the normative sample.

Table 2

Descriptive Information on the Covariates

Covariates	n	M	SD	Minimum	Maximum	% yes
Young adults						
Age (years)	140	18.11	1.10	16.97	21.36	
BMI (kg/m^2)	135	25.86	4.96	18.01	45.84	
Cholesterol level (mg/dL)	135	314.48	192.11	48.20	1276.10	
Total fat (g/day)	135	87.78	43.57	18.90	300.70	
Total protein (g/day)	135	75.99	35.62	19.30	271.80	
Ravens: RPM	137	54.70	25.51	1.00	99.00	
TOMAL: CMIS	137	101.18	9.73	69.00	123.00	
WJ-R: BCAE	121	101.82	12.31	73.00	135.00	
Computer in household	139					74.10
Video games in household	139					72.66
Toxicants						
HCB (ppb)	140	.04	.01	.01	.09	
p,p´-DDE (ppb)	140	.38	.24	.00	1.61	
Maternal						
WJ-R: BCAS	127	95.46	10.62	72.00	125.00	
Breastfeeding duration (weeks)	138	11.43	19.92	.00	120.00	
Birth order	136	2.38	1.54	1.00	8.00	
Socioeconomic index	140	24.06	6.21	1.00	37.00	
Cigarette use during pregnancy (#/day)	139	3.47	6.86	.00	40.00	

Abbreviations. BMI = body mass index; ppb = parts per billion; Ravens: RPM = Ravens progressive Matrices; TOMAL: CMIS = The Test of Memory and Learning: Composite Memory Index; WJ-R: BCAE = Woodcock Johnson-Revised Tests of Cognitive Ability: Broad Cognitive Ability Extended; WJ-R: BCAS = Woodcock Johnson-Revised Tests of Cognitive Ability Broad Cognitive Ability Standard; SES index includes maternal education, maternal employment, marital status and various assets.

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Table 3

Correlation of Covariates with Conners CPT

Possible covariate	Errors of omission		Errors of commission		Hit RT SE		Hit RT block change	
Young adult measures	**r**	**p**	**r**	**p**	**r**	**p**	**r**	**p**
Age (years)	.02	.78	.20	**.02**	.07	.40	.14	**.11**
Sex (M/F)	.15	**.08**	.09	.32	.18	**.03**	.34	**.00**
BMI (kg/m^2)	.09	.30	-.03	.77	-.03	.77	-.15	**.09**
Cholesterol level (mg/dL) [a]	.03	.73	.07	.43	.02	.79	-.08	.37
Total fat [a]	.04	.65	.07	.39	.02	.82	-.11	**.22**
Total protein [a]	-.01	.95	.07	.43	.00	.97	-.12	**.15**
Ravens: RPM	-.00	.99	.00	.99	-.14	**.15**	.18	**.03**
TOMAL: CMIS	.04	.67	.06	.53	-.19	**.03**	.25	**.00**
WJ-R: BCAE	-.01	.90	.02	.86	-.17	**.07**	.12	.25
Computer in household	-.02	.86	-.21	**.02**	-.09	.28	-.05	.56
Video games in household	-.12	**.16**	-.15	**.08**	-.10	**.23**	-.07	.40
Toxicants								
HCB (ppb) [a]	.04	.67	.02	.80	.01	.94	.04	.66
p,p′-DDE (ppb) [a]	.12	**.15**	.04	.64	.09	.27	.14	**.09**
Maternal measures								
WJ-R: BCAS	.05	.56	.05	.60	-.08	.36	.13	**.16**
Breastfeeding duration [a]	.03	.77	-.05	.60	.05	.59	-.07	.43
Birth order	.04	.68	-.03	.76	-.04	.62	-.12	**.15**
Socioeconomic index	.07	.45	-.07	.42	-.12	**.15**	.02	.84
Cigarette use during pregnancy (#/day)	.20	**.02**	.05	.55	.12	**.17**	-.16	**.05**

Note. CPT outcomes are T-scores and higher scores mean poorer performance.

Abbreviations. BMI = body mass index; ppb = parts per billion; Ravens: RPM = Ravens Progressive Matrices; TOMAL: CMIS = The Test of Memory and Learning: Composite Memory Index; WJ-R: BCAE = Woodcock Johnson-Revised Tests of Cognitive Ability: Broad Cognitive Ability Extended; WJ-R: BCAS = Woodcock Johnson-Revised Tests of Cognitive Ability Broad Cognitive Ability Standard; SES index includes maternal education, maternal employment, marital status and various assets.

Italic denotes variables collected earlier during MAWBS.

[a]Log transformed.

Bold denotes $p < .20$.

Table 4

Regression Analysis for CPT T-Scores and Persistent PCBs

Measures	Unstd. β	SE	Std. β	p	95% CI
Omission scores	1.45	.92	.13	.12	[-.36, 3.26]
Commission scores	1.84	1.80	.09	.31	[-1.72, 5.39]
Hit RT SE scores	.25	1.29	.02	.85	[-2.31, 2.81]
Hit RT block change scores	1.35	1.30	.09	.30	[-1.23, 3.93]

Note. T-score mean is 50 and *SD* is 10 in the normative sample.

Covariates. Omission scores: sex, video games in household, *p,p′*-DDE, and maternal smoking during pregnancy; Commission scores: age, computer, and video games in the household; Hit RT SE scores: sex, Ravens, TOMAL, WJ-R: BCAE, video games in household, SES, and maternal smoking during pregnancy; Hit RT block change scores: age, sex, BMI, total fat, total protein, Ravens, TOMAL, *p,p′*-DDE, maternal cognitive ability, birth order, and maternal smoking during pregnancy.

Table 5

Regression Analysis for CPT T- Scores and Persistent PCBs Split by Sex

Measures	Males					Females				
	Unstd. β	SE	Std. β	P	95% CI	Unstd. β	SE	Std. β	p	95% CI
Omission Scores	3.87	1.35	.36	**.01**	[1.16, 6.59]	-.08	1.20	-.01	.95	[-2.46, 2.31]
Commission Scores	-.54	2.98	-.03	.86	[-6.53, 5.45]	3.74	2.25	.17	.10	[-.74, 8.22]
Hit RT SE scores	2.79	1.87	.25	.14	[-1.00, 6.58]	-.97	1.80	-.06	.59	[-4.56, 2.62}
Hit RT block change scores	2.52	2.03	.21	.22	[-1.59, 6.64]	1.47	1.88	.10	.44	[-2.30, 5.24]

Covariates. Omission scores: video games in household, *p,p′*-DDE, and maternal smoking during pregnancy; Commission scores: age, computer, and video games in the household; Hit RT SE scores: Ravens, TOMAL, WJ-R: BCAE, video games in household, SES, and maternal smoking during pregnancy; Hit RT block change scores: age, BMI, total fat, total protein, Ravens, TOMAL, *p,p′*-DDE, maternal cognitive ability, birth order, and maternal smoking during pregnancy.

Bold denotes $p < .05$.