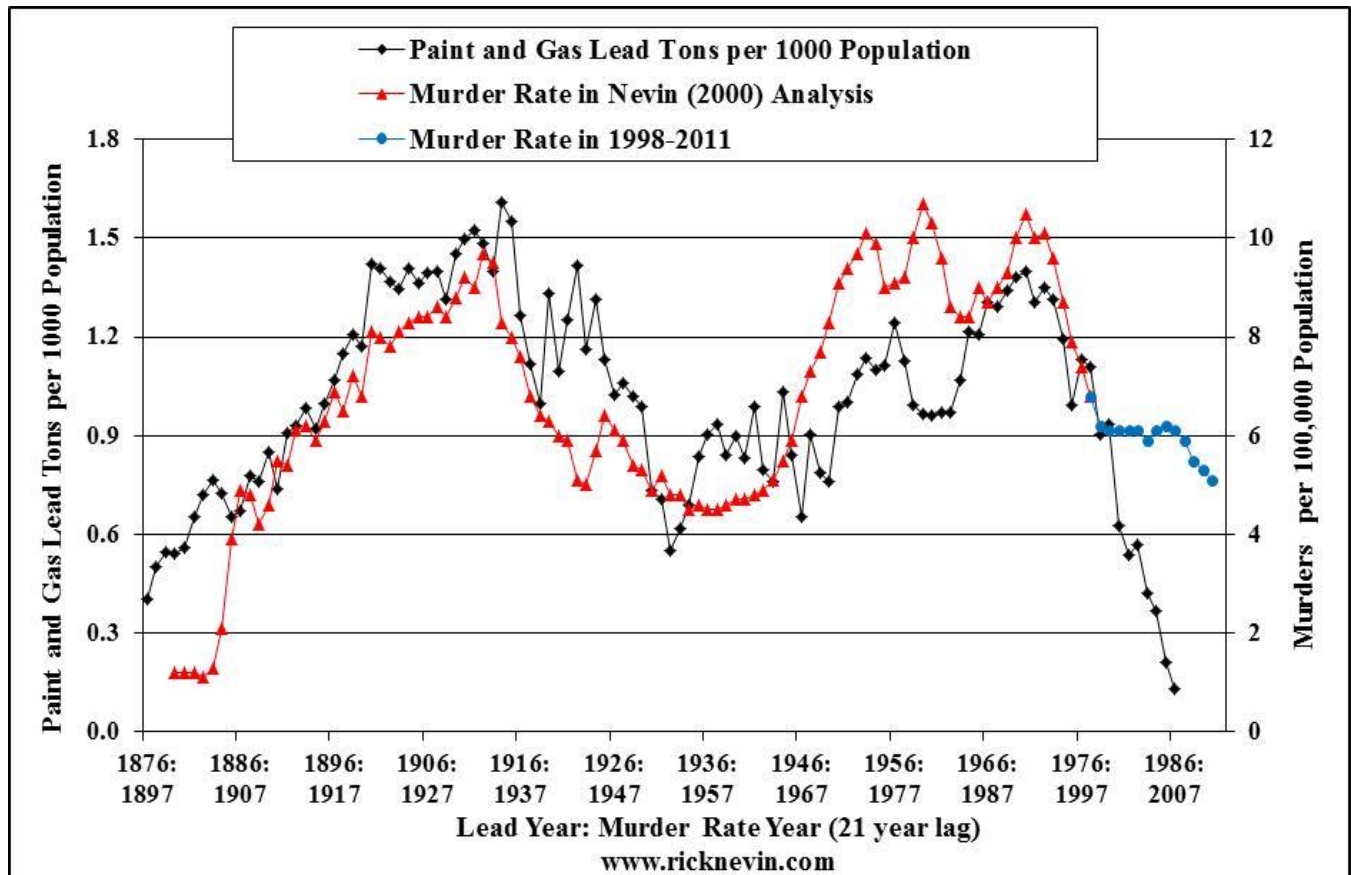# The Answer is Lead Poisoning

Lead poisoning can be caused by lead paint chip ingestion, air lead inhalation, and many other sources, but the most common exposure pathway for children is ingestion of lead-contaminated household dust via normal hand-to-mouth activity as they crawl. Ingested lead is absorbed into the bloodstream and carried to the brain where lead causes many types of developmental damage.

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 to 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.

Lead Poisoning and Homicide

Nevin (2000) showed that nationwide USA murder rates from 1900 to 1998 tracked the rise and fall (and rise and fall) of per capita use of lead in paint and gasoline from 1879 to 1986, with preschool lead exposure trends affecting the murder rate with a 21-year time lag. In 2011, the USA murder rate fell to a 47-year low.

Lead Year: Murder Rate Year (21 year lag)
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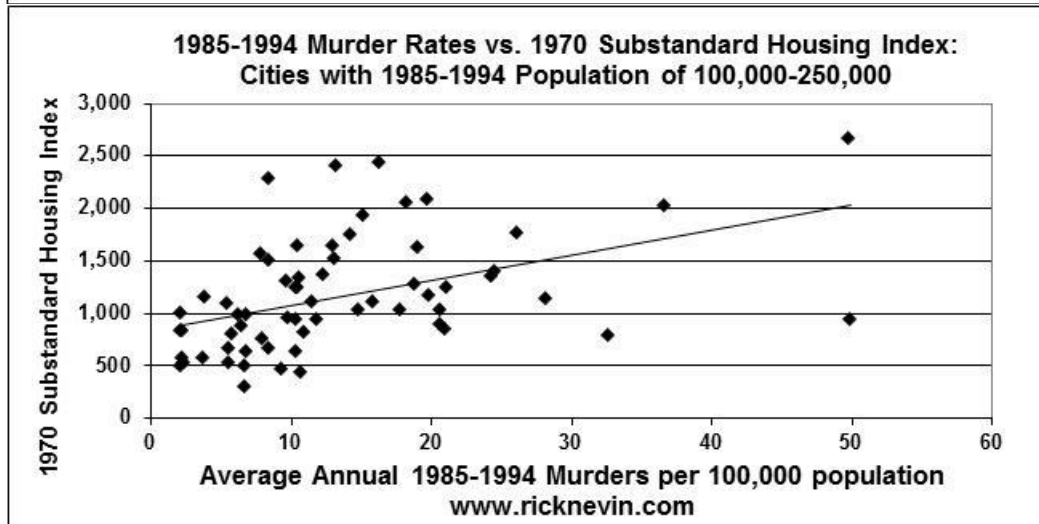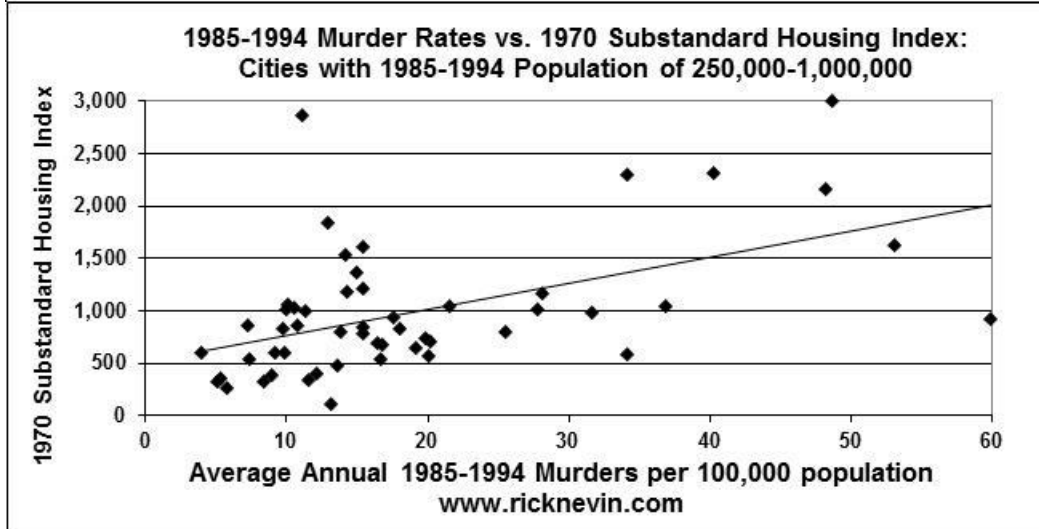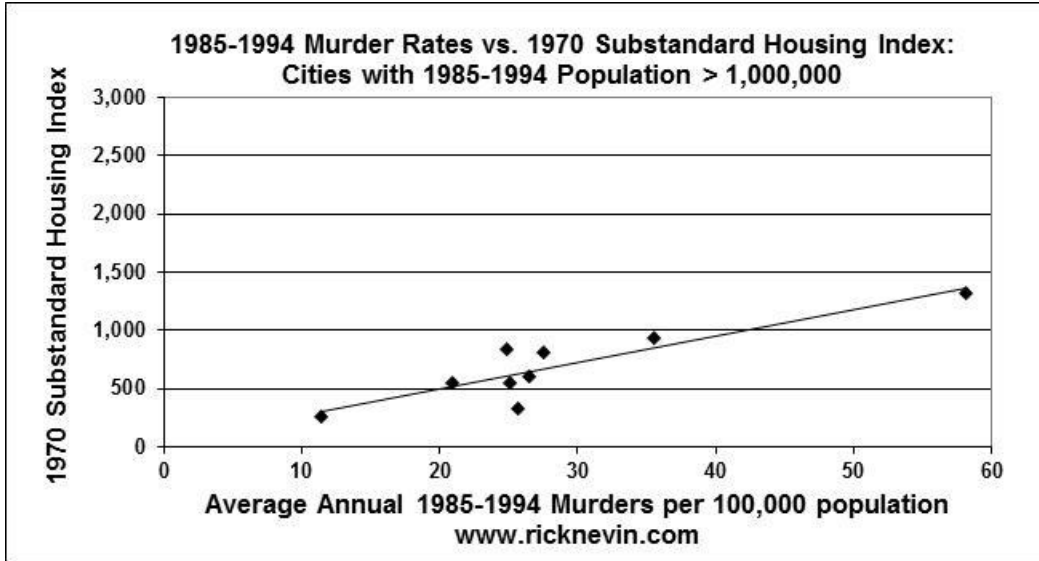
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Atmospheric emissions from gas lead affected blood lead even in rural areas, but traffic caused severe city exposure because 55% of emissions settled within 12 miles of the roadway. Cities with population over a million had 1960s ambient air lead that was twice as high as in cities with population of 250,000 to a million. Cities with population over a million then had an average homicide rate from 1985-1994 that was 57% higher than in cities of 250,000 to a million. The 1980s phase-out of leaded gas left little air lead difference by city size, and cities with population over a million had an average 2000-2005 homicide rate that was 3% lower than in cities of 250,000 to a million. (Fox & Zawitz, 2007)

Homicide offending rates for cities over 100,000 population, 1976-2005
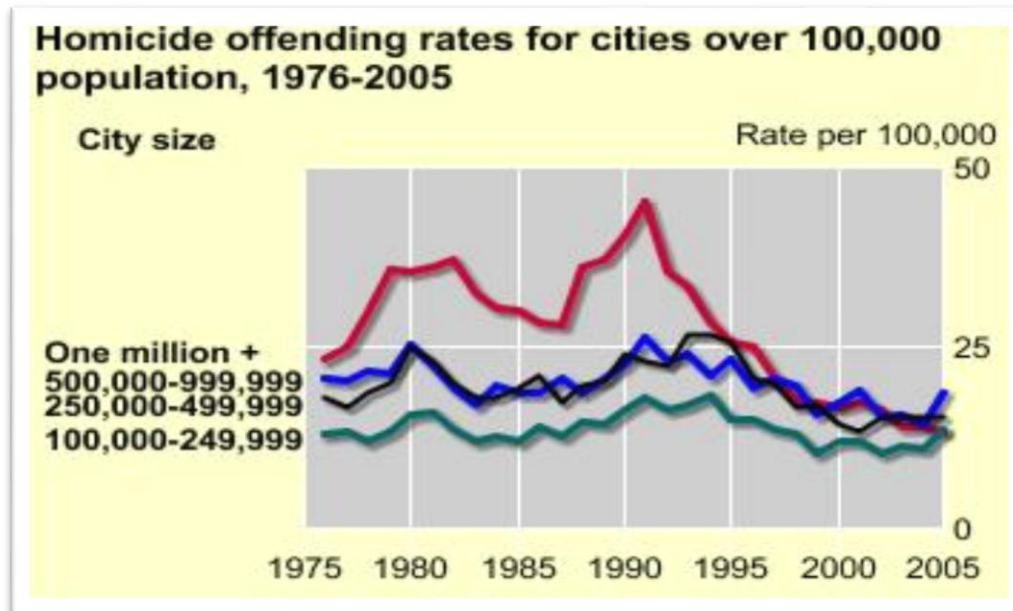
From 1950-1970, many children suffered severe lead poisoning from additive exposure to city air lead and lead paint in slum housing. Most 1950-1970 substandard (deteriorated and dilapidated) city housing was built around 1900 when use of heavily leaded interior paint was common. Extensive paint deterioration in slum housing contaminated dust with lead from circa-1900 paint, and paint chip ingestion caused severe lead poisoning in many children. Slum demolition reduced lead paint hazards over the 1960s, but the percent of children living in substandard housing still explained most of the 1970 census tract variation in city children with severe lead poisoning, because severe poisoning was especially common among children with additive exposure to urban air lead and lead paint hazards.

Nevin (2007) showed that variations in substandard housing prevalence also explained a large part of the variation in average 1985-1994 city murder rates that was not explained by higher air lead levels associated with city size. In cities with population over a million, for example, Detroit had an exceptionally high percent of housing that was substandard in 1970, and an exceptionally high murder rate in 1985-1994. San Diego had an exceptionally low percent of 1970 housing that was substandard, and an exceptionally low 1985-1994 murder rate for such a large city. Scatter plots show the same trend line relationship between 1970 substandard housing and the variation in average 1985-1994 murder rates across cities with population of 250,000 to 1 million, and for cities with population of 100,000 to 250,000.

The Answer is Lead Poisoning

The Answer is Lead Poisoning

High-Rise Housing, Highways, and Homicides

Urban renewal slum demolition programs in the 1950s and 1960s were often criticized for giving insufficient thought to how displaced slum residents could find other affordable housing. Still, one profound benefit of urban renewal was the eradication of severe lead paint hazards in dilapidated housing with heavily-leaded circa-1900 paint. Ironically, one deadly legacy of urban renewal was the effort to provide new affordable apartments for displaced slum residents, in high rise public housing located beside highways built on slum clearance land. An early and deadly example of this tragedy was the 1950s demolition of slum housing on Chicago's South Side, followed by the 1962 opening of both the Robert Taylor Homes housing project and the adjacent Dan Ryan expressway.

The near fallout from leaded gasoline caused higher air lead in larger cities with more traffic, *and* caused especially high air lead and severe lead dust hazards in areas near major highways, because about 10% of lead emissions settled within 100 meters of the roadway. In the 1960s, ambient air lead in Chicago was 33% higher than in Cincinnati, but air lead measured along Cincinnati "streets loaded heavily" with traffic was about 1500% higher than Cincinnati's ambient air lead. The long narrow Robert Taylor Homes project was all within about 400 meters of the 16-lane Dan Ryan expressway. The air lead along Cincinnati "streets loaded heavily" with traffic specifically referred to 2150 cars per hour, and that traffic would have to continue for 24 hours to reach 51,600 cars per day. Traffic on the Dan Ryan was 150,000 vehicles per day in 1963 (and close to 300,000 per day by 2002). That 1963 traffic produced air lead and lead-contaminated dust hazards with murderous consequences by 1980, when Robert Taylor Homes accounted for 0.5% of Chicago's population, and 11% of all Chicago murders.

An influx of African Americans moving to Chicago during and after World War II, combined with legal covenants restricting blacks to housing in certain neighborhoods, led to overcrowding in increasingly deteriorated slums. Urban renewal demolished thousands of homes, replaced (in part) by high-rise public housing like Robert Taylor Homes. Venkatesh documented the history of Robert Taylor Homes in *American Project*. Hoffman highlighted some of his findings in an article entitled "High-Rise Hellholes":

> When it opened in November 1962, Robert Taylor Homes was the world's largest public housing project. ... By 1965 it was home to 27,000 souls, 20,000 of them children and young people ...

> ... Early on, about half the households received some form of assistance; but two-thirds of the households were two-parent families ...

> ... By 1992 only 12,300 people lived in Robert Taylor Homes legally, and of these an incredible 95 percent were unemployed and dependent on welfare. The city authorities gave up. When Congress appropriated billions for demolition of public housing, Chicago signed up to raze Robert Taylor Homes and its other high-rise housing projects. ...

> ... The site of Robert Taylor Homes, near railroad tracks and expressways, was a terrible place to put children. Yet, as Venkatesh makes clear, Robert Taylor in its early years functioned pretty much as it was intended.

The reason why Robert Taylor Homes functioned as intended in its early years was because neurodevelopmental damage done to children born and raised beside major highways was not evident until those children reached adolescence.

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Hagedorn has concluded that "expressways and housing projects concentrated Chicago homicides in Black areas." He maps local murder rates against expressways in 1965, presented beside a picture of Robert Taylor Homes looming over the Dan Ryan, and states: "overcrowding, poverty, and segregation of Chicago's Black community contributed to escalating rates of homicide".

The concentration of 1965 homicides near major expressways on the south and west sides of Chicago can also be linked to lead paint in late-1940s slum housing, with additive exposure to city gasoline lead emissions that surged after World War II. The murder rate impact of that additive lead exposure occurred about 20 years later, when lead-poisoned children reached the ages when criminal offending peaks: New expressways in 1965 ran through high murder rate areas because young children raised in slum housing cleared for new highways still lived in those neighborhoods as teenagers and young adults.

Expressways then contributed to rising homicide rates that peaked about two decades after the early-1970s peak in lead emissions. Hagedorn presents a spatial analysis of 1992 murder rates and notes: "Murder in Chicago is now more common in the far western and southern areas of the city. Why?" His animated maps of local murder rates from 1965 to 2000 show that murders in Chicago tracked the path of lead emissions along the Eisenhower expressway west, the Stevenson expressway southwest, and the Dan Ryan south, 20 years after gasoline lead fallout had spread lead poisoning well beyond the inner city.
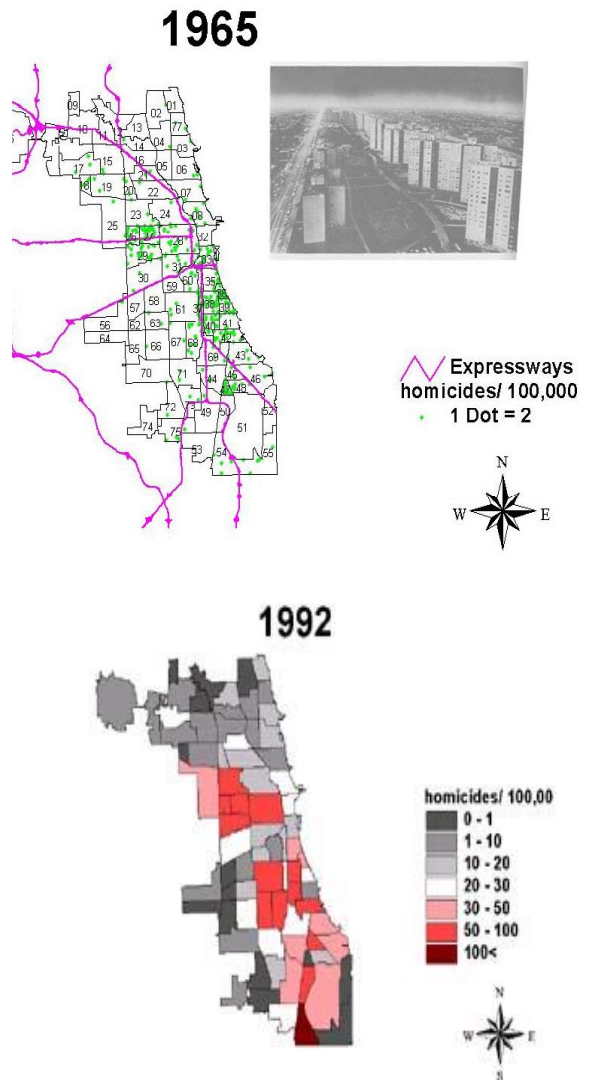
Divergent International Crime Trends Track Earlier Blood Lead Trends

Nevin (2007) showed a consistent relationship between preschool blood lead and crime rate trends in nine nations. Statistical analysis found that blood lead explained:

- 65% to 91% of year-to-year variation in burglary rates in the USA, Britain, Canada, Australia, West Germany, France, and in New Zealand, with an 18-year lag;
- 91% to 93% of variation in aggravated assault rates in the USA and in Britain, with a 23-year lag;
- 70% to 89% of variation in robbery rates in the USA, Britain, Canada, West Germany, New Zealand, and in Australia, with a 23-year lag;
- 84% to 90% of variation in rape in the USA and in Britain, with a 24-year lag; and
- 63% to 93% of variation in index crime rates (violent plus property crimes) in all nine nations examined, with a 19-year lag.

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These findings were based on crime through 2002. From 2002-2011, the burglary rate fell 40% in Canada, 47% in Britain, and 51% in Australia, tracking earlier blood lead trends.

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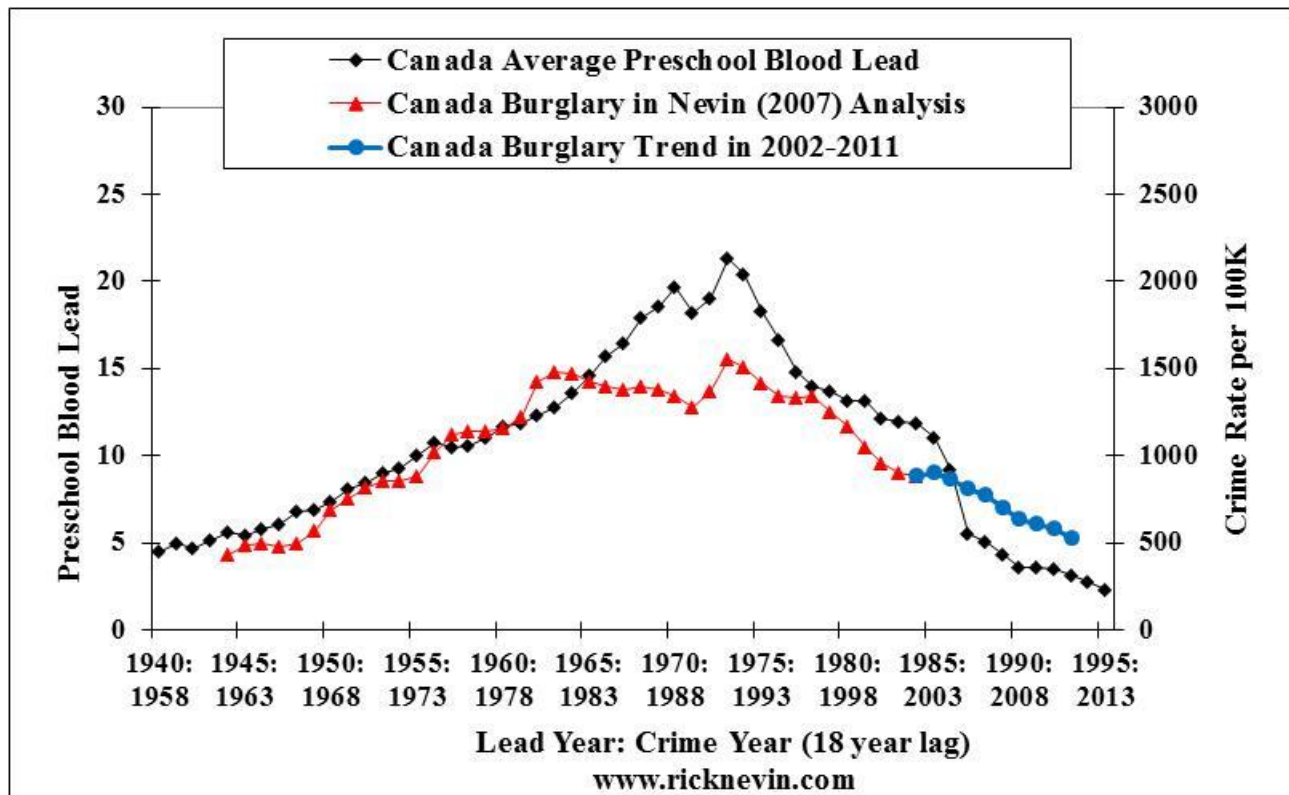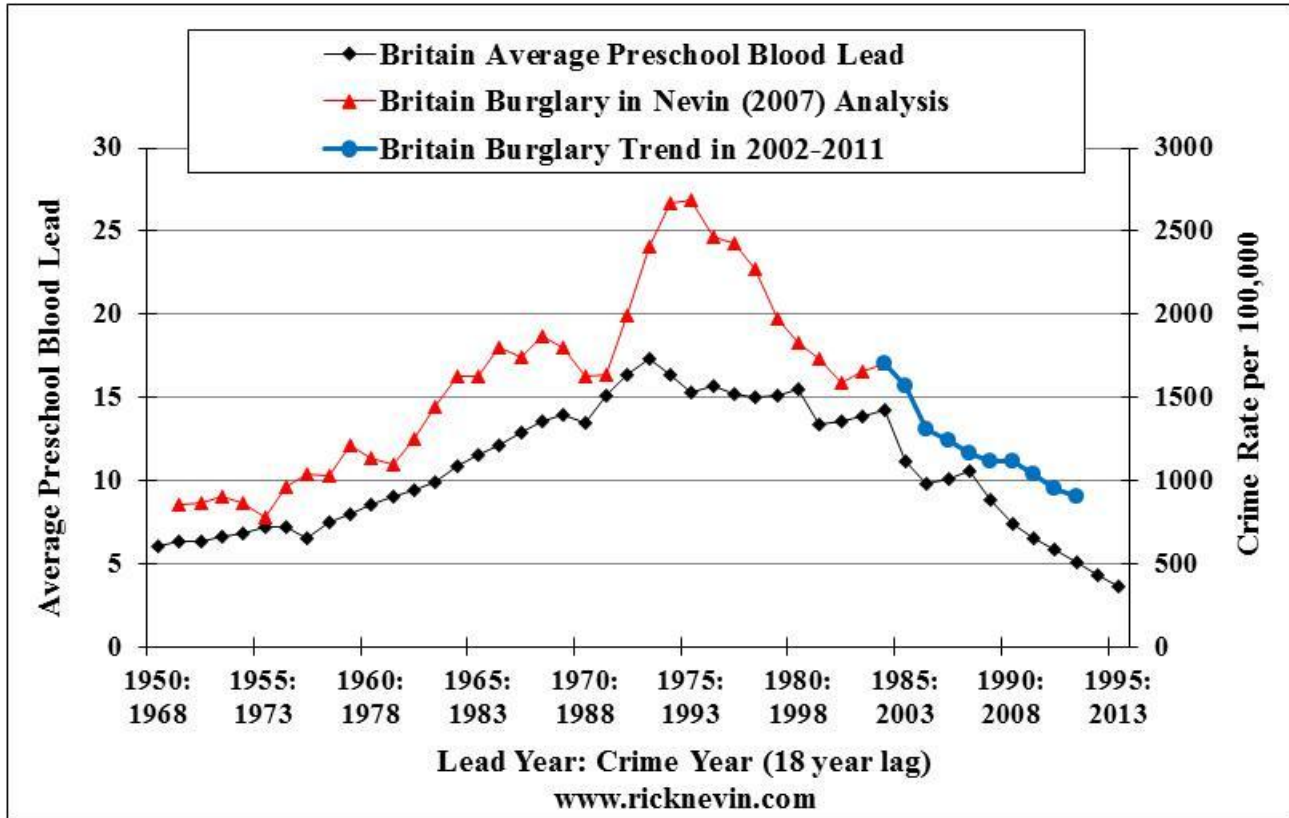
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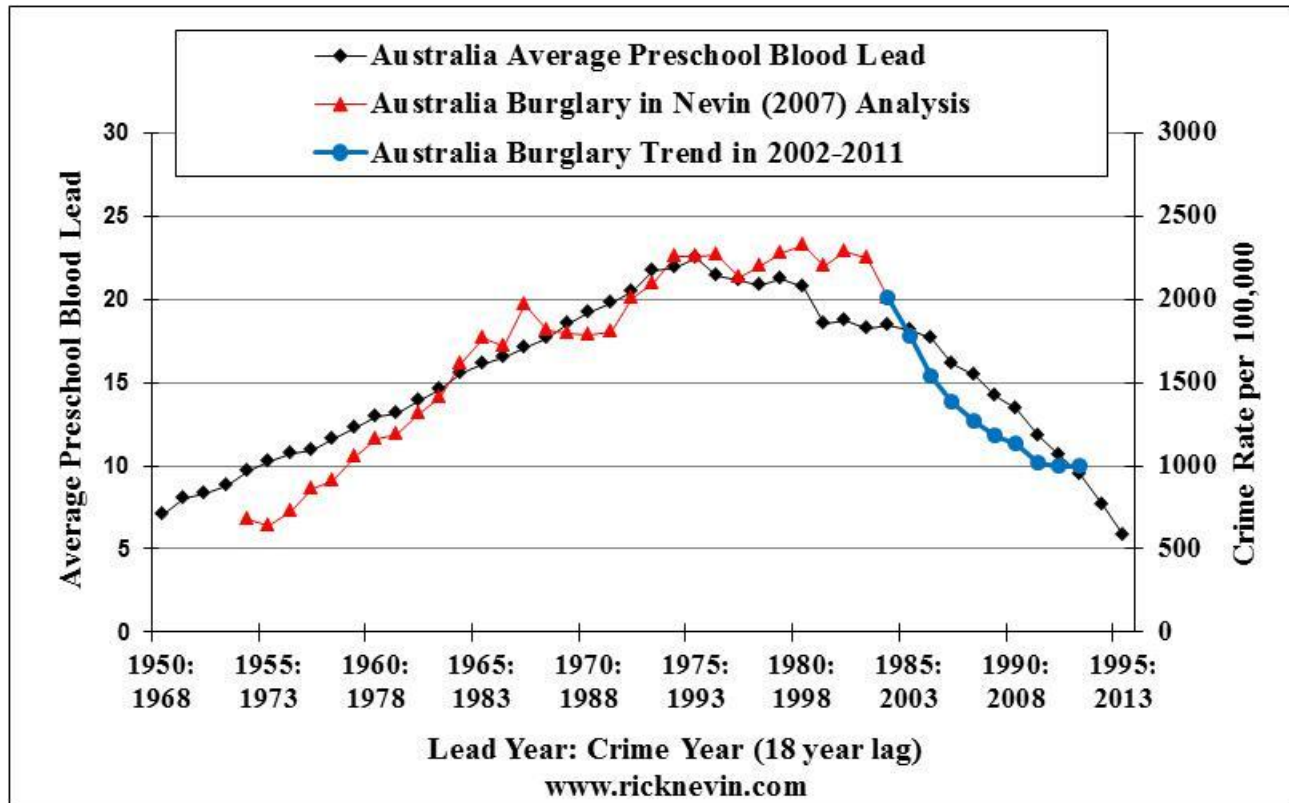
Time lags that relate lead exposure to crime trends reflect analysis of a wide range of lags to identify the "best-fit" with the highest statistical significance. In every crime category, the best-fit lag is consistent with lead-induced neurobehavioral damage in the first year of life and the peak age of offending. The 18-year lag for burglary reflects age-specific arrest rates for property crime (burglary and theft) that peak at ages 15 to 20 and fall sharply by age 30. The 23-year and 24-year lags for robbery, aggravated assault, and rape reflect age-specific violent crime arrest rates that peak at ages 15 to 24 and decline slowly through age 50. The broad category of "index" crime is about 90% property crimes and 10% violent crimes, and the best-fit lag for index crime is 19 years.

The consistent relationship between lead exposure and crime trends *within* each nation can explain 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.

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➢ The USA rape rate was eight times the British rate in 1960, but USA and British rape rates were almost equal in 2009.

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. The USA accounted for the majority of global use of lead in gasoline before 1970. The USA also produced over 40% of world lead output from 1900-1914, and used almost a third of that lead in paint, causing severe USA lead paint hazards throughout the 20th Century. Additive exposure to urban air lead and lead paint hazards in city slums in the 1960s resulted in USA city hospitals treating large numbers of convulsing children with lead poisoning. Canada used less lead in paint, but Canada like the USA did use a disproportionate share of global gas lead before 1970. USA and Canadian gas lead use fell from 1975-1985, but leaded gas use in many industrial nations was near its peak through the mid-1980s, delaying crime declines in those nations.

Lead Poisoning, IQ, Brain Growth, and Crime

Many studies have documented the relationship between IQ lost and preschool blood lead. Preschool blood lead levels over 20 mcg/dl (micrograms of lead per deciliter of blood) lowers IQ to less than 90 among children who would have had average IQ of 100. Blood lead over 40 mcg/dl reduces IQ to less than 75 for children who would have had IQ of 90.
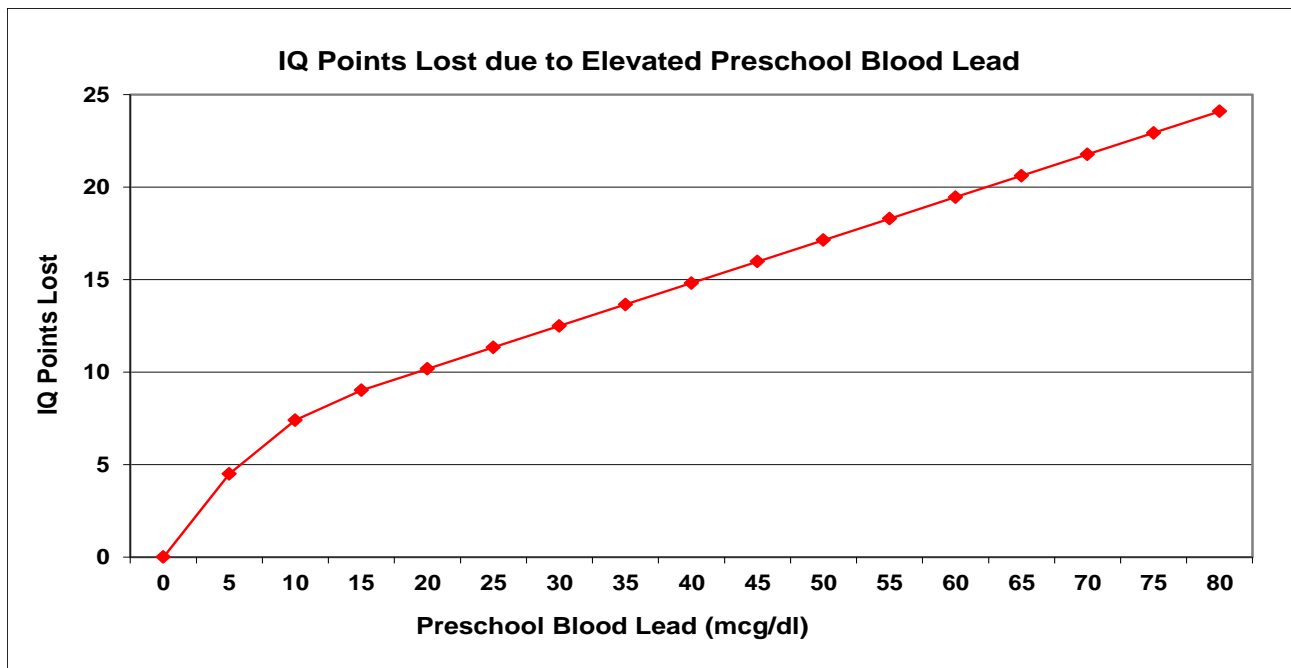
Sources: Schwartz (1994), Canfield (2003), and Lanphear (2005)

Low IQ is associated with increased risk of incarceration, but there is also a documented distinction between relatively common Adolescence-Limited property crime offenders and more violent Life-Course-Persistent offenders who account for most adult offending. The theory that low IQ is a root cause of criminal offending ignores the fact that IQ is relatively stable after adolescence, as arrest rates fall sharply with age.

Magnetic resonance imaging (MRI) studies reveal that critical brain growth before age two is followed by a second gray matter growth surge in the early-teens, and scans at ages 12-16 compared to ages 23-30 show substantial myelin growth in the frontal lobe, the seat of

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impulse control. Myelin insulates and thickens white matter connections between neuron cell bodies. Another MRI study shows frontal lobe white matter growth to age 50, as gray matter volume declines. The study author explains: "What keeps growing is the myelin ... [which] affects the speed of the signals that travel from neuron to neuron ... [and] allows your brain to work in concert; you're not as prone to impulse."

Elevated maternal and preschool blood lead cause many neurological effects that impair IQ, learning, and behavior. Neurodevelopmental effects include gray matter damage, the destruction of myelin sheaths, and decreased activity of an enzyme integral to myelin synthesis. IQ losses are permanent, but neurotransmission damage can be reversible absent continuous exposure, which could cause an IQ-crime correlation due to separate lead effects. Age-related offending could be linked to incomplete myelination among youths with or without preschool lead exposure, but criminal behavior could be more common and severe with lead-induced neurotransmission damage. White matter growth to age 50 suggests that lead-induced damage could also affect behavior beyond adolescence, especially if more continuous exposure causes irreversible effects.

Age-Specific Arrest Rate Shifts and Index Crime Trends

From 1980 to 2011, the USA juvenile (under 18) index crime arrest rate fell by 57%, and the age-18-24 index crime arrest rate fell by 21%, but the index crime arrest rate increased by 32% for ages 35-49. The fall in the juvenile arrest rate from 1980-2011 compares youths born in the 1960s - near the peak in leaded gasoline exposure - with those born after leaded gas was eliminated in the mid-1980s. The 1980-2011 increase in the age-35-49 arrest rate compares adults born before the 1950s surge in leaded gas use with those born near the peak in leaded gas exposure. The decline in the USA index crime rate over recent years has been somewhat slower than the earlier decline in preschool lead exposure because older offenders are accounting for a larger share of the overall crime rate. Still, the USA index crime rate fell to a 44-year low in 2011, tracking earlier preschool blood lead trends.

In Britain, "cautions and convictions for indictable offenses" are similar to USA index crime arrest rates, except that British "indictable offenses" include simple assaults (without serious injury or the use of a lethal weapon) and other non-felony offenses excluded from USA index crimes. Despite this difference in crime recording, Britain and the USA have experienced similar shifts in arrest rates and index (indictable offense) crime trends tracking earlier lead exposure trends. Age-14 British males had the highest offending rates in 1958, but peak offending shifted to age 18 by 1997. The age-10 offense rate fell 70% from 1958 to 1997, as age 18-29 offending increased 300% to 500%. Males ages 12-14 in 1958, born as leaded gas use rose, had higher offending rates than older teens born before that rise in lead exposure. By 1997, offending declined relative to 1958 only for males under 14, reflecting the mid-1980s fall in British gas lead use. In 2011, the British index crime rate fell to a 29-year low, tracking the belated reduction in British preschool lead exposure.

In Canada, "Criminal Code violations (excluding traffic)" encompass a broad range of "index" crimes, similar to British "indictable offenses". In 2011, the Canada index crime rate fell to a 38-year low. The decline in Canada index crime offending from 1998 to 2008 was almost entirely due to a decline in offending by juveniles, ages 12-17.

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1980-2011 Shift in USA Index Crime Arrest Rates by Age Group
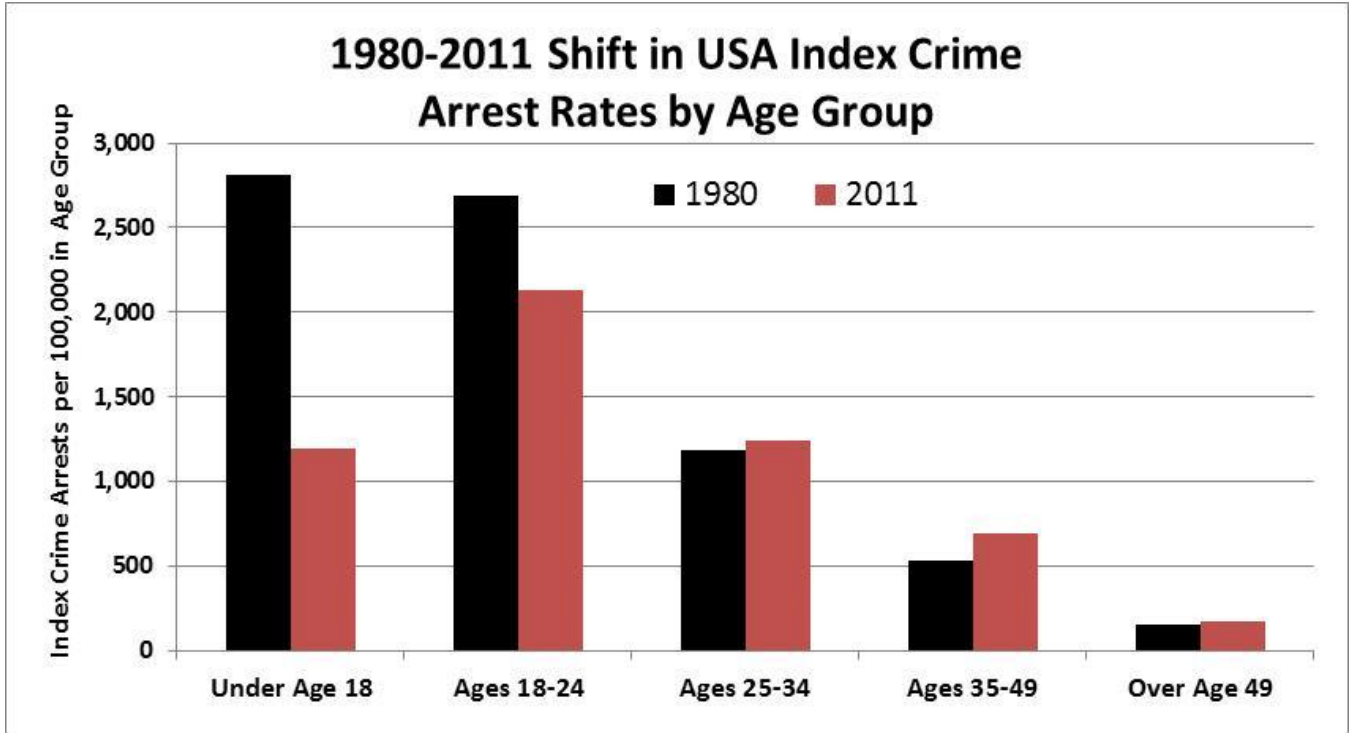
Source: [FBI Uniform Crime Reports, index crime arrests by age](#)
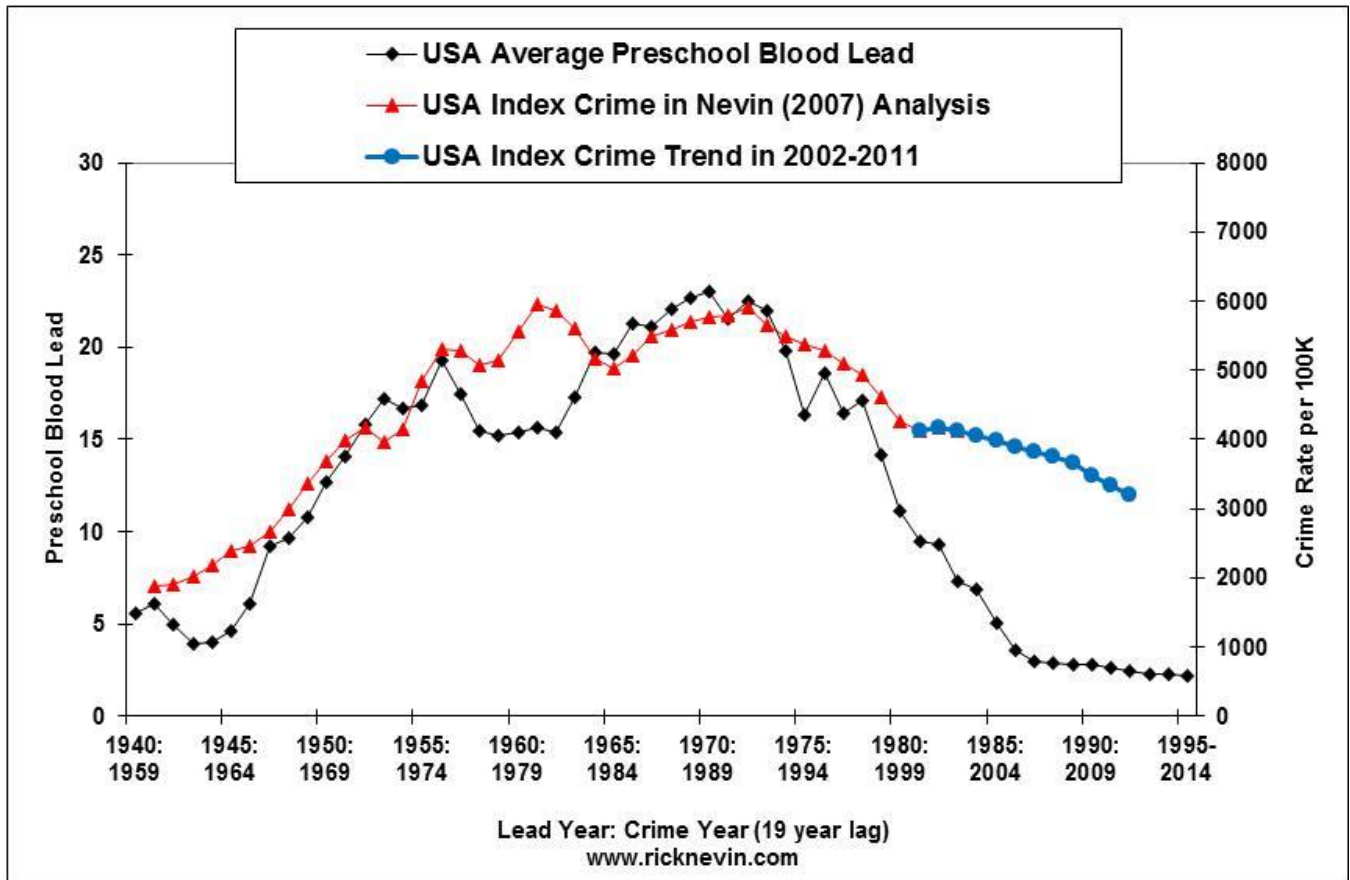
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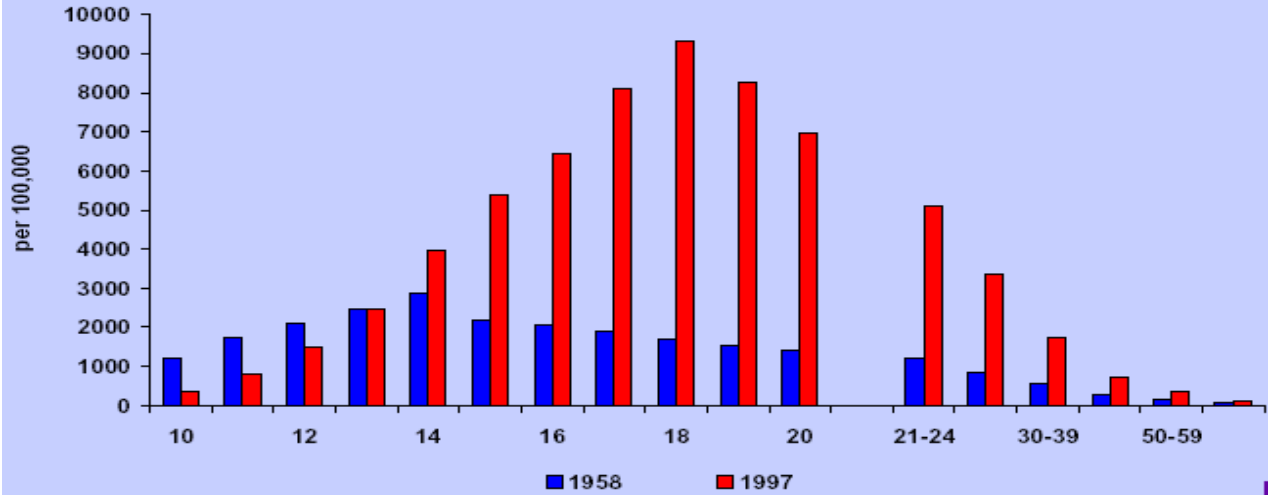
Source: Taylor (1999) Forty years of crime and criminal justice statistics, 1958 to 1997, UK Home Office

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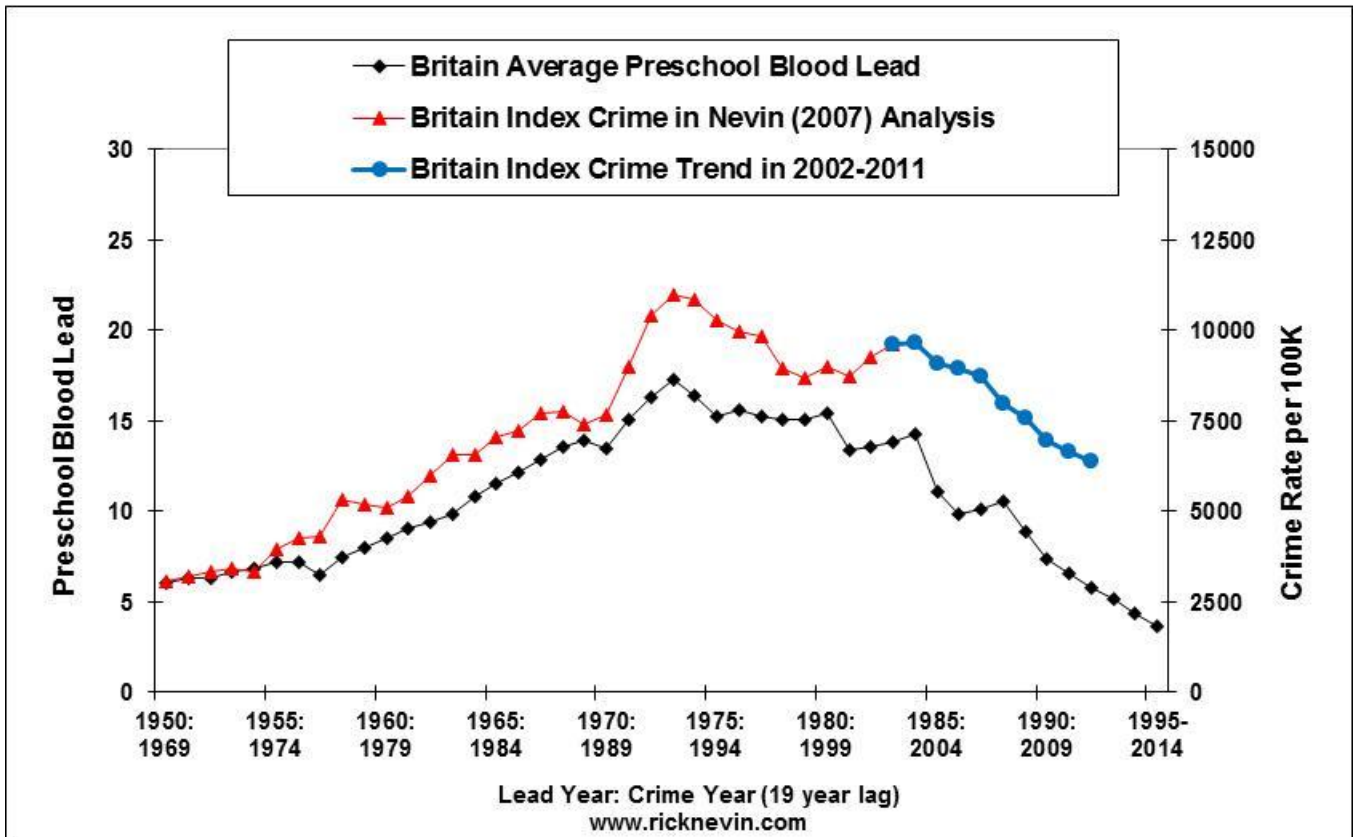
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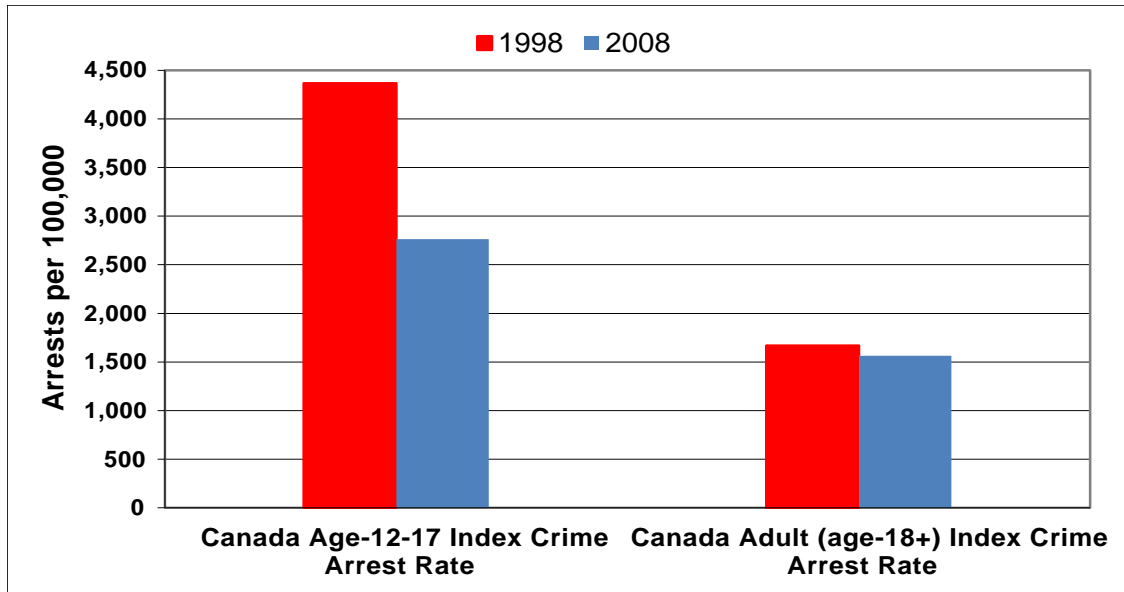
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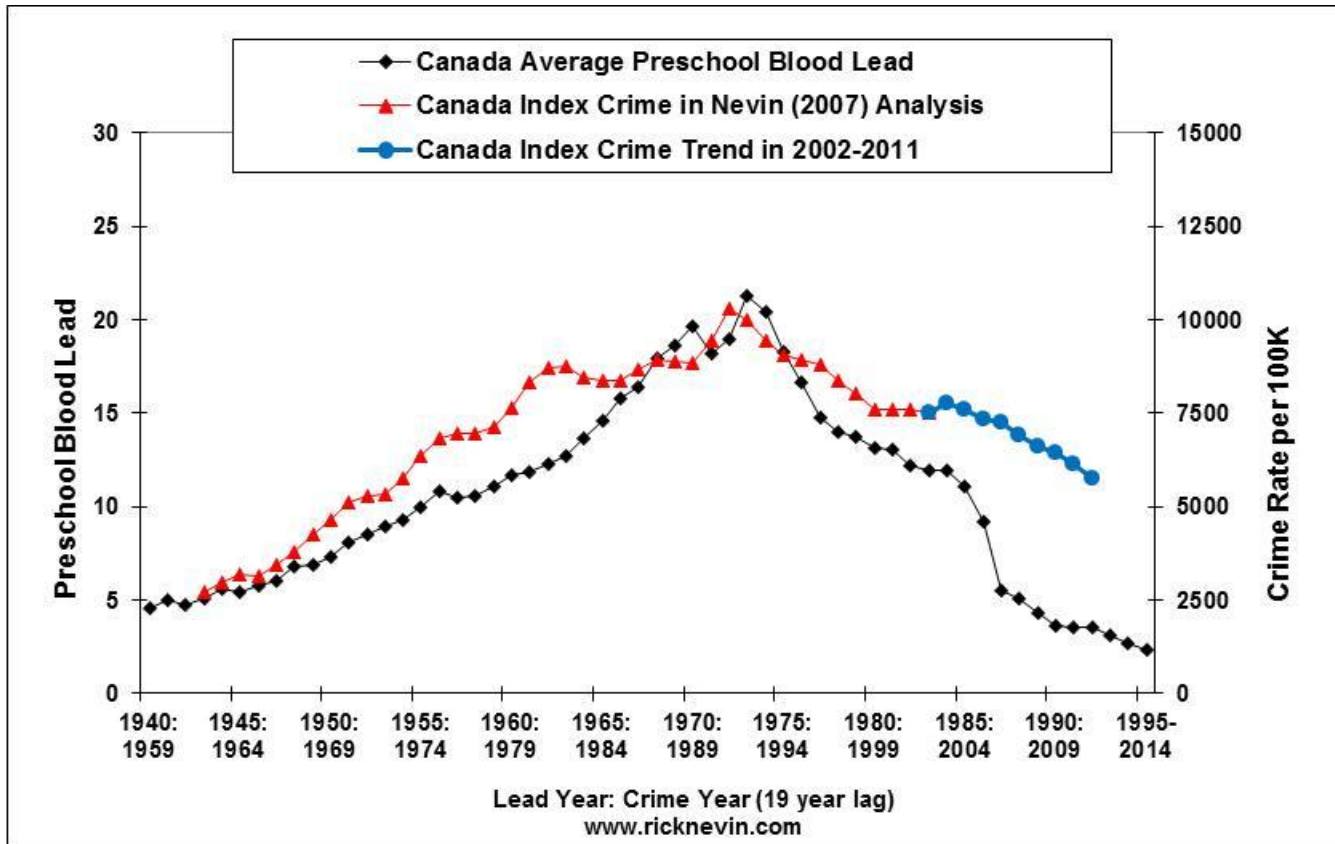
"Unwanted" Children, Abortion, and Crime

Donohue and Levitt (2001) argued that the 1990s USA crime decline resulted from the early-1970s legalization of abortion. This theory, like evidence linking crime to preschool blood lead, highlights the time lag between birth and the typical age of offenders. In the USA, abortion legalization coincided with the early-1970s peak in gasoline lead emissions,

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but unlike the abortion-crime theory, preschool lead exposure can also explain the rise in USA crime from 1960 to 1990.

Donohue and Levitt also highlight early crime declines in California and New York State, where abortion was legalized two years before it became legal in the rest of the USA. Those two states also had early declines in preschool lead exposure.

New York City recorded a sharp decline in preschool blood lead at least as early as 1970. That decline likely began earlier due to 1950-1970 slum demolition reducing lead paint hazards. New York City also banned lead paint in 1960, 18 years before the national ban, and reduced municipal waste incinerator lead emissions in the 1960s. Moreover, if the 1971 state-wide abortion legalization in New York caused an early crime decline, then that decline should have been evident state-wide, but the early New York crime decline was only evident in New York City, not in upstate New York.
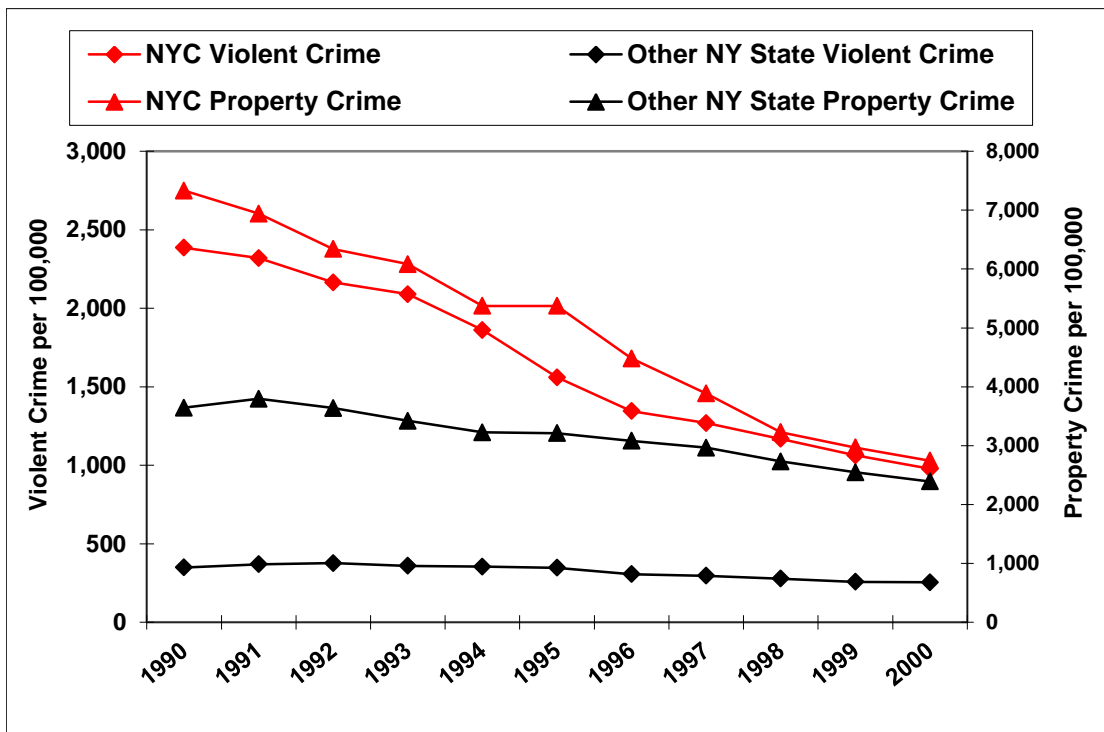
Source: NYS Division of Criminal Justice Services

California limited the lead content of leaded gasoline to 0.26 grams per liter in 1977, and 0.18 grams in 1978, well before the USA set a national limit of 0.29 grams per liter in 1983. Therefore, the abortion-crime theory and the lead exposure theory are both consistent with an early crime decline in California, but the abortion-crime theory cannot explain why California's violent and property crime rates were much higher than overall USA violent and property crime rates from 1960-1990. High 1960-1990 California crime rates are consistent with California per capita gasoline use that was 30% higher than the USA average excluding California in 1950, 20% higher during the 1950s, and 10% higher in the 1960s.

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Ratio of California per capita Gasoline Use to USA x-California per capita Gasoline Use
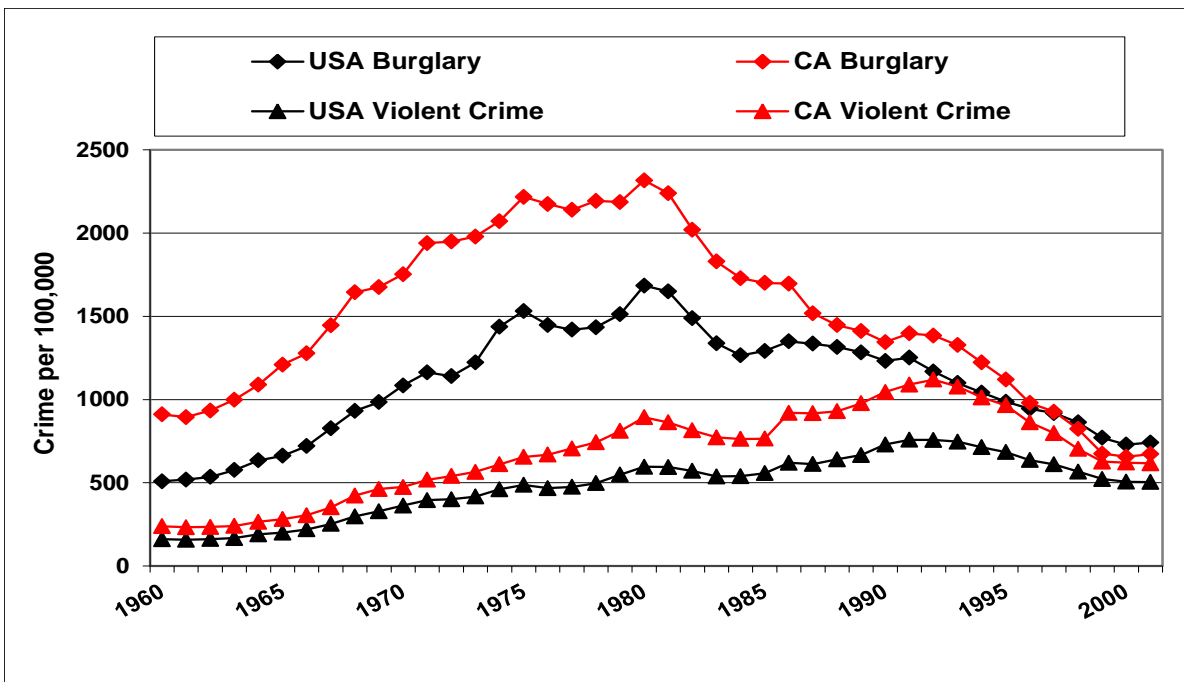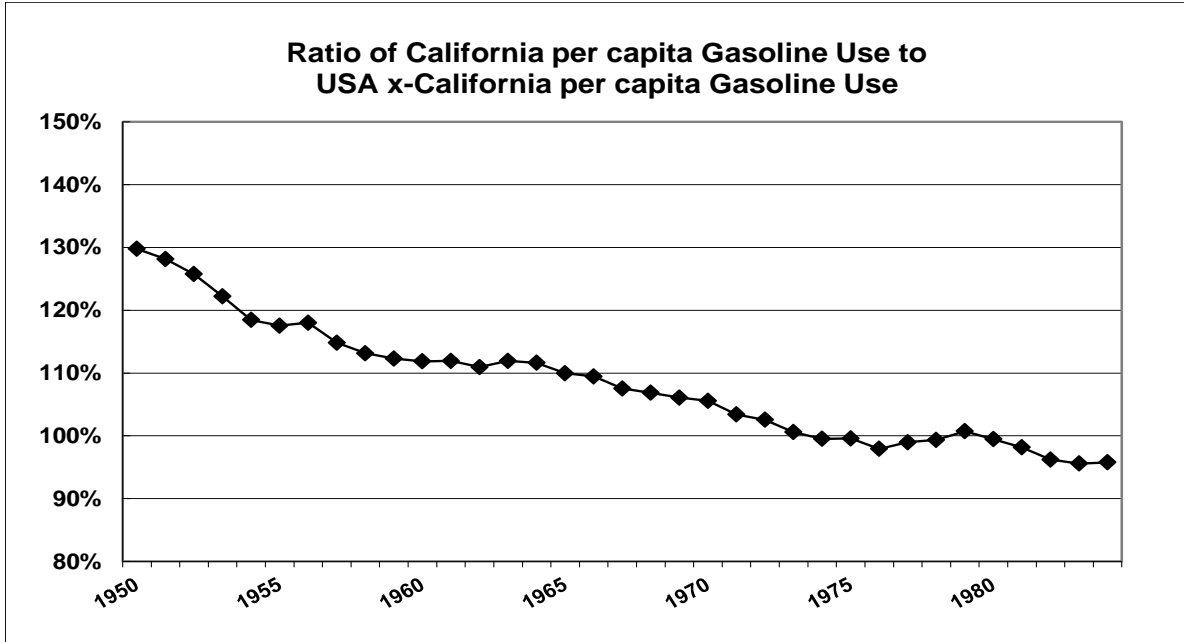
The abortion-crime theory posits that "unwanted" children are more likely to become criminals, but there are no data on criminal offending by "unwanted" children. Therefore, this theory relies on proxy variables for "unwanted", noting that poor children and those raised by single mothers are more likely to become criminal offenders, and women who obtain abortions are disproportionately unmarried and poor. One apparent flaw in this logic is that legalized abortion did not reduce the supposed indicators of "unwanted" births. The percent of USA births to unwed women more than doubled from the early-1970s through the late-1990s. The percent of children in poverty dropped from 27% in 1960 to 14% in 1973, before abortion was legalized (and as crime surged), and rose after abortion was legalized, with about 20% of USA children in poverty from 1980 to 2000.

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Britain also recorded large increases in the percent of children living in poverty and the percent of births to unwed mothers in the decades after abortion was legalized. However, Britain and the USA experienced very different crime trends after abortion was legalized in Britain in the late-1960s, before it was legal in New York or California: The violent crime rate in Britain increased almost 80% over the 1990s, and the burglary rate peaked in 1993, 13 years after the USA burglary peak. Those divergent crime trends were consistent with divergent USA and British lead exposure trends in the 1970s and 1980s.

USA women who obtain abortions have been disproportionately unmarried, poor, and black, but the 1990s crime decline was primarily due a dramatic decline in offending by the children *who were born* to unmarried, poor, black women, foreshadowed by a change in preschool lead exposure that especially affected those children. When USA gas lead use peaked in the early-1970s, 62% of blacks under age six lived in central cities, versus 24% of white children under six. The 1980s phase out of leaded gas benefitted all USA children but the largest declines in blood lead were recorded by central city children.

The average blood lead for black two-year-olds tested in Chicago and New York City fell about 30% from 1970 to 1978, but the late-1970s average for all black children under age-3 was still 50% above the average for white children under age-3. Moreover, the percent of black children under age-3 with blood lead over 40 mcg/dl in the late-1970s was eight times higher than the percent of white children with blood lead that high. Nevin (2007) found that such severe cases of lead poisoning appeared to be especially associated with homicide and other violent crimes. From 1993 to 2003, the white juvenile murder arrest rate fell from 6.4 to 2.1 murders per 100,000 whites ages 10-17, as the black juvenile murder arrest rate fell from 58.6 to 9.7 murders per 100,000 blacks ages 10-17. That 83% fall in the black juvenile murder arrest rate occurred over a single decade, with almost no change in the percent of black children living in poverty or the percent living in two-parent families.

Wolpaw Reyes (2007) concluded that lead exposure and abortion both had a significant impact on USA violent crime, based on analysis of state-level data for crime in the years 1985 to 2002. This analysis, like the Donohue and Levitt study, focuses on crime years well after the USA legalization of abortion, offering little insight into why the violent crime rate surged by 250% from 1960 to 1985, as the property crime rate rose by 170%. The Wolpaw Reyes study includes a graph of the national trend in lead per capita versus violent crime from 1970-2002 (with a 22-year lag), similar to a Nevin (2000) graph showing the trend in lead per capita versus violent crime from 1964-1998 (with a 23-year lag), but her conclusion that abortion has a significant impact on crime is apparently based only on 1985-2002 crime data. It seems likely that an analysis that included earlier USA violent crime trends might show no impact from abortion, in light of the apparent absence of any violent crime impact resulting from earlier abortion legalization in Britain, and in light of the very large percent of long term USA violent crime variation explained by lead exposure.

Nevin (2000) found that per capita use of lead in gasoline from 1941-1975 explained 90% of the variation in the USA violent crime rate from 1964 to 1998. From 1998-2011, the violent crime rate fell 32%, tracking earlier preschool blood lead trends. The ongoing fall in violent crime is clearly associated with birth years of declining lead exposure: From 1980 to 2011, the juvenile violent crime arrest rate fell by 35% and the age-18-24 rate fell by 18%, as the violent crime arrest rate increased by 16% for ages 35-49 and 34% for those over ages 49.

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1980-2011 Shift in USA Violent Crime Arrest Rates by Age Group
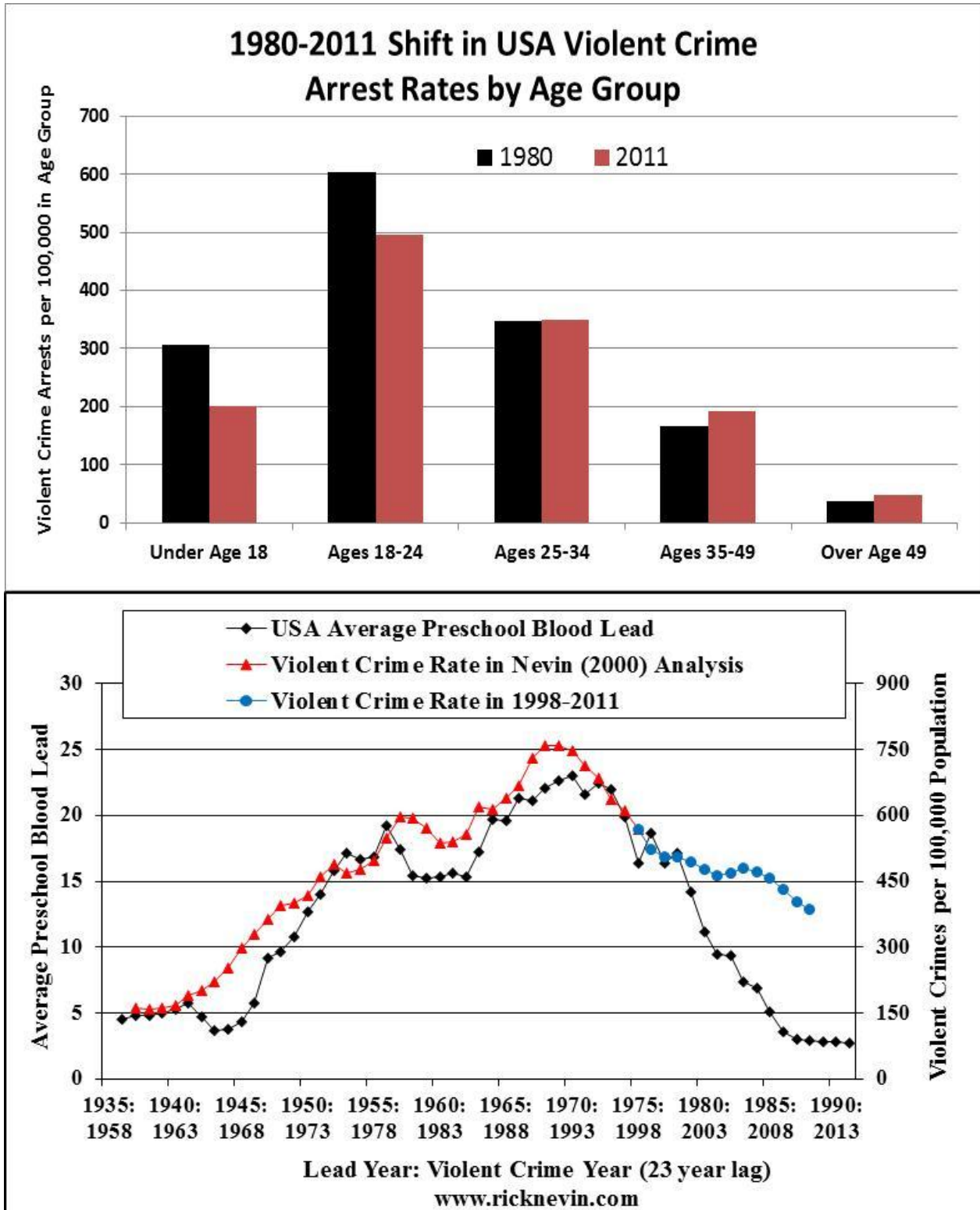
The Wolpaw Reyes study also showed no significant impact of lead exposure on property crime. James Q. Wilson described this finding as an "oddity ... yet to be explained", but this finding with respect to property crime is unique to the Wolpaw Reyes study. Researchers at the University of Cincinnati have collected blood lead data from pregnant women and their

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children since 1979, and Wright (2008) and colleagues have reported that preschool blood lead was significantly associated with both violent and non-violent offending among those subjects two decades later, at ages 19-24. Nevin (2007) has also shown a highly significant relationship between national trends in preschool blood lead and subsequent trends in burglary rates and index crime rates (mostly property crime) in every nation examined.

The Bell Curve behind *The Bell Curve*

 A 1998 Scientific American article by Gottfredson included an illustration showing "the odds of various kinds of achievement and social pathology change systematically across the IQ continuum". The data in this illustration was from *The Bell Curve*, based on background and annual interview data from the 1979-1990 National Longitudinal Survey of Youth (NLSY). In 1979, the NLSY participants were ages 14 to 22, and the Bureau of Labor Statistics describes this large sample as "representative of all American men and women born in the late 1950s and early 1960s." NLSY participants were given the Armed Forces Qualification Test in 1980 and their scores were converted to the IQ scale.

The IQ scale measures individual IQ relative to 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 norm sample scores, creating a bell curve distribution, so 5% of people 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 youths with IQ below 90 had a greater risk of incarceration, unwed births, and failure to get a high school degree. Gottfredson's illustration showed the odds for white youths.

The Second National Health and Nutrition Examination Survey (NHANES II), from 1976 to 1980, provided the first representative data on the USA blood lead distribution. NHANES II revealed another type of bell curve that was the mirror image of the IQ bell curve with respect to income and race: Poor children and black children were more likely to be at the high end of the blood lead bell curve. The NHANES II preschool blood lead distribution would have had a large impact on any IQ norm sample for Americans born in the late-1970s, when one fourth of young children had blood lead over 20 mcg/dl, and 4.1% had blood lead over 30 mcg/dl.

NHANES III data, from 1988 to 1991, showed that the phase out of leaded gasoline shifted the entire preschool blood lead distribution to lower values. The 1988-1991 NHANES III distribution was also concentrated in a much narrower range than the 1976-1980 NHANES II distribution, with important implications for behavioral correlates of low IQ based on any IQ norm sample associated with specific birth years.

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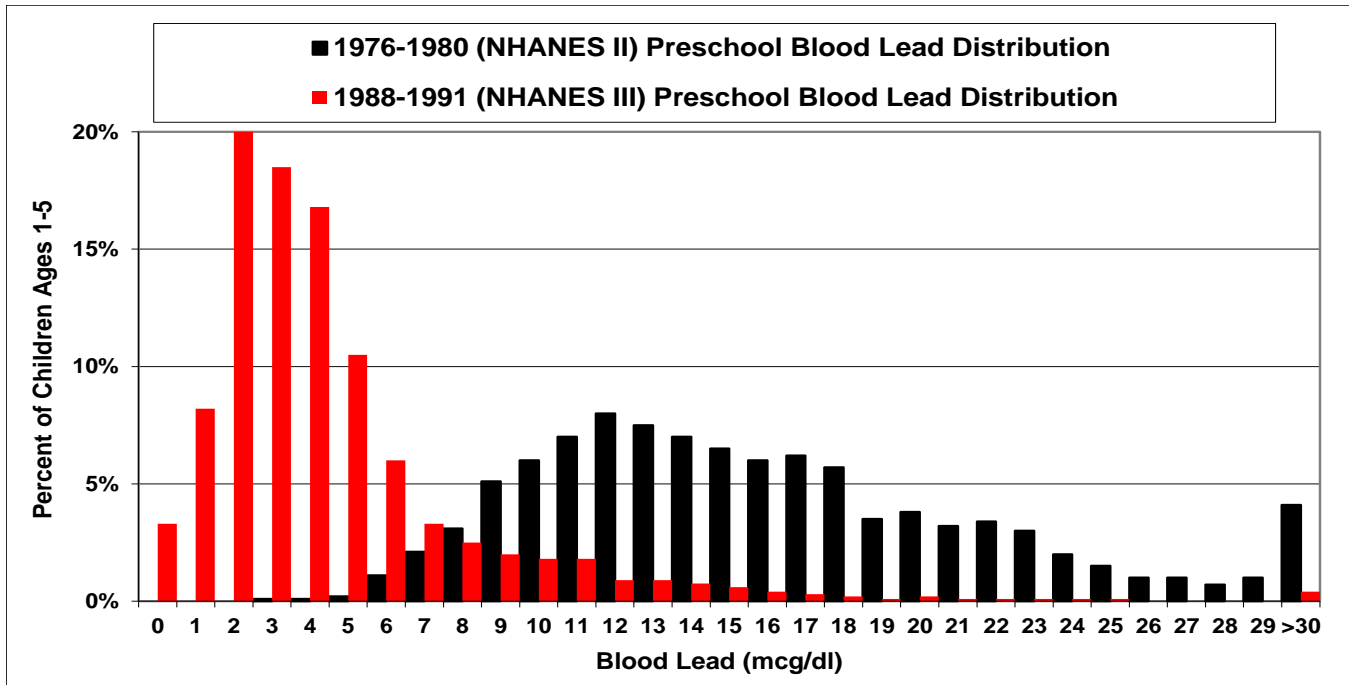
The Gottfredson illustration odds for men "ever incarcerated" reflected the percentage of white males who reported being incarcerated before their 1980 NLSY interview (less than 1% of those with IQ over 110 versus 7% of those with IQ below 90). *The Bell Curve* also reported that white males with IQ below 75 were especially likely to have at least one of their 1979-1990 interviews actually conducted in a correctional facility. Less than 1% of white males with IQ over 110 had a NLSY interview while incarcerated versus 7% of those with IQ of 75 to 90 and 12% of those with IQ below 75. The probability of a correctional facility interview reflects both the probability of being incarcerated and the duration of time served. If time served reflects offense severity, then the high rate of correctional facility interviews for white males with IQ below 75 suggests that the lowest 5% of the IQ distribution was especially likely to engage in serious (violent) offenses. Gottfredson also states: "An IQ of 75 is perhaps the most important threshold in modern life. At that level, a person's chances of mastering the elementary school curriculum are only 50-50, and he or she will have a hard time functioning independently without considerable social support."

Trends in Mental Retardation and Lead Exposure

A 1982 National Research Council report on special education found that an IQ below 75 was also the threshold that most states used for identifying "significant limitations in intellectual functioning" indicative of mental retardation (MR). Some states used a higher IQ threshold, and many others used a threshold of IQ below 70. The statistical method used to calculate individual IQ from a representative norm sample means that 5% of the population should have IQ below 75, and 2.5% below 70, but the percent of public school students in special education for MR has never been as high as 2.5% because a diagnosis of MR also requires significant limitations in "adaptive behavior" (often based on teacher observations of learning and behavior problems).

Public school MR prevalence increased from 1914 to 1939 as IQ testing increased, but fell from 1939 to 1947, after a 38% decline in per capita use of lead in paint from 1920 to 1930,

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before the rise in gas lead use. MR prevalence then rose from 0.37% in 1948, peaked at 2.16% in 1976, and fell to 1.3% in 2001, tracking preschool blood lead trends with a best-fit 12-year lag, for children ages 6-18. Nevin (2009) showed that 1936-1990 preschool blood lead trends explained 65% of 1948-2001 variation in USA public school MR prevalence. From 2001-2010, public school MR prevalence fell by 30%.
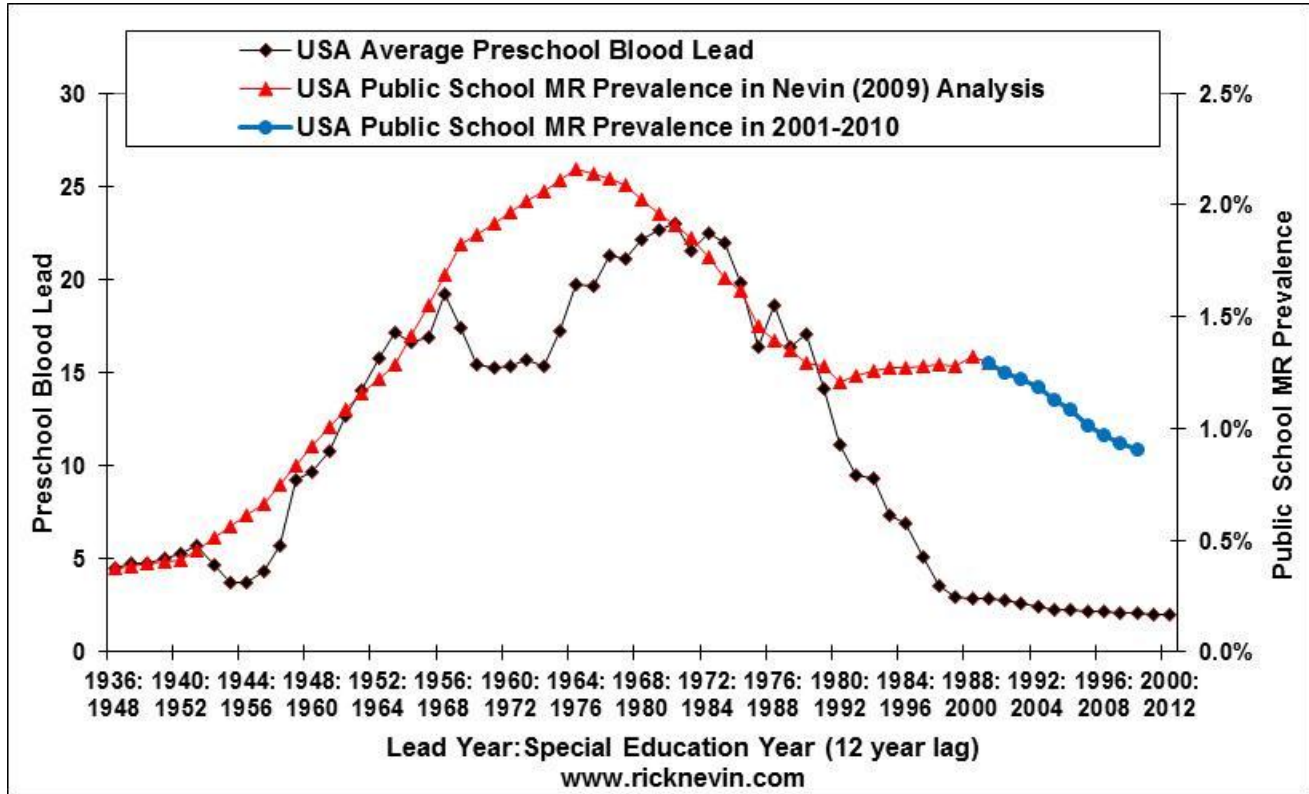

MR prevalence was 1.2%-1.3% from 1991-2004, but this was when public schools switched from the 1974 WISC-R IQ test to the 1991 WISC-III, with the latter based on a norm sample of children born as lead exposure declined in the 1970s and 1980s. Students with mild MR (IQ above 55) who took both tests recorded IQ that averaged 5.6 points lower on the WISC-III than on the WISC-R. 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 level 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). In 2008, public school MR prevalence fell below 1% for the first time since 1960, and MR prevalence was still falling through 2010.

The 1982 National Research Council report found that 75% to 80% of all MR students had mild MR and most of these mild cases were of unknown cause, with especially high prevalence among children living in slums. Lead dust hazards are still present in 61% of homes with deteriorated interior lead paint, and children with x-ray evidence of lead paint chip ingestion in 1990 (after the era of leaded gas) still had average blood lead of 63 mcg/dl, but the paint chip ingestion and lead-contaminated dust risks were much worse in 1950-1970 city slum housing.

Urban renewal slum demolition reduced lead paint hazards in the 1960s, but 25% of city children tested in 1970 still had blood lead over 40 mcg/dl. Gas lead use peaked around 1970, but substandard housing still explained 95% of 1970 Census tract variation in the prevalence

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over 40 mcg/dl, because severe lead poisoning was especially associated with additive exposure to lead paint hazards and urban air lead. Nevin (2009) noted that the 1976 peak in MR prevalence was consistent with severe lead poisoning prevalence that likely peaked in the early 1960s, before urban renewal slum demolition increased rapidly after 1960.


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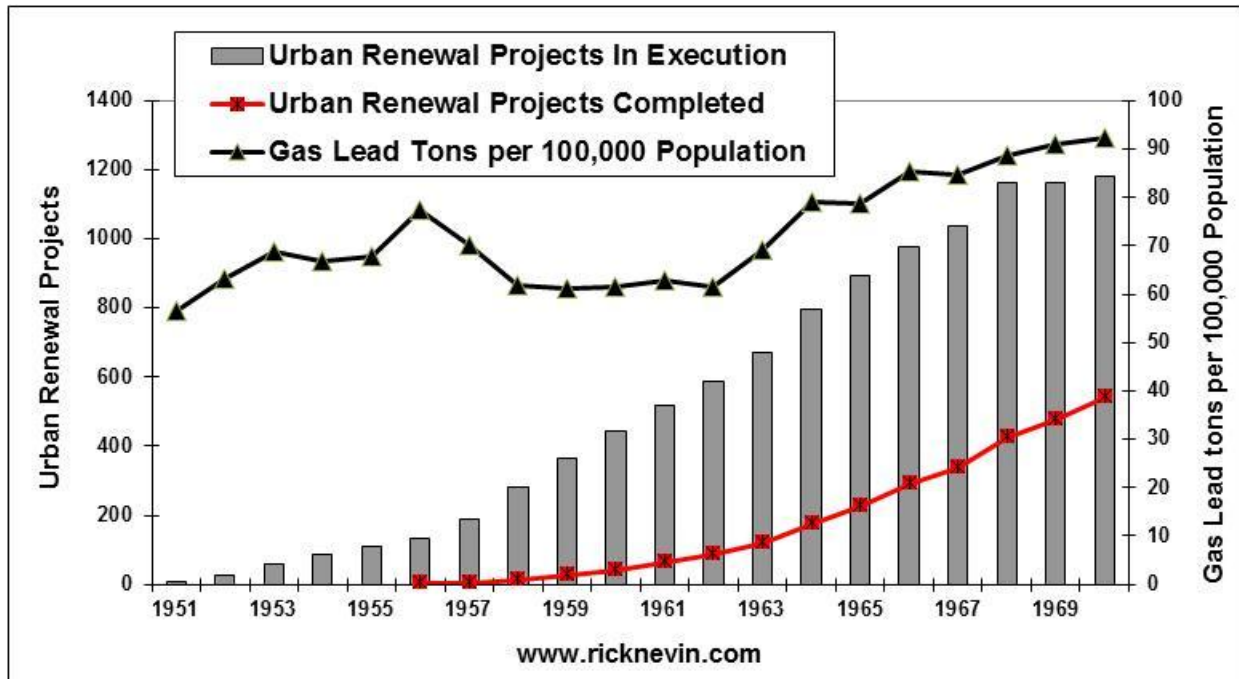
Slow changes in population exposure to lead paint had little impact on *average* preschool blood lead across the decades of gas lead use, but 1960s slum clearance must have affected the prevalence of severe lead poisoning, especially among black children. Blacks accounted for 15% of households in 1960 central cities (population over 50,000) but occupied 56% of substandard city housing, and African-Americans were disproportionately displaced slum clearance. As lead paint hazards were reduced by slum clearance, the severity of city air lead exposure for most urban children was probably not much worse than during the 1956 interim peak in gas lead use, because the early-1970s peak in gas lead use was associated with increasing urban sprawl, spreading more of the near-fallout from gas lead to suburbs that had relatively little traffic in the 1950s.

Robbins (2010) has confirmed that lead concentrations in tooth enamel formed in early childhood from 1936-1993 indicate that preschool lead exposure in a predominantly black urban population peaked around 1960. This peak in tooth lead, a decade before the peak in gas lead emissions, is consistent with severe urban lead poisoning before slum demolition removed many housing units with lead paint hazards. 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, with 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 fall in public school MR from 1976 to 1992 was almost entirely due to a decline among black children. Other researchers have observed that the racial difference in average National Assessment of Educational Progress scores narrowed at different times for ages 9, 13, and 17, but black gains at each age were traced to changes over the same 1962-1973 birth years. Nevin

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(2009) also linked those birth years to a narrowing of the racial difference in Scholastic Achievement Test (SAT) scores, and Nevin (2007) linked those same birth years to a narrowing of the racial difference in juvenile burglary arrest rates. All of these trends are consistent with 1960s slum clearance especially reducing lead poisoning among black children, as urban sprawl spread higher air lead to predominantly white suburbs.
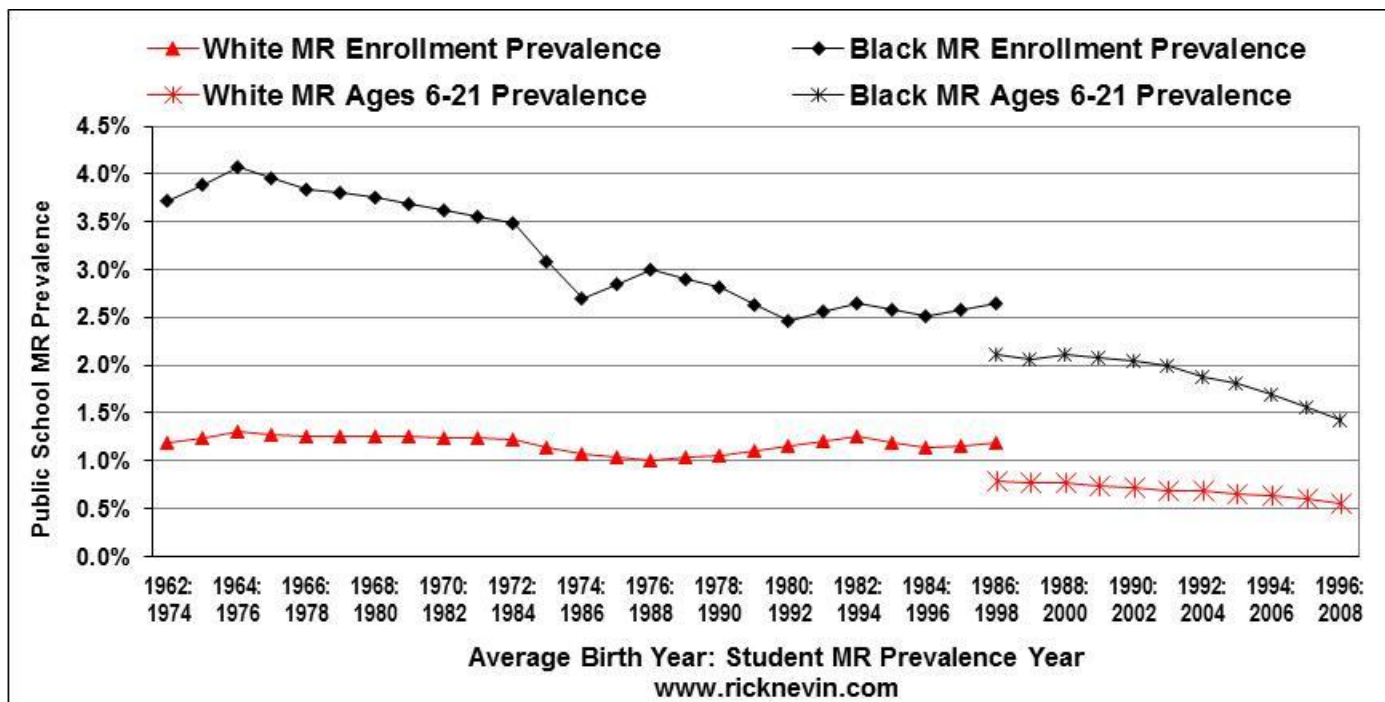

The 1982 National Research Council report stated that students ages 10-14 had twice the mild MR prevalence of students ages 15-19. This is consistent with data in *The Bell Curve* showing that 55% of white NLSY students with IQ below 75 became dropouts, because MR enrollment prevalence for ages 15-19 would reflect only MR students who stayed in school. That NLSY data was for students born in the late-1950s and early-1960s, but MR students who left school as dropouts fell by 23% from 1993-2005 as those graduating with a certificate or diploma rose 97% and 32%, respectively. There has also been a shift in the peak age of MR prevalence, with peak prevalence at age-14 in 1993 and age-16 in 2005. The impact of an ongoing decline in lead paint hazards is evident in a fall in age 6-11-year-old MR prevalence from 1% in 1996 to 0.6% in 2008 and in age 12-17-year-old MR prevalence from 1.3% in 2001 to 1% in 2008, associated with the same birth years *after* the 1980s gas lead phase-out.

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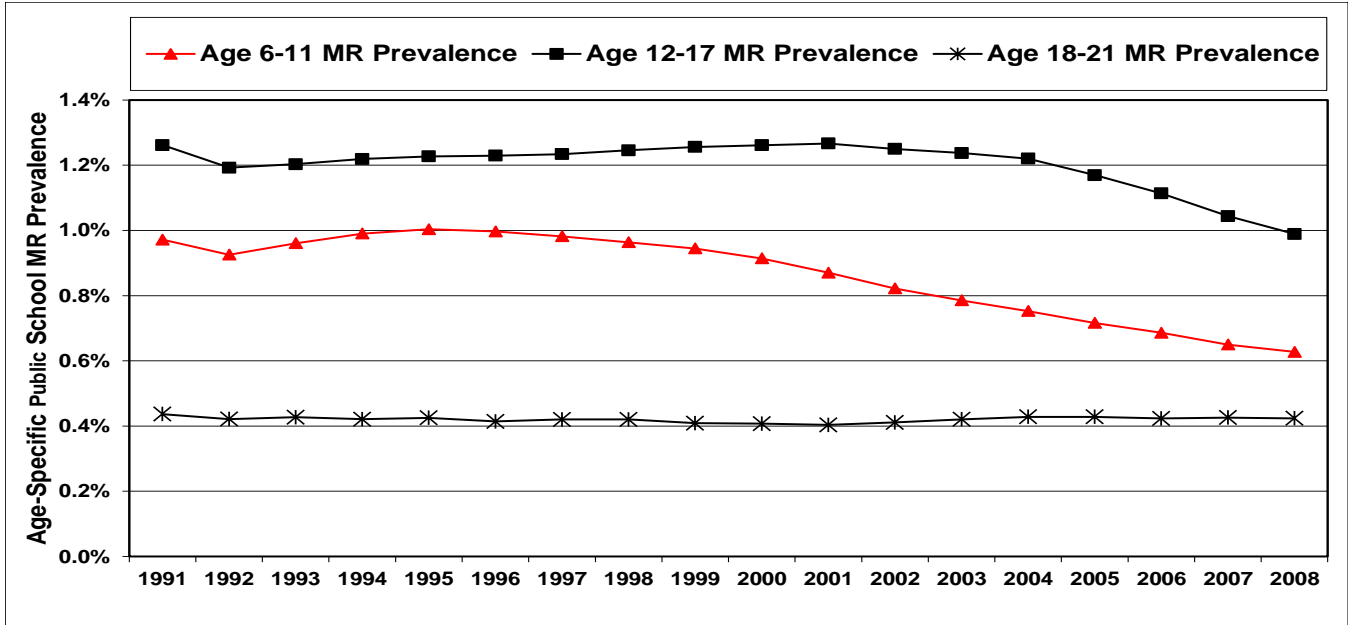
Trends in Lead Exposure and Education Achievement and Attainment

Nevin (2009) also showed that 1936-1990 preschool blood lead trends explained 45% of the 1953-2003 variation in the average SAT verbal score and 65% of variation in SAT math scores, with a best-fit lag of 17 years. The fall in SAT scores was blunted by a surge in students taking prep courses from 1977-1986, and the post-1990 rise was slowed by a large increase in students who speak a foreign language at home, especially affecting verbal scores. (All data in this analysis were based on the same SAT norm, after adjustments to older SAT data.)
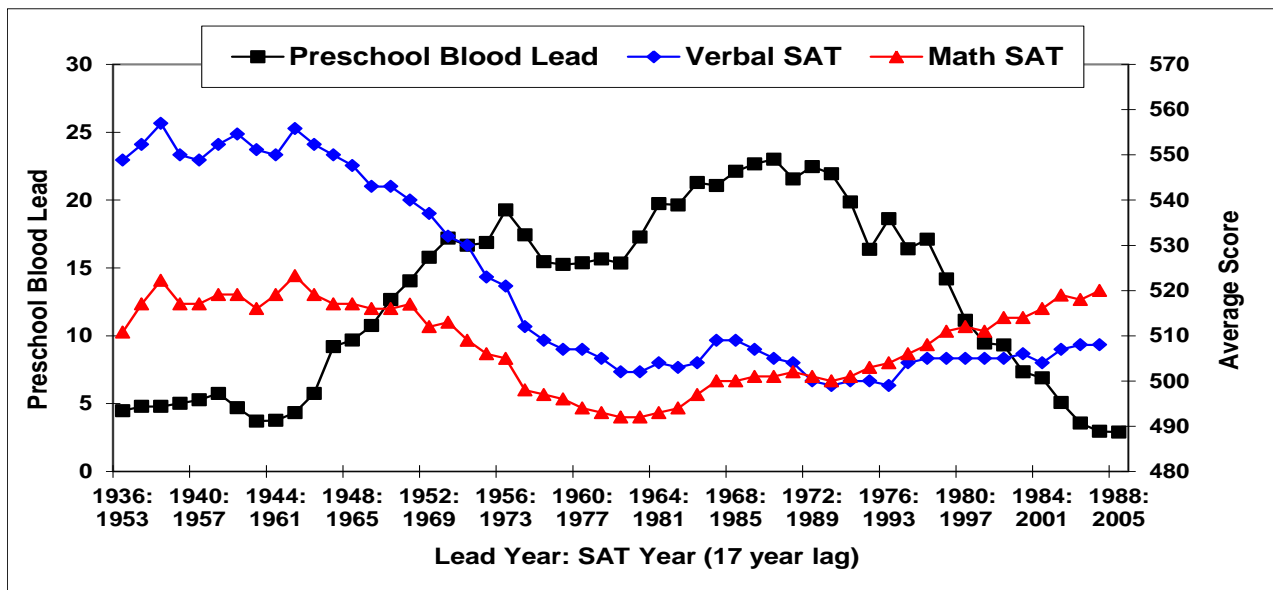
The theory that SAT scores fell from 1960 to 1980 due to an increase in test-takers, reducing the average ability of students taking the SAT, is not consistent with trends in education attainment. SAT math scores were relatively stable from 1960-1968, as the 16-24-year-old status dropout rate (percent not in school and without a diploma or GED) fell from 27% to 16%, and the 16-24-year-old college enrollment rate (within 12 months of diploma or

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GED) rose from 45% to 55%. SAT scores fell as the status dropout rate stayed at 13.9% or higher until 1983, and the college enrollment rate stayed below 51% from 1972-1980 and did exceed the 1968 rate until 1985. The later rise in SAT scores occurred as the dropout rate fell from 13.7% in 1983 to 9.4% in 2005 and the college enrollment rate rose from 55% in 1984 to 68.6% in 2005. High school enrollment as a percent of the population ages 14 to 17 also rose from 83.4% in 1959 to 93.1% in 1968, but fell to 89.8% by 1979 and did not exceed 93.1% until 1990, then reached a new record in every year from 2002 to its 2010 high of 96.9%.

The USA also experienced an unexplained late-1800s decline in education attainment after per capital use of lead in paint surged after 1870. In 1880, 64% of whites and 34% of blacks ages 5-17 were enrolled in school, but enrollment fell to 53% of whites and 29% of blacks by 1900, a century before *The Bell Curve* linked low IQ to high school dropout risk.
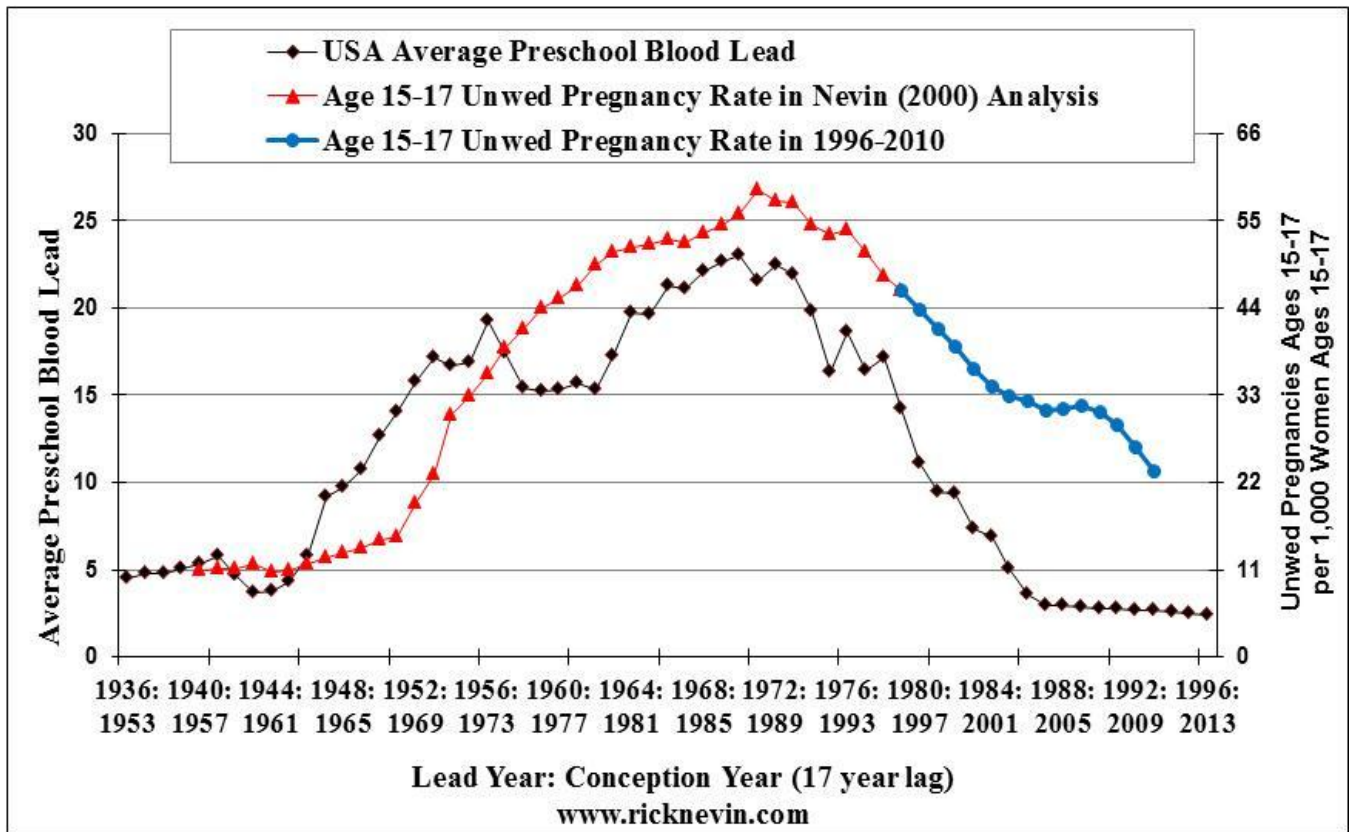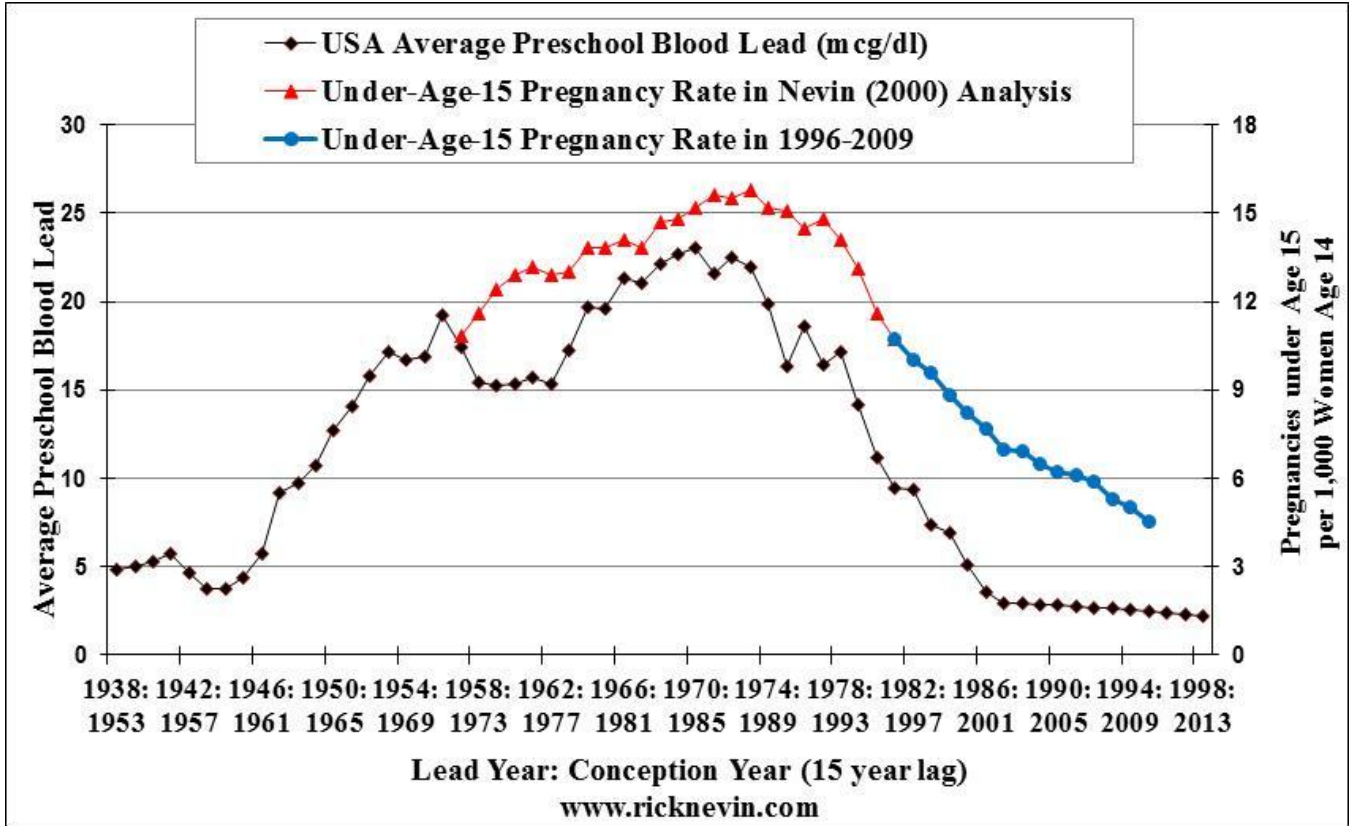
Trends in Lead Exposure, Unwed births, and Abortion

The Gottfredson illustration in *Scientific American* also showed a higher risk of unwed births among women with low IQ, based on data reported in *The Bell Curve* for white youths born in the late-1950s and early-1960s. The notion that unwed births are directly affected by some kind of abstract problem solving ability measured by IQ tests might be dismissed as absurd, but preschool lead exposure is known to reduce IQ *and* impair neurodevelopment associated with impulse control and planning. Moreover, the adverse behavioral impacts of preschool lead exposure could be especially evident when the brain goes through another important stage of neurodevelopment during adolescence.

The Spring 2010 issue of the Guttmacher Policy Review reported that California had the highest teen pregnancy rate in the nation in 1992, but also had the steepest decline in the teen pregnancy rate for any state from 1992 to 2005. This report says that "public health experts in California credit teen pregnancy prevention efforts dating back to the 1990s for the state's record declines", but this claim does not explain why California had the highest teen pregnancy rate of any state in 1992. The high 1992 California teen pregnancy rate, like the high California crime rate in 1992, is consistent with higher per capita gasoline use in California before the state limited the lead content of gasoline in 1977. The large decline in California's teen pregnancy rate since 1992 is also consistent with the large decline in California lead emissions after 1977.

Nevin (2000) showed that lead exposure trends explained most of the temporal variation in pregnancy (birth and abortion) rates for girls under 15 with a best-fit lag of 15 years, and unwed pregnancy rates for girls ages 15-19 with best-fit lags of 17 years for ages 15-17 and 20 years for ages 18-19. These findings were based on teen pregnancy data through 1996. From 1996 to 2010, the USA pregnancy rate for girls under the age of 15 fell by 58%, and the unwed pregnancy rate for ages 15-17 fell by 49%, tracking earlier blood lead trends.

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Legend (top chart):
- USA Average Preschool Blood Lead (mcg/dl)
- Under-Age-15 Pregnancy Rate in Nevin (2000) Analysis
- Under-Age-15 Pregnancy Rate in 1996-2009

Left axis: Average Preschool Blood Lead
Right axis: Pregnancies under Age 15 per 1,000 Women Age 14
X-axis: Lead Year: Conception Year (15 year lag)
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Legend (bottom chart):
- USA Average Preschool Blood Lead
- Age 15-17 Unwed Pregnancy Rate in Nevin (2000) Analysis
- Age 15-17 Unwed Pregnancy Rate in 1996-2010

Left axis: Average Preschool Blood Lead
Right axis: Unwed Pregnancies Ages 15-17 per 1,000 Women Ages 15-17
X-axis: Lead Year: Conception Year (17 year lag)
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The Receding Risk

As the years of peak preschool lead exposure recede into the past, the peak in age-specific MR prevalence has shifted to older students, the peak in age-specific arrest rates has shifted to older offenders, and the peak in age-specific unwed birth rates shifted to older women. The USA incarceration rate also fell from 2000 to 2008 for men under the age of 30, but increased for men over the age of 34.
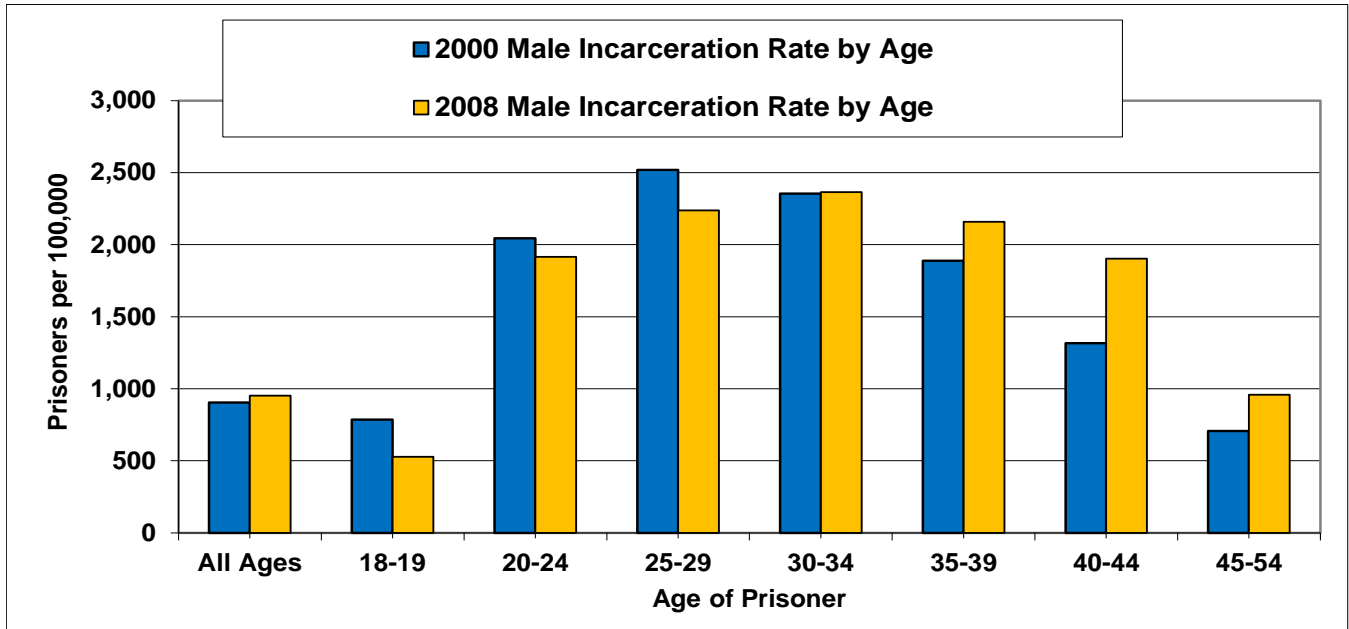
The NLSY data in Gottfredson's illustration are representative of youths "born in the late 1950s and early 1960s", before extensive slum demolition, when urban air lead was near its peak, and city hospitals treated many convulsing children with lead poisoning. Those birth years were associated with the 1976 peak in MR prevalence, the 1979 low in the age-14-17 high school enrollment rate, the rapid rise in unwed teen pregnancy rates in the 1970s, the extremely high arrest rates for juveniles and young adults in 1980, and rising incarceration rates from 2000-2008 for men over the age of 40.

The analysis in *The Bell Curve* controlled for race by first examining the relationship between IQ and behavior among white youths, but the preschool blood lead distribution for white children during the NLSY birth years had to be wider than at any time before or since. Many white children born in the late 1950s and early 1960s lived in new suburban homes with little or no lead paint, in neighborhoods with little traffic and relatively low air lead, but other white children still suffered additive exposure to lead paint hazards and urban air lead in those years. In 1960, 51% of blacks and 30% of whites lived in central cities, where air lead was much higher than in suburban or rural areas. Blacks occupied 56% of substandard central city housing in 1960, but whites still occupied almost half of all 1960 substandard city housing.

The extreme variation in the white preschool blood lead distribution in 1960 profoundly affected NLSY data in *The Bell Curve*, but the statistical method used to calculate IQ from representative norm samples obscures the impact of the blood lead bell curve. By definition, 5% of the 1974 WISC-R norm sample had IQ below 75, and 5% of the 1991 WISC-III norm sample had IQ below 75, but students with mild MR today have lower IQ on the WISC-III because the blood lead bell curve shifted to lower levels between the birth years of the WISC-R

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and WISC-III samples. By definition, average IQ for the NLSY was 100, based on the Armed Forces Qualification Test converted to the IQ scale, but "the odds of various kinds of achievement and social pathology" associated with lower IQ on the WISC-III are not at all comparable to the odds in Gottfredson's [illustration](). Increases in education attainment and achievement and declines in MR prevalence, arrests, incarceration, and unwed pregnancy since 1990 mean that the 1979-1990 NLSY data clearly overstate IQ-related risks for youths today. Moreover, the NLSY data especially overstate risks for those with low IQ, because the risk for those with higher IQ could not have fallen much below the near-zero levels reported in *The Bell Curve*, so the risk for those with low IQ must have plummeted since 1990.

Why Windows? (The Remaining Risk)

In 2009, the National Institutes of Health (NIH) awarded an American Recovery and Reinvestment Act grant to the NYU School of Medicine and the [National Center for Healthy Housing]() for "Preventing Child Residential Lead Exposure by Window Replacement". One specific aim of the NIH grant was the launch of a ["Windows of Opportunity" website]() to explain the many benefits of "lead-safe window replacement", defined as the following four-step upgrade in homes with single-pane windows:

1. Replace all single-pane windows with ENERGY STAR windows

2. Stabilize any significantly deteriorated paint

3. Perform specialized cleaning to remove any lead-contaminated dust

4. Perform dust wipe tests to confirm absence of lead dust hazards after cleanup.

The ["Why Windows]()" segment of the ["Windows of Opportunity" website]() shows how a national lead safe window replacement initiative could [slash energy bills and emissions](), [slash peak-load electricity demand](), [prevent childhood lead poisoning](), [increase home value](), [stabilize neighborhoods hard hit by foreclosures](), and [reduce the long-term federal deficit]().

Double-pane windows became widely used after lead paint was banned in 1978. More efficient ENERGY STAR windows became available in the 1990s. About half of pre-1978 homes have had most or all single-pane windows replaced, but that still leaves **32 million pre-1978 homes with single-pane windows**. Those windows are indicators of lead poisoning risks, because the majority of homes with lead dust hazards have lead paint on interior single-pane window surfaces. Windows have the highest levels of lead in paint of any building component, lead paint chips are common in old window troughs, and friction surfaces on windows create lead dust hazards even in homes without any deteriorated paint. Pre-1978 homes with ENERGY STAR or other double-pane windows do not have these risks because the original windows have been replaced.

Lead paint hazards are not the only cause of preschool lead exposure, but the risk today is largely related to age of housing: 20% of all preschool children living in pre-1940 homes have blood lead over 5 mcg/dl, versus 14% of preschool children in homes with year-built not reported (mostly low-income rental units that are older housing), 10.4% in 1940-49 homes, 6.2% in 1950-59 homes, 4.4% in 1960-77 homes, 2.8% in 1978-89 homes, and just 1.2% in post-1989 homes. The relationship between age of housing and preschool blood lead reflects the historic use of lead in paint and the current risk of lead paint hazards.

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Preschool Blood Lead Prevalence over 5 mcg/dl by Housing Year Built
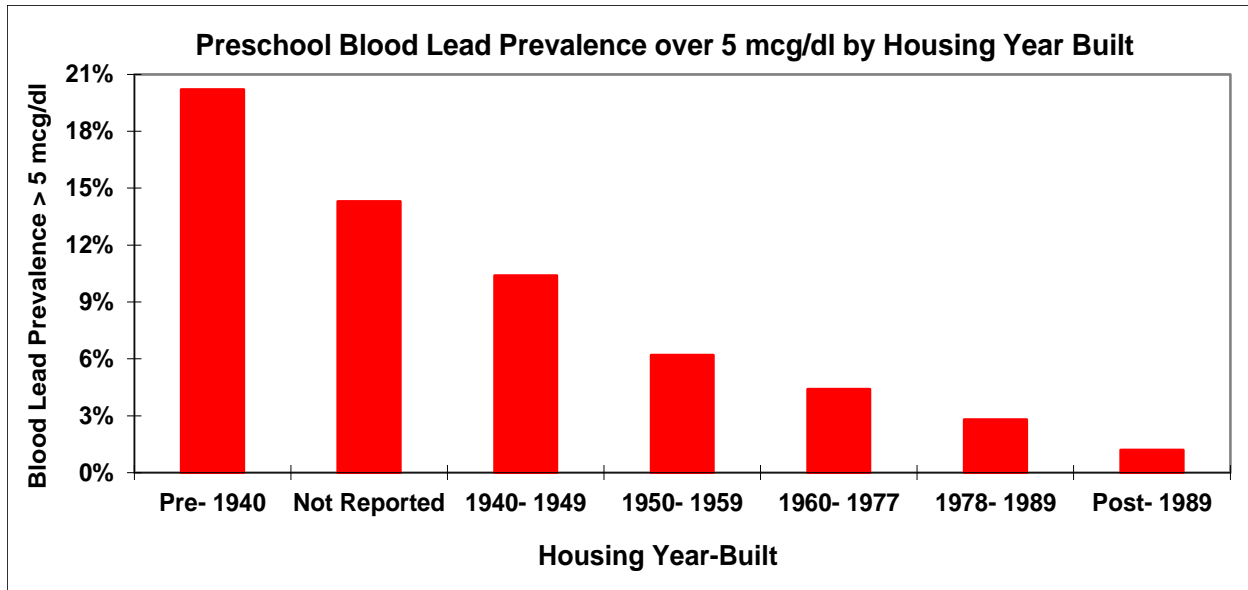
Evidence of Causation

The relationship between lead exposure and subsequent societal trends poses a specific variation of the question addressed by Bradford Hill (1965) in The Environment and Disease: Association or Causation?

> Our observations reveal an association between two variables, perfectly clear-cut and beyond what we would care to attribute to the play of chance. What aspects of that association should we especially consider before deciding that the most likely interpretation of it is causation? (Bradford Hill, 1965)

Nevin (2009) showed that Bradford Hill's classic indicators of causation are all evident in extensive research on the biological effects of developmental lead exposure and the consistent association between preschool lead exposure trends and subsequent trends in "various kinds of achievement and social pathology". **This evidence should lend urgency to eliminating lead paint hazards.** In evaluating this evidence, it is also important to note that Bradford Hill explicitly cautioned against dismissing the improbable:

> In short, the association we observe may be one new to science or medicine and we must not dismiss it too light-heartedly as just too odd. As Sherlock Holmes advised Dr. Watson, 'when you have eliminated the impossible, whatever remains, *however improbable*, must be the truth.' (Bradford Hill, 1965)

It might seem improbable that any single factor could explain so many important societal trends, but there is now overwhelming evidence that "lead poisoning" is the answer to an astonishing number of profoundly important questions.

About the Author: Rick Nevin is an Economist with ICF International, and worked with the National Center for Healthy Housing as a Co-Investigator on the NIH grant for "Preventing Child Residential Lead Exposure by Window Replacement".