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## Longitudinal effects of prenatal exposure to air pollutants on self-regulatory capacities and social competence

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### Abstract

**Background**—We evaluated the influence of prenatal exposure to widespread urban air pollutants on the development of self-regulation and social competence in a longitudinal prospective cohort of children born to nonsmoking minority women in New York City.

**Methods**—Air pollutant exposure was estimated categorically by level of polycyclic aromatic hydrocarbon (PAH)-DNA adducts in maternal blood collected at delivery, providing a biomarker of maternal exposure to PAH over a 2–3 month period. DESR was defined as moderate elevations on three specific scales of the Child Behavior Checklist (Anxious/Depressed, Aggressive Behavior, and Attention Problems). We used Generalized Estimating Equations to assess the influence of prenatal exposure to PAH on DESR in children at 3–5, 7, 9 and 11 years of age, adjusted for gender, and race/ethnicity. Next, we assessed the association of prenatal exposure to PAH with social competence, as measured by the Social Responsiveness Scale (SRS), the association of impaired self-regulation with social competence, and whether impairment in self-regulation mediated the association of prenatal exposure to PAH with social competence.

**Results**—We detected a significant interaction (at  $p=.05$ ) of exposure with time, in which the developmental trajectory of self-regulatory capacity was delayed in the exposed children. Multiple

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linear regression revealed a positive association between presence of PAH-DNA adducts and problems with social competence ( $p < 0.04$ ), level of dysregulation and problems with social competence ( $p < 0.0001$ ), and evidence that self-regulation mediates the association of prenatal exposure to PAH with SRS ( $p < 0.0007$ ).

**Conclusions**—These data suggest that prenatal exposure to PAH produces long-lasting effects on self-regulatory capacities across early and middle childhood, and that these deficits point to emerging social problems with real-world consequences for high-risk adolescent behaviors in this minority urban cohort.

### Keywords

Polycyclic aromatic hydrocarbons; self-regulation; prenatal exposure; social competence

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### Introduction

Polycyclic aromatic hydrocarbons (PAH), including benzo[a]pyrene (B[a]P), are neurotoxicant pollutants released during incomplete combustion of fossil fuel, tobacco, and other organic material (Bostrom et al., 2002), found in air and dietary sources. Human exposure to PAH is ubiquitous. Differential siting of outdoor pollution sources in low-income, urban, and minority communities produces striking disparities in exposure levels (Heritage, 1992; Metzger, Delgado, & Herrell, 1995; Olden & Poje, 1995; Pirkle et al., 1996; Wagenknecht, Manolio, Sidney, Burke, & Haley, 1993; Wernette & Nieves, 1992). Exposures to PAH and other environmental pollutants during the prenatal and early postnatal stages are of particular concern for child health and development (Grandjean and Landrigan 2006; National Research Council 1993; Perera et al. 2004). Early exposure may add risk because of the heightened susceptibility of the developing brain to these exposures (Nijland, Ford, & Nathanielsz, 2008; Rodier, 2004). During the fetal period and early childhood years, the brain is rapidly developing and vulnerable to neurotoxic insults that may manifest as adverse outcomes in childhood and adulthood (Shonkoff et al., 2012; Stein, Schettler, Wallinga, & Valenti, 2002). Animal studies of PAH exposure during the prenatal, neonatal, and adult periods have reported a range of neurodevelopmental and behavioral effects (Brown et al., 2007; Wormley, Ramesh, & Hood, 2004), including hyperactivity (Grova et al., 2007; Schellenberger et al., 2013). In humans, a significant dose-response relationship is detected between prenatal PAH exposure and significant reductions in white matter surface in middle childhood (Peterson et al., 2015). Prenatal exposure to PAH is associated with autism (Becerra, Wilhelm, Olsen, Cockburn, & Ritz, 2013; Volk, Hertz-Picciotto, Delwiche, Lurmann, & McConnell, 2011; Volk, Lurmann, Penfold, Hertz-Picciotto, & McConnell, 2013; von Ehrenstein, Aralis, Cockburn, & Ritz, 2014), ADHD (Perera et al., 2014; Perera et al., 2012; Peterson et al., 2015), symptoms of anxiety, depression and inattention (Perera et al., 2014), and externalizing behaviors (Peterson et al., 2015). These disorders all derive at least in part from deficits in self-regulation.

Self-regulation is an important transdiagnostic dimension of behavior. Deficits in self-regulation as measured by cognitive control tasks and alterations in frontostriatal control systems are implicated in many childhood psychopathologies including Attention Deficit Hyperactivity Disorder (Casey et al., 2007; Nigg & Casey, 2005), Obsessive Compulsive