Lead Poisoning and The Bell Curve

Rick Nevin

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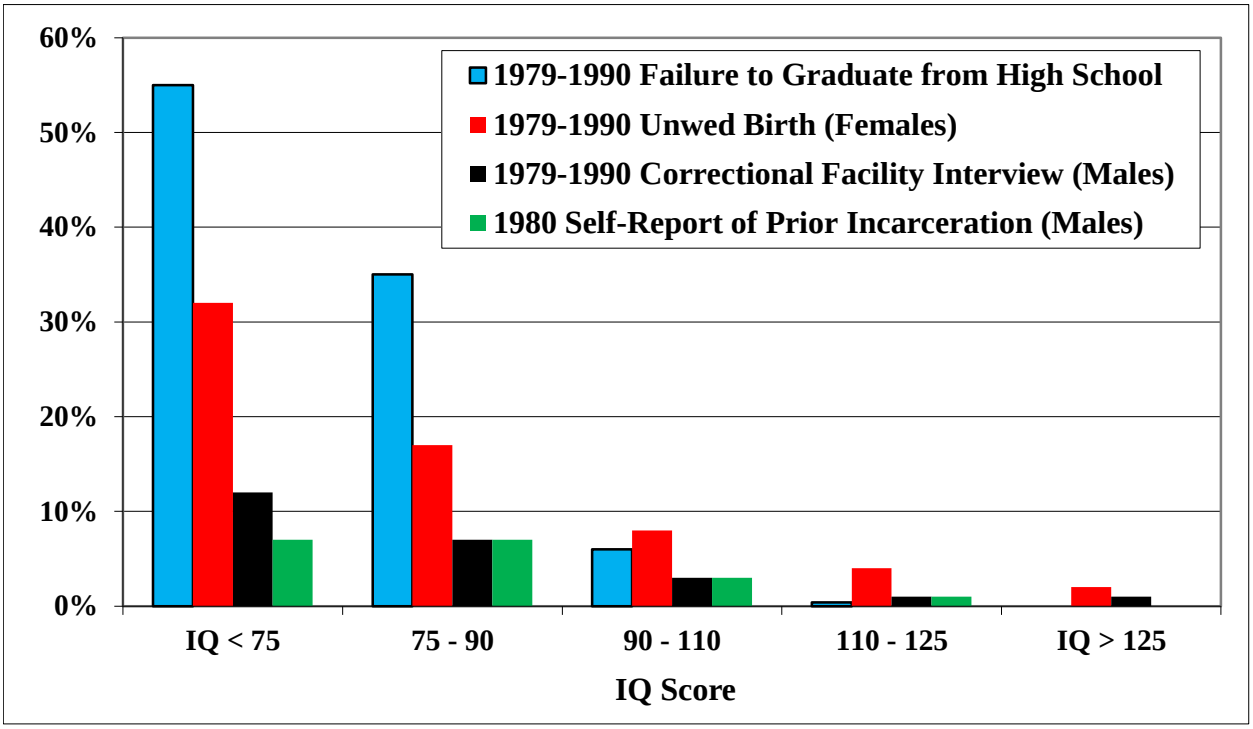
Abstract

A robust environmental health literature demonstrates that preschool lead exposure can cause neurodevelopmental damage and associated adverse impacts on IQ, education, and behavior. Cognitive psychology research also shows an association between IQ and education and behavior risks, but finds that IQ is largely inherited. The impact of lead exposure was barely acknowledged in a fierce debate over IQ after the 1994 publication of *The Bell Curve*, but subsequent research has shown that trends in behavior linked to IQ in *The Bell Curve* have tracked lead exposure trends across decades and around the world. Preschool lead exposure trends continue to predict global crime trends and USA trends in education attainment, mental retardation, and teenage pregnancy. Evidence from temporal analyses and other lead toxicity research suggest a causal relationship between lead exposure and important societal trends. Trends in tooth enamel formed in early childhood also confirm that *The Bell Curve* reflected birth years of extreme variation in lead exposure, resulting in extreme differences in estimated behavior risks associated with IQ. This evidence also presents a new perspective on cognitive research indicating that IQ is inherited.

Lead Poisoning and *The Bell Curve*

The Bell Curve, by Herrnstein and Murray (1994), reviewed research showing that IQ is largely inherited, and examined background and annual interview data from the 1979-1990 National Longitudinal Survey of Youth (NLSY), a representative sample of Americans born in the late-1950s and early-1960s. NLSY participants, ages 14 to 22 in 1979, were given the Armed Forces Qualification Test in 1980. Those scores were converted to the IQ scale, which measures individual IQ relative to the scores recorded by a representative "norm" sample of test-takers. Average IQ of 100, by definition, corresponds to the average norm sample score. A statistical method calculates individual IQ relative to the norm sample score distribution, so 5% of the norm test-takers have IQ below 75, 20% have IQ of 75-90, 50% have IQ of 90-110, 20% have IQ of 110-125, and 5% have IQ above 125. *The Bell Curve* found that white NLSY participants with IQ below 90 had a greater risk of unwed births, incarceration, and failure to get a high school degree, with even higher risks for youths with IQ below 75 (Figure 1).

Figure 1: Behavior Risks by IQ for White Youths Ages 14-22 in 1979[1]



[1] Herrnstein and Murray (1994)

Based on a comparison of NLSY data for white and black youths, Herrnstein and Murray argued that racial differences in academic attainment and undesirable behavior prevalence can be largely explained by racial differences in IQ. The authors did concede that a relationship between inherited IQ and crime could not explain changes in national crime rates over time. Since the 1994 publication of *The Bell Curve*, juvenile offending, unwed teen pregnancy, and dropout rates have all plummeted, with the most dramatic declines recorded by black youths.

In response to controversy over *The Bell Curve*, the American Psychological Association (APA) prepared a report on Intelligence: Knowns and Unknowns. (Neisser et al., 1996) This report states that IQ is positively correlated with education attainment (years of schooling) and achievement test scores (curriculum knowledge). Other research confirms that low IQ is associated with increased risk of impulsive and criminal behavior. (Moffitt, 1993)

The APA report briefly notes that lead exposure has "well-established negative effects on intelligence". Nevin (2000; 2007; 2009) has shown that lead exposure trends explain most of the variation across many decades in USA mental retardation prevalence, unwed pregnancy rates, Scholastic Achievement Test scores, and violent and property crime rate trends in the USA, Canada, Britain, France, Finland, Italy, West Germany Australia, and New Zealand. An analysis of lead in tooth enamel formed in early childhood also shows that USA urban lead exposure peaked around the mid-point of the 1979 NLSY birth years. (Robbins et al. 2010)

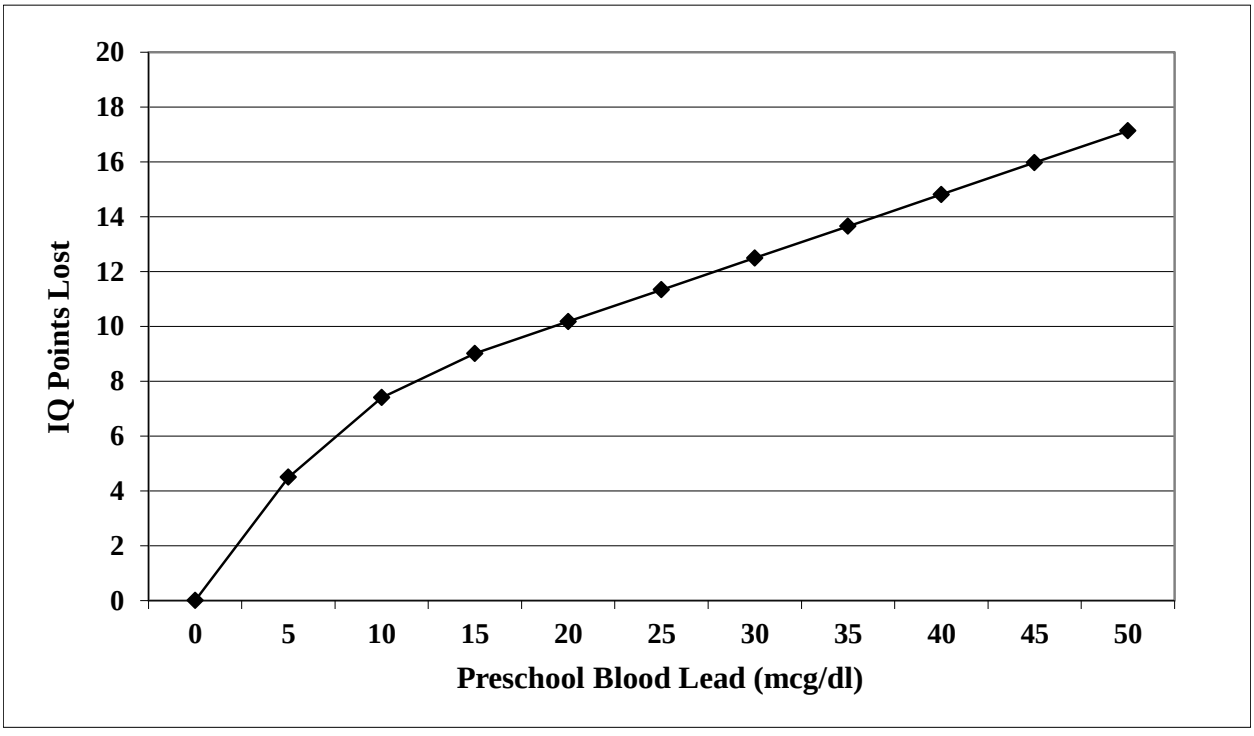
Lead Exposure and Societal Trends: Evidence of Causation

Lead poisoning can be caused by lead paint chip ingestion, air lead inhalation, and other sources, but the most common exposure pathway for children is lead-contaminated house dust ingested via normal hand-to-mouth activity as they crawl. (Lanphear et al. 1998) Ingested lead is absorbed into the bloodstream and carried to the brain where it causes many effects

that establish a basis for expected neurobehavioral damage, and "the unfortunate expectations based on ... lead's toxic effects are fulfilled by the findings from studies of neuropsychological functioning in lead-exposed children". (Lidsky and Schneider, 2003)

An increase in blood lead from 1 to 10 mcg/dl (micrograms of lead per deciliter of blood) is associated with a loss of 7.4 IQ points. (Canfield et al. 2003) Another one-third IQ point is lost per mcg/dl increase from 10 to 15 mcg/dl, and one-quarter IQ point lost per mcg/dl over 15 mcg/dl. (Schwartz 1994) Therefore, blood lead over 20 mcg/dl can lower IQ to less than 90 among children who would have had average IQ of 100, and blood lead over 40 mcg/dl can lower IQ to less than 75 for children who would have had IQ of 90 (Figure 2). When large scale blood lead screening began in many USA cities around 1970, 25% of city children tested had blood lead over 40 mcg/dl. (Gilsinn, 1972) In addition to reducing IQ, preschool lead exposure is directly associated with an increased risk of violent and delinquent behavior. (Denno, 1990; Dietrich et al., 2001; Needleman et al., 1996; 2003; Wright et al., 2008)

Figure 2: IQ Loss Associated with Preschool Blood Lead

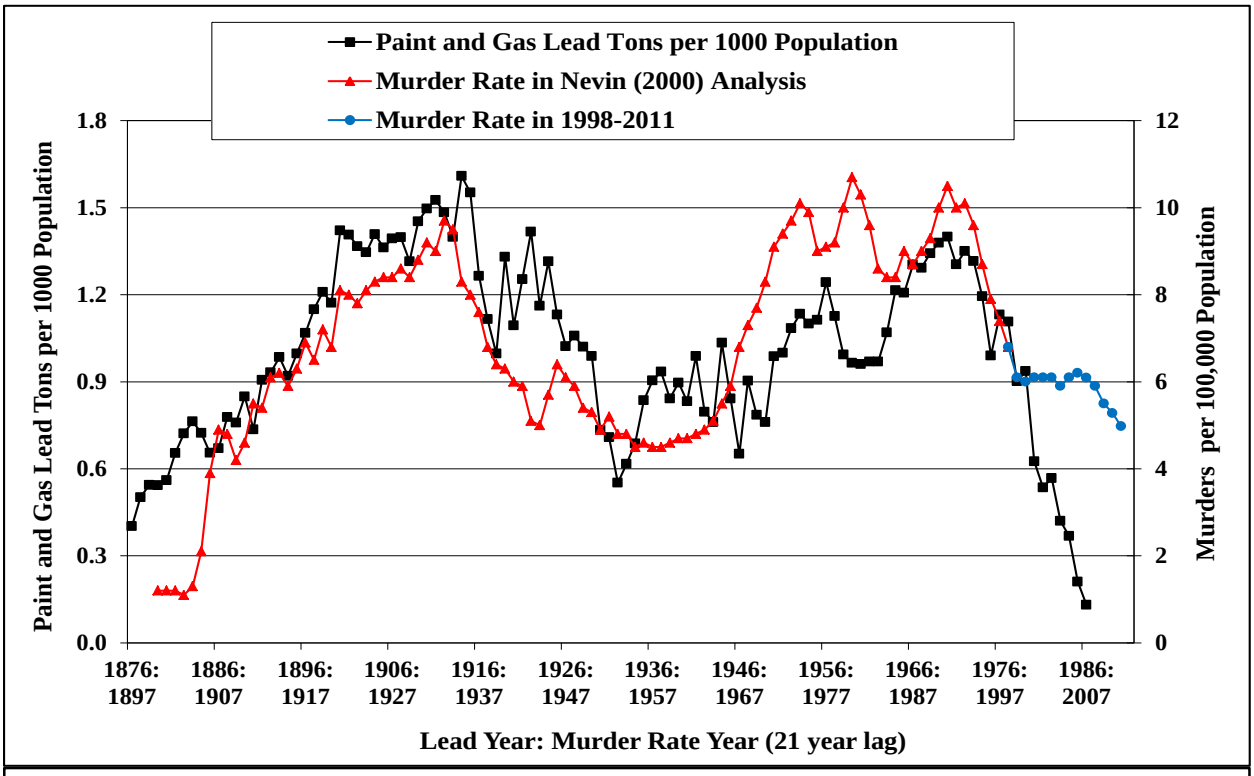


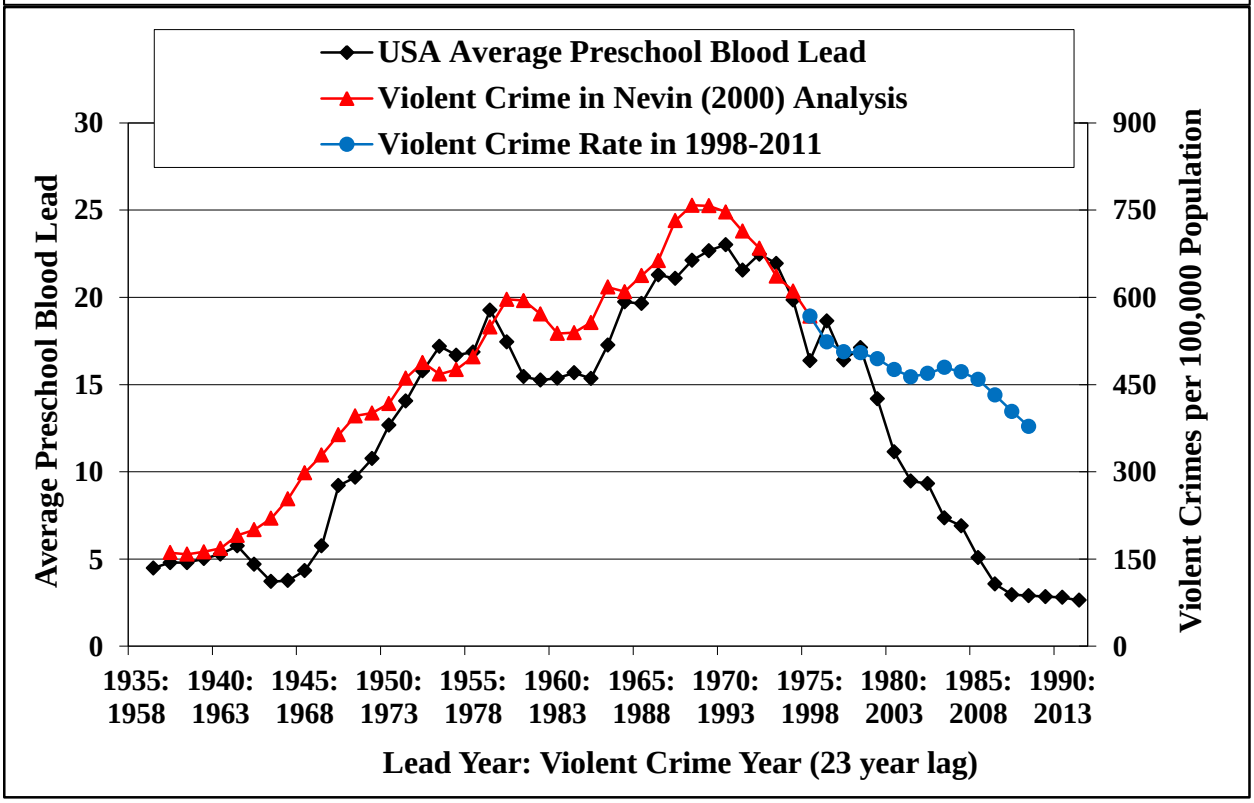
The use of lead in paint and gasoline caused global exposure to lead-contaminated dust over the 20th Century. Lead paint use surged in the 1800s, and heavily-leaded circa-1900 paint deteriorated by "chalking", causing severe lead dust hazards. The leaded share of USA pigments fell from near 100% in 1900 to 35% by the 1930s, but the USA didn't ban lead paint until 1978. From 1935 through the mid-1980s, average USA preschool lead exposure tracked trends in per capita use of lead in gas, as air lead fallout contaminated dust while lead paint exposure changed slowly with changes in the housing stock. Lead paint in older homes is the main cause of USA preschool lead exposure today. (Nevin et al., 2008; Nevin, 2010)

USA murder rates have tracked the rise and fall of per capita use of lead in paint and gasoline, with a 21-year time lag, for over a century (Figure 3). This correlation should not be dismissed as coincidental because the evidence from temporal analyses, in the context of the broader lead toxicity literature, presents compelling evidence of the indicators of causation identified by Bradford Hill (1965), now widely-accepted in public health research.

The ***Biological Plausibility*** of lead-induced cognitive and neurobehavioral impairment is established by neurochemical, subcellular, and cellular effects of lead exposure in animal and human studies. (Banks et al., 1997) Neurodevelopmental effects include a reduction in gray matter (neuron cell bodies) in the frontal lobe, the seat of impulse control (Cecil et al. 2008), and the destruction of myelin sheaths and decreased activity of an enzyme needed for myelin synthesis. Myelin insulates and thickens the white matter connections between neuron cell bodies, affecting the speed of neuronal signals, allowing the brain to work more in concert. Brain scan studies (Sowell et al. 1999; Bartzokis et al. 2001) suggest that impulsive behavior in all youths could be affected by a gray matter growth surge in the early-teens, followed by rapid white matter growth through the 20s, and ongoing white matter growth to age 50.

Figure 3: USA Lead exposure and Murder and Violent Crime Rate Trends[2]





[2] Nevin (2000); U.S. Centers for Disease Control and Prevention, 2011a; U.S. Department of Justice, 2011a; 2011b (2011 crime rate trend based on six-month data)

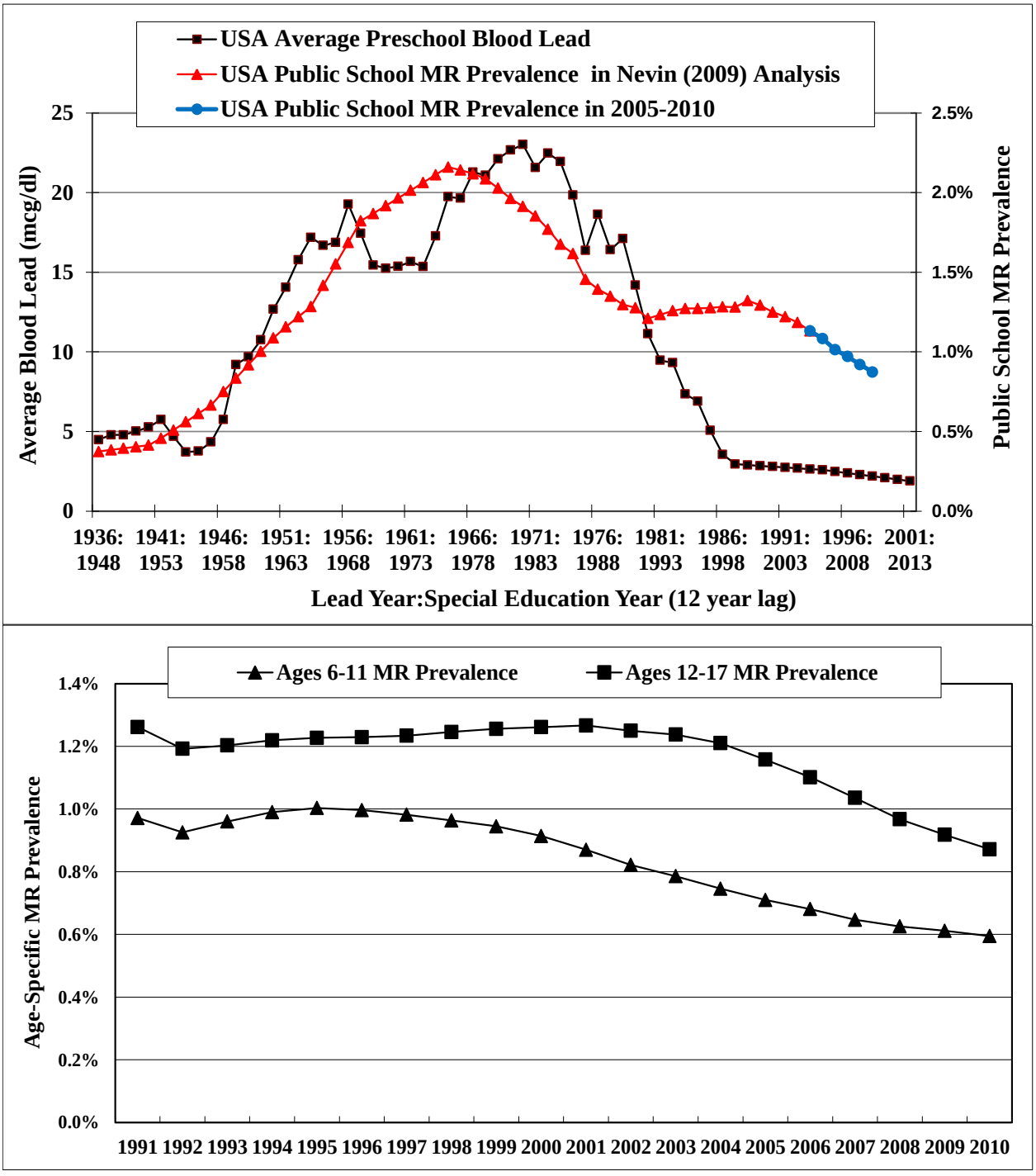
Brain growth parallels age-related property crime offending that surges in the early-teens, peaks in late-adolescence, and falls sharply by age 30, and violent offending that peaks in the early-20s and declines through age 50. These age-related offending patterns are not explained by IQ because individual IQ is relatively stable after adolescence. If white matter growth reduces impulsive behavior, then lead-induced myelin impairment could cause more common and severe behavior problems, especially among youths, and the association between low IQ and criminal behavior could be caused by separate neurodevelopmental effects of lead.

The ***Strength*** of the relationship between lead exposure trends and trends in Scholastic Achievement Test (SAT) scores, mental retardation (MR), and unwed pregnancy and crime is evident in the statistical significance of lead exposure in regression analyses and in the very high percent of variation in education and behavior trends explained by lead exposure. USA blood lead trends explain 65% of the 1953-2003 variation in average SAT math scores, 45% of variation in SAT verbal scores, and 65% of 1948-2001 variation in MR prevalence. USA blood lead trends also explain 58% of the 1972-1996 variation in the pregnancy rate for girls under age 15, and the combined impact of abortion legalization and blood lead trends explains 96% of 1955-1996 variation in unwed pregnancy rates for ages 15 to 17, and 94% of the 1955-1996 variation for ages 18 and 19. International blood lead trends explain: 63% to 93% of variation in index crime rates (violent plus property crime) over several decades in every one of nine nations examined; 91% to 93% of variation in aggravated assault rates in the USA and Britain; 84% to 90% of variation in rape rates in the USA and Britain; 70% to 89% of variation in robbery rates in the USA, Britain, Canada, West Germany, New Zealand, and Australia; and 65% to 91% of variation in burglary rates in the USA, Britain, Canada, Australia, West Germany, New Zealand, and France.

The ***Consistency*** of the relationship between lead exposure and crime trends *within* each nation explains otherwise bewildering divergences in crime rates across nations over time. In 1980, the USA index crime rate was 22% higher than the rate in France and 40% higher than Australia's rate, but the 2001 USA index crime rate was 39% below the French rate and 45% below Australia's rate. Canada's index crime rate was 60% higher than the rate in Britain in the early-1970s, but 20% lower in 2001. In 1974, the USA burglary rate was 50% higher than the rate in Britain and twice the rate in Australia, but the 2002 USA burglary rate was less than half the rates in Britain and Australia. The Canadian robbery rate was five times the rate in Britain in 1962, but the 2002 Canadian robbery rate was less than half the rate in Britain. The 1960 USA aggravated assault rate was almost three times the rate in Britain, but the 2002 USA rate was half the rate in Britain. Crime in the USA and Canada rose and fell earlier than in other nations because gasoline lead exposure rose and fell earlier in the USA and Canada.

Temporal Precedence requires, at a minimum, that a suspected cause precede the effect. The statistical best-fit time lags that relate lead exposure and societal trends present especially compelling evidence, linking every outcome to neurodevelopment in the first year of life: A 12-year time lag for ages 6-18 mental retardation; A 17-year lag for SAT scores; A 15-year lag for under-age-15 pregnancy; A 17-year lag for age 15-17 unwed pregnancy; An 18-year lag for burglary; A 23-year lag for violent crime; A 19-year lag for overall index crimes that are about 90% property crimes and 10% violent crimes. ***Temporal Precedence*** is also evident in peak MR prevalence shifting to older students (Figure 4), peak arrest rates shifting to older offenders, and peak age-specific unwed birth and abortion rates shifting to older women, as the years of peak preschool lead exposure recede into the past.

Figure 4: USA Preschool Blood Lead and Mental Retardation (MR) Trends[3]



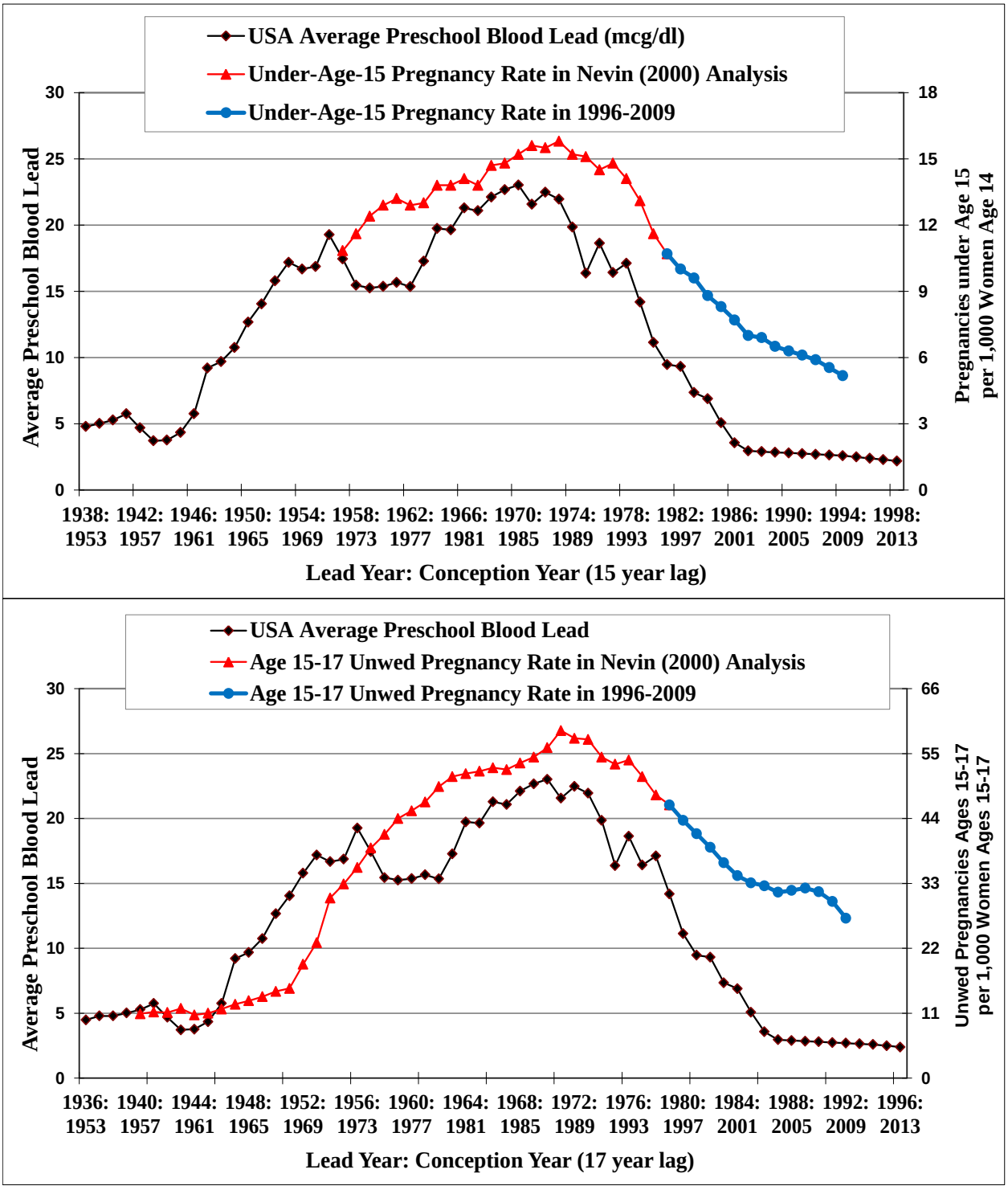
[3] Nevin (2009); U.S. Department of Education, 2011; 2008-2011: MR prevalence increased slightly from 1992 to 2000, as public schools switched from the 1974 WISC-R IQ test to the 1991 WISC-III. The WISC III was based on a norm sample of children born as lead exposure declined in the 1970s and 1980s. Students with mild MR (IQ above 55) who took both tests recorded IQ that averaged 5.6 points lower on the WISC-III than on the WISC-R. (Kanaya et al., 2003) As a result, more students have WISC-III IQ scores associated with MR, when many of those students would have WISC-R scores above the threshold associated with MR. The impact on MR prevalence due to this change in IQ tests dissipated after 2000 (when the WISC III had been in use for almost a decade).

With respect to ***Experimental Evidence***, Bradford Hill states that "the strongest support for the causation hypothesis may be revealed" when preventive action is taken and it does in fact prevent. Regulatory actions to phase out leaded gasoline and reduce lead paint hazards anticipated societal benefits from education attainment gains associated with higher IQ. That promise has been fulfilled by large gains in high school completion and college enrollment rates associated with birth years of declining preschool lead exposure, after decades devoid of national academic attainment progress across birth years of gasoline lead exposure. National blood lead trends also continue to forecast trends in USA teenage pregnancy and international crime rates with remarkable accuracy (Figures 5 and 6).

A ***Dose-Response*** relationship between preschool blood lead and IQ later in life is clearly established. Temporal analyses show a corresponding population-dose-response relationship between preschool blood lead trends and population MR prevalence, crime, and unwed teen pregnancy rates. Average USA preschool blood lead rose by almost 500% from the 1930s through the 1960s. MR prevalence then rose by 500% with a 12-year lag; age-15-17 unwed teen pregnancy rates rose by 500% with a 17-year lag; the Index crime rate rose by 500% with a 19-year lag; and the violent crime rate rose by 500% with a 23-year lag.

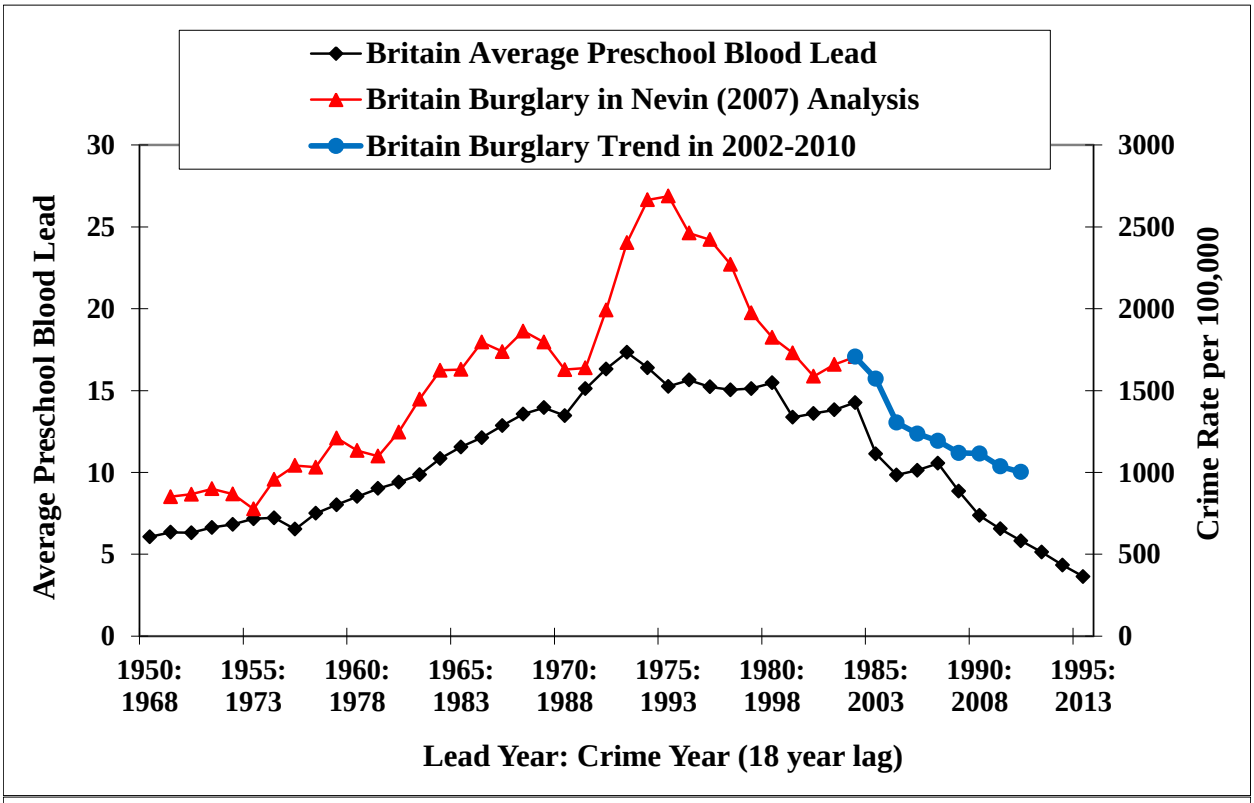
The ***Specificity*** indicator of causation might seem to be lacking in light of the diverse societal impacts of preschool lead exposure, but rising MR prevalence, falling SAT scores, stagnant or falling education attainment, and rising crime and unwed teen pregnancy rates are all manifestations of the same specific outcome of lead-induced neurodevelopmental damage.

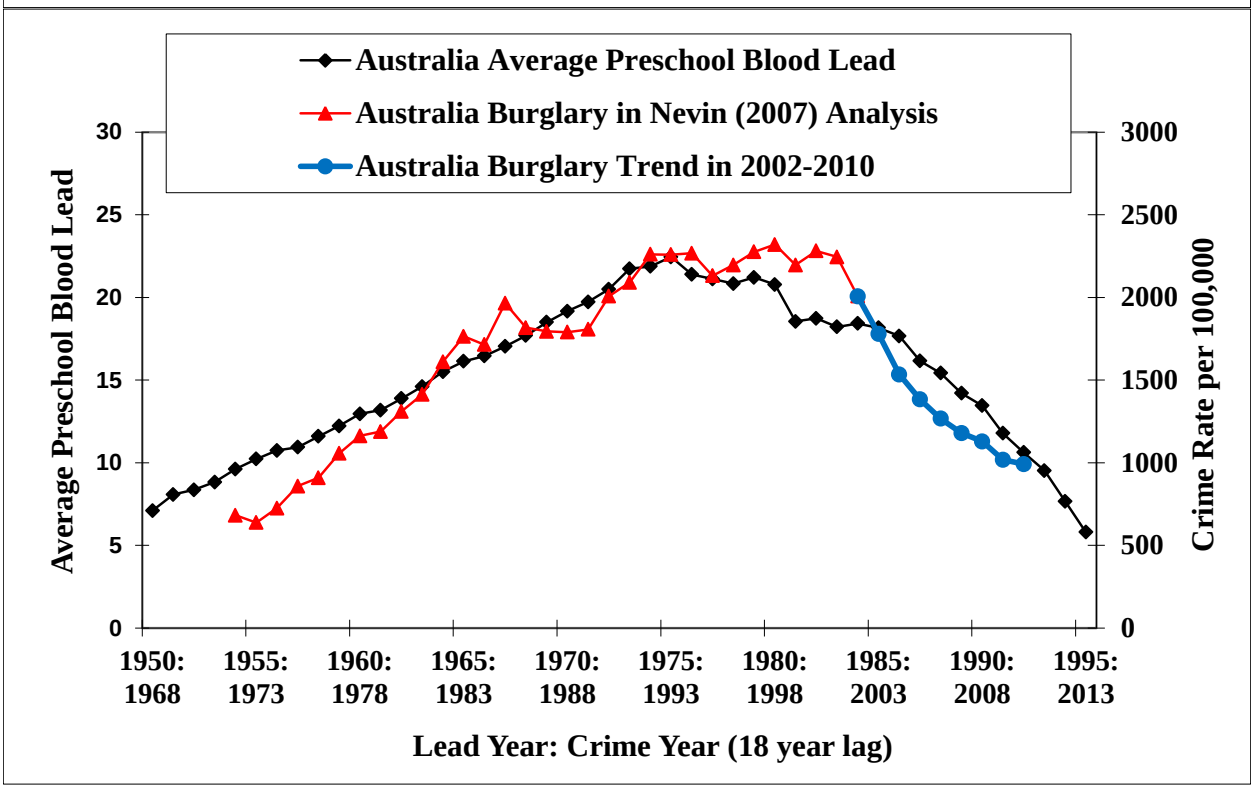
Figure 5: USA Preschool Blood Lead and Teenage Pregnancy Trends[4]



[4] Alan Guttmacher Institute, 2010; U.S. Centers for Disease Control and Prevention, 2011b; 2011c: Teen pregnancy rates shown reflect age-specific abortion rate for each year plus the corresponding birth rate for the following year, to approximate the pregnancy rate associated with year of conception. Trend shown for 2009 is based on 2010 USA birth data and 2009 teen abortion rate trends for Texas, Pennsylvania, Illinois, Ohio, Minnesota, and New York.

Figure 6: Australia and Britain Preschool Blood Lead and Burglary Trends[5]





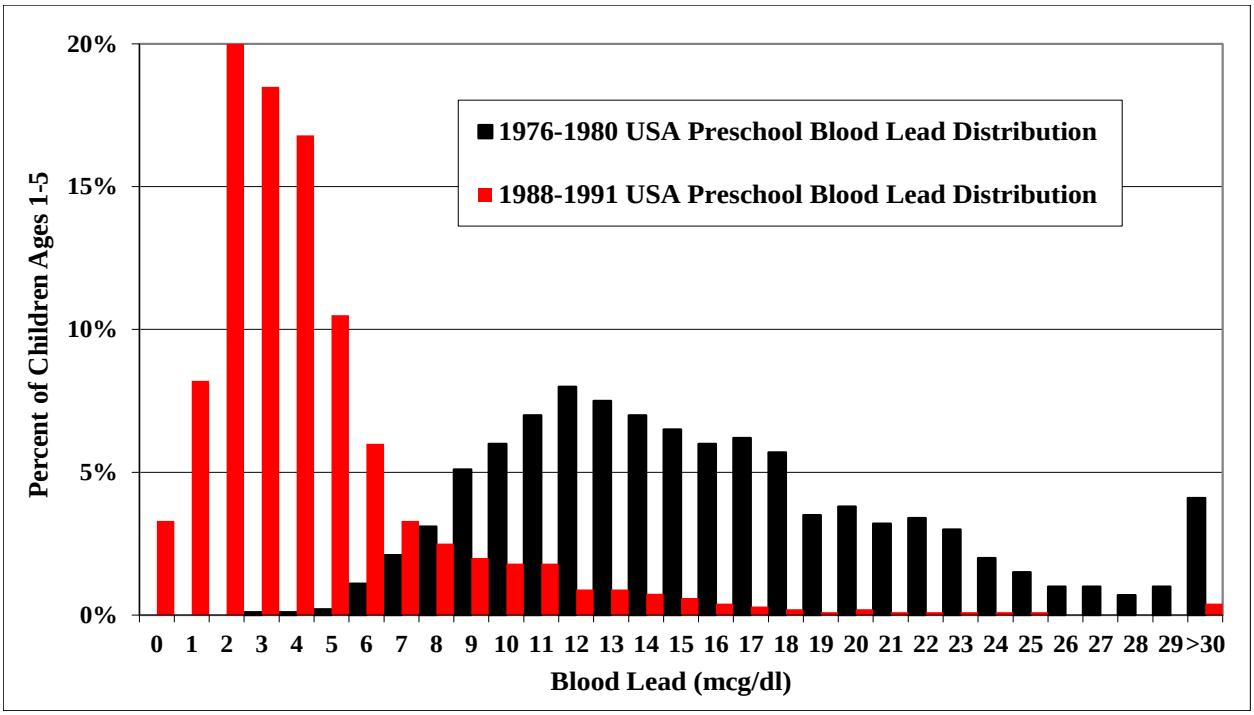
[5] Australian Bureau of Statistics, 2010; 2011; U.K. Home Office, 2011

With respect to ***Coherence***, Bradford Hill states that a causal interpretation "should not seriously conflict with the generally known facts of the natural history and biology of the disease". This principle is inadequately addressed by *The Bell Curve* interpretation of NLSY data, concluding that inherited IQ is an important *causal* factor in criminal offending, when that interpretation is not coherent with national crime trends. Ironically, evidence that lead exposure affects so many interrelated societal trends can incite disbelief that any one factor could cause so many effects, but that coherence *is evidence of causation*.

The Bell Curve behind *The Bell Curve*

The Second National Health and Nutrition Examination Survey (NHANES II), from 1976 to 1980, provided the first representative data on the USA preschool blood lead distribution. NHANES III data, from 1988-1991, showed that the phase out of leaded gasoline shifted the preschool blood lead distribution to lower levels, concentrated in a narrower range (Figure 7).

Figure 7: Shift in USA Preschool Blood Lead Distribution: 1976-1980 vs. 1988-1991[6]



[6] Pirkle et al., 1994

NHANES II revealed another bell curve that was the mirror image of the IQ bell curve with respect to income and race: Poor children and black children are more likely to be at the high end of the blood lead bell curve and at the low end of the IQ bell curve. Poor children have higher blood lead because they are more likely to live in older housing with deteriorated lead paint and with lead paint on windows that create lead-contaminated dust (Jacobs et al., 2002; Nevin and Jacobs, 2006). Black children regardless of income are more likely to live in older housing, and had more gas lead exposure because they were concentrated in cities where traffic increased air lead and caused more severe lead dust hazards. From 1950-1970, many children suffered additive exposure to city air lead and lead paint in deteriorated slum housing that was built around 1900, when the use of heavily leaded interior paint was common. When MR prevalence peaked in the 1970s, the mildly retarded (IQ over 55) accounted for 75% to 80% of MR students, with most cases due to unknown cause, and high prevalence among "low income groups - who often live in slums" (National Research Council, 1982).

Nevin (2007) derived preschool blood lead trends across several decades in nine nations by combining available blood lead data with trends in per capita gasoline lead exposure, citing evidence that national trends in blood lead and leaded gas use were very highly correlated. Those national blood lead trends reflect a temporal shift in the entire blood lead distribution, encompassing a rise and fall in marginally higher blood lead associated with marginally lower IQ, academic achievement and attainment, and juvenile property crime offending, and a rise and fall in severe lead poisoning more associated with MR and violent offending.

The dose-response relationship between preschool blood lead and IQ means that the wider NHANES II blood lead distribution would have profoundly affected any IQ norm sample based on test-takers born in the mid-1970s. By comparison, the much narrower NHANES III

distribution would have caused much less variation in lead-induced cognitive losses for an IQ norm based on test-takers born in the mid-1980s, but ***the statistical method used to calculate IQ from a norm sample obscures this impact of the preschool blood lead bell curve***. By definition, 5% of ***every*** IQ norm sample has IQ below 75, 20% of those test-takers have IQ of 75-90, 50% have IQ of 90-110, 20% have IQ of 110-125, and 5% have IQ above 125.

The APA report cited studies showing IQ is largely inherited, but also noted that some sort of "environmental" influence was evident in a racial convergence in National Assessment of Educational Progress (NAEP) scores. The racial difference in average NAEP scores narrowed at different times for ages 9, 13, and 17, but black gains at each age are traced to changes over the same 1962-1973 birth years. Nevin (2007; 2009) has linked those same birth years to narrowing racial differences in SAT scores, MR prevalence, and juvenile burglary arrest rates, and linked all of these trends to a racial convergence in lead exposure over the 1960s. African-Americans occupied 56% of substandard city housing in 1960, as white children were increasingly concentrated in suburbs with far less gasoline lead exposure, in new homes with little or no lead paint. As urban sprawl spread more lead emissions to suburbs over the 1960s, African-Americans were disproportionately displaced by city slum clearance programs. Those trends suggest that lead exposure among black children, and the average racial difference in preschool lead exposure, likely peaked around 1960.

A study of lead concentrations preserved in tooth enamel formed from 1936 to 1993 in Cleveland has now confirmed that average preschool lead exposure peaked around 1960 in this largely black urban population. This peak in urban tooth lead, a decade before the peak in USA gas lead emissions, is consistent with a peak in lead poisoning prevalence before slum demolition removed many dilapidated housing units with severe lead paint hazards during the

1960s. Across the entire span of birth years from 1936 to 1993, this study also confirms a very high correlation between tooth lead and gasoline lead trends, and confirms the same order-of-magnitude temporal variation in lead exposure derived from USA gasoline lead trends: The circa-1960 peak in average tooth lead was about 500% higher than average tooth lead in 1936–1950 and in 1986–1993.

The Bell Curve controlled for race by first examining the relationship between IQ and behavior among white youths, but did not control for the wide variation in the white preschool blood lead distribution during NLSY birth years of the late-1950s and early-1960s. In 1960, 51% of blacks and 30% of whites lived in central cities, and the fact that blacks occupied 56% of substandard city housing means that whites still occupied almost half of 1960 substandard city housing. Most white children born in those years lived in new suburban homes, but many other white children still suffered additive exposure to lead paint hazards and urban air lead. The extremely wide variation in the white preschool blood lead distribution during birth years of the 1979 NLSY was the root cause of the wide variation in incarceration, unwed birth, and high school dropout rates attributed to inherited IQ.

Inherited IQ and an Unobserved Confounder

The APA report notes that an "environmental" influence on IQ is also evident in Flynn's research showing global 20th Century IQ gains. IQ of 100 is "redefined" as the average score on every new IQ test, based on the norm sample for that test, but new norm samples also take an older test so "norm comparisons" can verify that individual IQ is similar on both tests (to validate new tests). Individual IQ is similar on old and new tests, but Flynn discovered that almost every new norm sample has average IQ above 100 on older IQ tests, indicating gains in average IQ. By linking norm comparisons over time, he shows global gains of seven IQ

points per decade on spatial visualization and figure similarity tests, and smaller gains on number series and verbal tests more affected by education.

Nevin (2000) has shown that Flynn reports IQ gains in many nations that are relatively rapid across birth years of declining lead paint exposure in the first half of the 20th Century, followed by IQ gains that slowed or stopped across birth years when rising gasoline lead use offset ongoing declines in lead paint exposure. That pattern does not appear in USA data because many USA IQ norms span a wide range of birth years (e.g., adults age 16-48), and because Flynn's USA data are for white IQ only (to incorporate early IQ norms that included only whites). Blacks were increasingly concentrated in cities as air lead increased, as white children were increasingly born in suburbs with far less gas or paint lead exposure, muting the impact of gasoline lead on long-term trends in average white IQ.

While acknowledging some evidence of environmental influence on IQ, the APA report cited extensive evidence that IQ is inherited, based on studies showing the IQ correlation for adopted siblings raised in the same family is lower than the correlation for genetic siblings separated by adoption. Genetic siblings raised apart did not share the same socioeconomic environment through childhood, but even identical twins separated at birth shared the same maternal blood lead exposure, and many genetic siblings separated by adoption after the age of nine months shared the same exposure to lead contaminated dust as they learned to crawl.

Despite the extensive cognitive research showing that IQ is inherited, the APA report also notes that a genetic explanation for racial differences in IQ implies that African-Americans with lighter skin and more Caucasian heritage should have higher IQ than those with darker skin, but this is not the case. The known history of preschool lead exposure suggests that IQ could be unrelated to fractional Caucasian heritage because the "one-drop" rule of racial

discrimination restricted African-Americans of any shading to cities with severe air lead exposure and neighborhoods with older housing with lead paint.

The pioneers of research showing that lead exposure impairs IQ often faced skeptical questions about whether this was a coincidental correlation resulting from inadequate study controls for confounding by parental IQ, education, income, and other confounders associated with inherited IQ. The extensive research on this subject has now definitively shown the adverse impact of preschool lead exposure on IQ *after* controlling for confounders. In light of that evidence, and the history of global lead paint exposure predating the earliest IQ tests, and the strong, consistent, coherent, ongoing, dose-response relationship between lead exposure trends and subsequent trends in important IQ-correlates, it is now reasonable to ask: Could the cognitive research literature on inherited IQ reflect a coincidental correlation resulting from inadequate study controls for confounding by preschool lead exposure?

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