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Air Pollutions Impact on Violence During the Commission of a Crime

Erik Cruz
ecruz058@fiu.edu

FLORIDA INTERNATIONAL UNIVERSITY

Miami, Florida

AIR POLLUTIONS IMPACT ON VIOLENCE DURING THE COMMISSION OF A CRIME

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Erik M. Cruz

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To: Dean John F. Stack, Jr.
Steven J. Green School of International and Public Affairs

This dissertation, written by Erik M. Cruz, and entitled Air Pollutions Impact on Violence During the Commission of a Crime, having been approved in respect to style and intellectual content, is referred to you for judgment.

We have read the dissertation and recommend that it be approved.

Rosa Chang

Lisa Stolzenberg

Assefa Melesse

Stewart D'Alessio, Major Professor

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The dissertation of Erik M. Cruz is approved.

Dean John F. Stack
Steven J. Green School of International and Public Affairs

Andrés G. Gil
Vice President for Research and Economic Development
and Dean of the University Graduate School

Florida International University, 2020

DEDICATION

I dedicate this dissertation to my family and loved ones. Your support, patience, and guidance have emboldened me to pursue what is meaningful, not what is expedient.

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ABSTRACT OF THE DISSERTATION

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Erik M. Cruz

Florida International University, 2020

Miami, Florida

Professor Stewart D'Alessio, Major Professor

Recent research links exposure to air pollution with elevated violent crime rates, despite there being no strong theoretical rationale for why air pollution would influence an individual's decision to commit a violent crime. In contrast to prior research that used the violent crime rate as a proxy measure for aggressive behavior, this study employs the probability of a victim being physically injured during the commission of the crime to better quantify the degree of aggressive behavior exhibited by an offender. Results generated in a multilevel analysis of data drawn from 109 U.S. cities show that while carbon monoxide has little effect on the overall level of aggression displayed by the criminal offender, both the offender's sex and race appear to moderate the relationship between carbon monoxide levels and victim injury. These substantive conditioning effects are likely the consequence of both groups being disproportionately exposed to air pollution. Men tend to be overrepresented in jobs that require workers to spend most of the workday outdoors, thereby increasing their exposure to carbon monoxide. Black citizens are also disproportionately exposed to carbon monoxide emanating from vehicle exhaust because they are often forced to dwell in areas located near a major roadway or highway due to persistent residential racial segregation in society. The policy implications of these findings are discussed.

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ABBREVIATIONS AND ACRONYMS

Air Quality Index	AQI
American Lung Association	ALA
Assessment System for Population Exposure Nationwide	ASPEN
Autoregressive Integrated Moving Average Model	ARIMA
Carbon Monoxide	CO
Department of Toxic Substances and Control	DTSC
Department of Transportation	DOT
Environmental Protection Agency	EPA
Federal Bureau of Investigation	FBI
Generalized Least Squares	GLS
Gross Domestic Product	GDP
Hierarchical Generalized Linear Modeling	HGLM
Los Angeles Police Department	LAPD
Los Angeles Sheriff Department	LASD
National Climatic Data Center	NCDC.
National Environmental Policy Act	NEPA
National Incident-Based Reporting System	NIBRS
National Oceanic and Atmospheric Administration	NOAA
Not in My Backyard	NIMBY
Ordinary Least Squares	OLS
Particulate Matter	PM
South Coast AIR Quality Management District	SCAQMD

Uniform Crime Report	UCR
United Church of Christ Commission for Racial Justice	UCC
United States General Accounting Office	GAO

CHAPTER I

INTRODUCTION

Air pollution is composed of an assortment of different mixtures including gases (carbon monoxide, ground-level ozone, etc.), particulate matter (PM), organic compounds (polycyclic aromatic hydrocarbons, etc.), and metals (nickel, manganese, etc.) (Akimoto, 2003; Block & Calderón-Garcidueñas, 2009). The World Health Organization (2013) considers air pollution to be a carcinogen, with it being empirically linked to several health maladies including respiratory disease, cardiovascular disease, immune system deficiencies, and congenital disabilities (Environmental Defense Fund, 2018; World Health Organization, 2018).

Not only is air pollution associated with adverse health outcomes, but research suggests it has a noteworthy effect on human behavior. Studies find that air pollution is correlated with psychotic disturbances and mental health illness (Chen et al., 2018). Research also evinces a relationship between air pollution and increased suicide attempts (Biermann et al., 2009; Yang, et al., 2011), elevated incidents of psychiatric emergencies (Rotton & Frey, 1985), and increased accounts of depression (Guo & Barnett, 2015). Irrespective of how the method of exposure is conceptualized, several recent studies also find that air pollution is correlated positively with elevated occurrences of criminal activity (Herrnstadt et al., 2016; Liu, 2016). It is theorized that air pollution influences an individual's decision-making process adversely, which in turn elevates crime levels (Herrnstadt et al., 2016). While these and other contributions continue to advance the developing literature on crime and air pollution, the proffered causal nexus between air pollution and crime — with an emphasis on violent crime — warrants conceptual revision and a more comprehensive inclusion of salient theoretical variables.

In the current study, previous research on the effect of air pollution on criminal behavior is expanded in several meaningful ways. First, in contrast to prior research that used the frequency of violent crime as a proxy for aggressive behavior, this study employs the occurrence of aggressive behavior during the commission of a criminal offense to measure aggressive behavior. Specifically, aggressive behavior is defined as whether a crime victim suffered any physical injury during the commission of a crime. Physical injuries sustained by a victim are theoretically germane because they are a more appropriate measure of aggressive behavior. While there is ample evidence to suggest that air pollution has the potential to amplify aggression by causing inflammation in the brain (Calderón-Garcidueñas et al., 2009), producing psychological distress (Rotton et al., 1978), altering brain chemistry (Łopuszańska & Makara-Studzińska, 2017), impeding oxygen transport (Dutta et al., 2018), and damaging specific parts of the brain (Barrash et al., 2018), there is no strong theoretical rationale for why air pollution would be a precipitating factor in a person's decision to commit a crime. This form of conceptualization is also better equipped to account for crime type bias when assessing violent behavior because crimes committed with a weapon such as a robbery or aggravated assault typically do not involve actual violence, just the threat of violence (Cook, 1980; Kleck, 1997; Kleck & McElrath, 1991).

Second, most studies conducted to date on air pollution and crime consider a limited range of explanatory variables. Chiefly absent among these variables are the demographic variables of race and sex. This oversight is worth exploring, considering that literature suggests that both sex and race have the potential to influence exposure levels to air pollutants, thereby moderating the relationship between air pollution and violence. Job placement is often stratified by sex. Men are far more likely than women to work outside, thereby increasing the probability and intensity of their exposure to air pollution (Statista, 2019; Torpey, 2017). Additionally, due to persistent residential racial segregation, black citizens are frequently forced to live in areas located near a major roadway or highway (Boehmer et al., 2013; Clark et al., 2014). Living adjacent to a major roadway or highway overexposes resident populations to air pollution from vehicle exhaust (Strosnider et al., 2017).

This study utilizes both micro-level and macro-level data and a Hierarchical Generalized Linear Modeling procedure to evaluate the direct effect of air pollution, specifically the amount of carbon monoxide (CO) measured in the air, on the likelihood of a crime victim being physically injured during a criminal event in 109 U.S. cities. A secondary goal of this study is to determine whether the effect of CO on the likelihood of a crime victim sustaining a physical injury varies by the sex or race of the offender. Are male offenders or black offenders more inclined to physically injure their victims during the commission of a crime in cities with higher levels of CO in the air? As it currently stands, no research conducted to date has examined the relationship between air pollution and aggressive criminal behavior using multilevel data.

The Problem with Air Pollution

Air pollution has the potential to have substantial adverse effects on the wellbeing of humans. Several well-supported studies document the risks associated with exposure to air pollution. These risks include but are not limited to respiratory inflammation

(Wegmann et al., 2005), impaired mental development (Garza et al., 2006), induced hypoxia (Dutta et al., 2018), heart disease (Lee et al., 2014), cancer (Pope III et al., 2002), degenerative neurological diseases (Block & Calderón-Garcidueñas, 2009), increased mortality rate (Ghorani-Azam et al., 2016), and central nervous system impairment (Calderón-Garcidueñas et al., 2015).

The state of air emissions in the U.S. has changed significantly in the last 50 years, with aggregate national emissions declining by 73% from 1970 to 2017 (Environmental Protection Agency, 2018d). This decrease in air pollution emissions was accomplished in large part by the advancement of transportation technologies,[1] energy production technologies,[2] and by the passage of comprehensive legislation.[3] However, it is still important to recognize that this observed decline in air pollution emissions has proven insufficient and has failed to protect large populations in the U.S. from unsafe air conditions (Environmental Protection Agency, 2018d). As of 2019, about 141.1 million Americans live in cities across the U.S. with unhealthy levels of air pollution (American Lung Association, 2019b). This number represents a substantial increase from the 125 million Americans living in such conditions in 2017 and accounts for four in every ten people (41%) in the U.S. This figure is also likely underestimated due to missing data in

[1] Emissions from modern passenger vehicles are roughly 98-99% cleaner than most tailpipe pollutants from vehicles in the 1960s and 1970s (Environmental Protection Agency, 2018d; Environmental Protection Agency, 2018b). There has also been a considerable improvement in the quality of fuel utilized by combustion vehicles (Environmental Protection Agency, 2018b).

[2] The decrease in emissions from energy consumption is mainly the result of more electricity being generated from natural gas rather than from fossil fuels or coal (Energy Information Administration, 2018).

[3] The passage of the Clean Air Act in 1970 and the subsequent amendments to this law established national ambient air quality standards, motor vehicle emission standards, created National Emission Standards for Hazardous Air Pollutants, and set emission standards for facilities such as chemical plants, oil refineries, and aerospace manufacturing facilities (Environmental Protection Agency, 2018d; Environmental Protection Agency, 2017b).

certain regions in the U.S. (American Lung Association, 2019b). Additionally, the primary source of emissions, motor vehicle exhaust, rose in recent years despite an overall decrease in air pollution (Environmental Protection Agency, 2018d; National Oceanic and Atmospheric Administration, 2020). Domestic travel and aviation emissions grew 10% between 2012-2016, nearly offsetting the reduction of air pollution in some areas while leaving other areas located in close proximity to major roads, highways, and airports worse off (Health Effects Institute, 2010).

While aggregate emissions are expected to continue to decrease in the U.S. due to a shift away from energy production via fossil fuels or coal (Energy Information Administration, 2018), exposure levels for many city residents — particularly those who live near major roadways and highways — is not expected to improve for several reasons. First, approximately 80% of Americans currently live in urban areas, and this percentage is expected to grow in the immediate future (United States Census Bureau, 2016a). Not only do most Americans live in urban areas, but the vast majority of major roadways and highways are located in cities or run parallel to cities (Health Effects Institute, 2010). Exhaust generated by cars, trucks, buses, and other vehicles account for over half of all the air pollution generated in the U.S. (National Park Service, 2018). People dwelling in urban areas are thus overexposed to air pollution and will remain vulnerable to air pollution in the foreseeable future due to the high volume of automobile traffic (Strosnider et al., 2017) and to the steady increase in the number of automobiles on the road each year (Statista, 2019).

Second, the U.S. population must contend with other factors such as the average temperature increase in the U.S. and pollution drift. Prolonged warm temperatures act to increase the production of air pollution and amplify its adverse effects (Centers for Disease Control and Prevention, 2016). Research also demonstrates that the U.S. is being impacted by the pollution produced by countries in Asia (Wang et al., 2014). Among these countries are India, Pakistan, and Bangladesh, which all have had daily pollution rates five to ten times higher than the rates found in the U.S. (Health Effects Institute, 2017). These realities establish that the decrease in aggregate air pollution emissions in the U.S. are beneficial but not sufficient to safeguard Americans from air pollution in the near and immediate future.

Overview of the U.S. Highway System

Although the installment of major highways and roadways have fundamentally changed transportation in the United States, it has also fostered an insatiable reliance on automobile transportation. Initially, highways and other major roadways were envisioned to alleviate intra-city traffic and replace many main arteries in overburdened cities (Sherman, 2014). Centralizing the nation's commerce travels over roads specifically designed for a large capacity of cars stitched states, cities, and rural areas together to provide improved market efficiency. The initiative to build the United States highway system was expensive from the onset — reaching annual costs of more than $2 billion from 1921 - 1939 (Dearing, 1942). Most recent figures (2012), put the costs of maintaining federal highways at $105 billion (Federal Highway Administration, 2018). If the 2012 American highway maintenance budget were a sovereign nation, it would have the worlds 61st largest GDP, putting it just above Puerto Rico and slightly behind Hungary (World bank, 2019). Prior to the 1940s, most of the spending for these highways came from the states rather than the Federal government. However, with the passing of the Highway Act of 1956, The Federal Bureau of Public Roads was assigned with planning the routes for the new roads in America, which signified a strong shift from state to federal control. Bringing decision making authority and a large source of funding under one centralized force has its advantages: standardization and increased scale (Sherman, 2014). The federal protocol was primarily focused on inexpensive measures that would attenuate the impact of congestion in cities caused by motor vehicles. While good for cities initially, seeding the capacity to choose the methods and locations of highway construction from local to federal officials resulted in insensitive cultural routes that are often placed near low-income areas and racial minorities due to lower property costs (Fainstein & Fainstein, 1987). Although feedback mechanisms were put in place to communicate discontent with Federal planning, most cities did not protest, as they did not want to jeopardize a 90% subsidy for the cost of new roads.

The push to construct more roads meant a shift towards the suburbanization of cities. In the course of time between 1950-1960, metropolitan areas experienced considerable growth, but cities with highways and major roadways saw less investment in intra-city transportation networks in favor of more inter-community road networks — making suburban areas more accessible and allowing cities to serve as hubs between other destinations (Sherman, 2014). While this alleviated traffic in cities in the short term, it provided overt incentives for big cities to encourage more driving in and around the city. This shift towards suburbanization also resulted in money not being invested in modes of intra-city travel that was not reliant on personal cars and set up an unsustainable system where the number of vehicles will always exceed the road available to drive on.

Since the 1950s car ownership has steadily increased in metropolitan areas throughout the United States, a trend that still continues today (Statista, 2019).

To provide context, at the start of the construction of the interstate highway system (1960), roughly 64% of commuters utilized cars (United States Census Bureau, 2012), which increased to 86.5% by 1990 (73.2% drove exclusively alone) (United States Census Bureau, 2012). In the early 2000s, the percentage of people commuting to work using personal vehicles jumped to 91%, with the general public traveling 11 billion miles per day (United States Department of Transportation, 2017a). This is the result of an increase in available federal funds being used to expand highways, increased availability of affordable vehicles to the general public, and the increased convenience associated with vehicles. The last factor is the most important; the increased convenience and utility associated with cars precipitated the need to construct new roadways, which disincentivized public transportation investment. For example, despite the fact that expanding and maintaining public transportation is vital to alleviating intra-city traffic by reducing the amount of cars of the road, the national highway maintenance budget received 64% more funding —in just maintenance-related costs— than the entire amount of total spending on public transportation systems in the United States in 2012. This disparity in funding has increased precipitously in recent years, with the total maintenance budget for the national highway system increasing from $68.2 billion in 2002 to $105.2 billion in 2012 (United States Department of Transportation, 2016). During the same period, the total spending on public transit systems in the United States increased from roughly $52 billion to $62.5 billion. Figures 1 and 2 show these disparities visually.

Figure 1. Investments in Transportation.

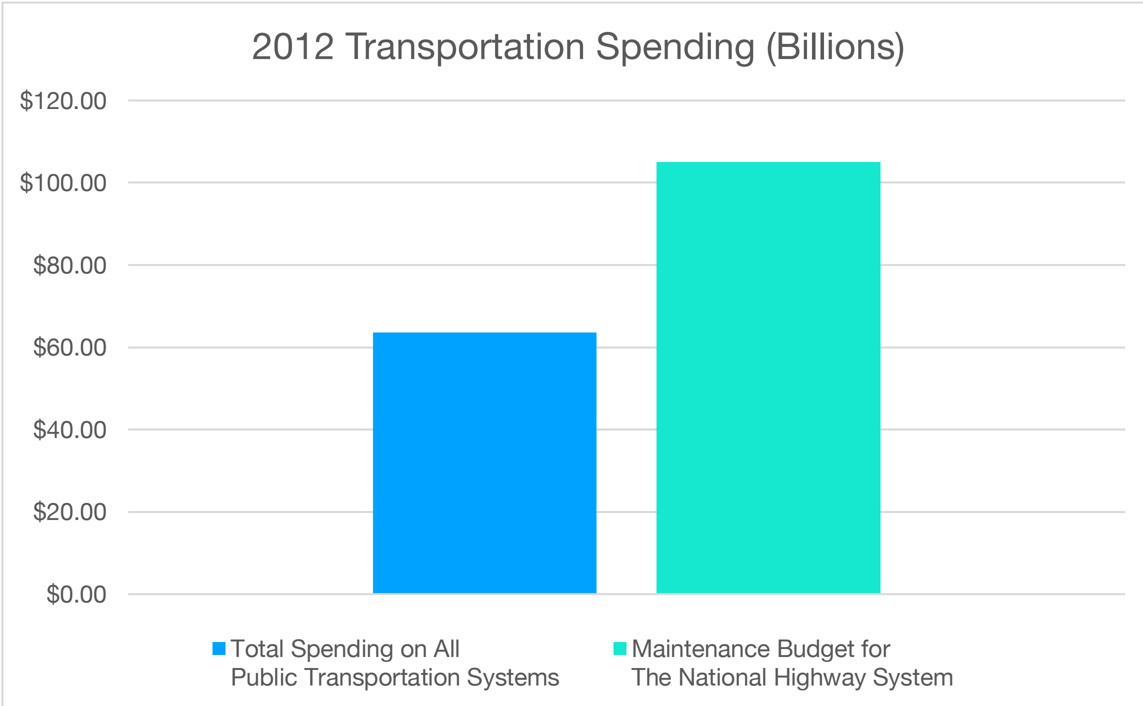
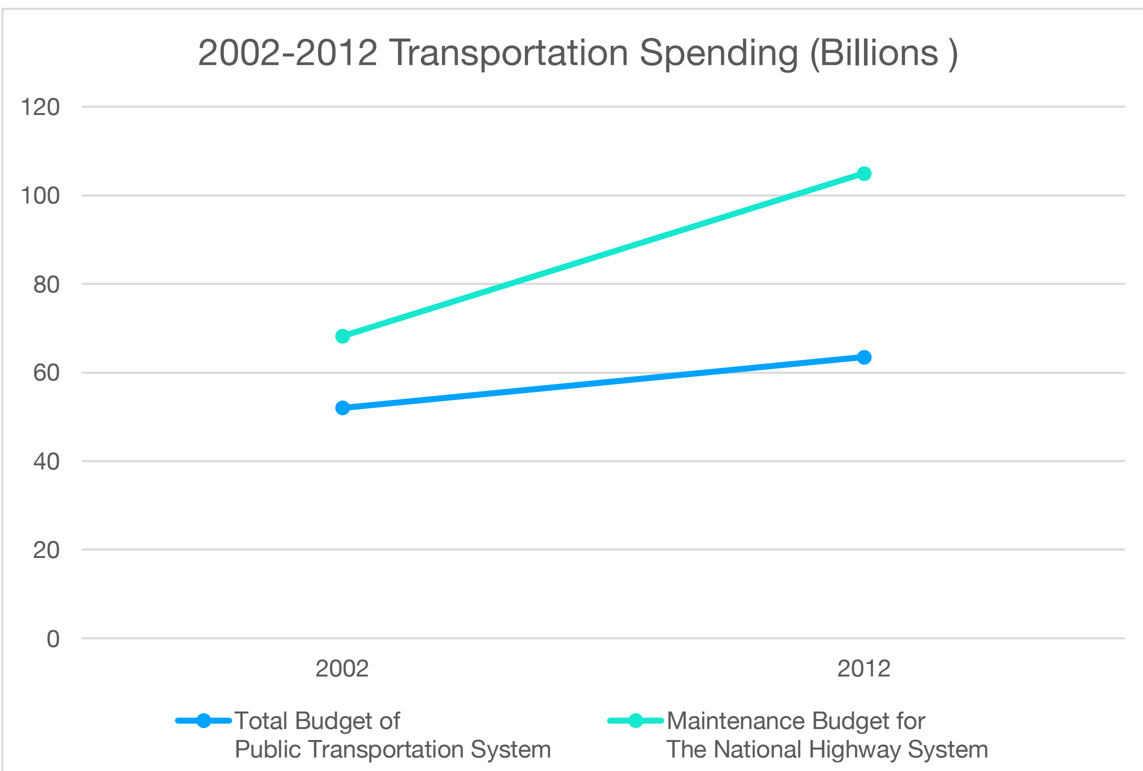


Figure 2. Investments in Transportation (2002 – 2012).



The Highway System

The planning for highways is theoretical and often methodical; roads are built as parts of a long-term plan, generally following a pre-published roadmap displaying overall goals for the construction (Tomazinis, 1967). The federal government establishes stipulations that must be considered during the construction: (1) proper consideration of travel relative to established capacity and (2) the potential costs and benefits of the designed system (Tomazinis, 1967). Success of the first goal is moderately easy to assess — less congestion on previously overburdened roadways. The second goal is a bit more elusive to measure accurately, and thus may not be as inclusive as desired. The prescribed legislation requires that the construction plan focuses on the overall costs to the transportation system, such as elevated congestion on roads that will be designated exits or adjusting traffic light patterns (Sherman, 2014).

While these are practical considerations, they do little to account for the diversity of race and other intangibles that will be affected due to the construction process. The Federal Bureau of Public Roads requires that urbanized areas with more than 50,000 people have a centralized planning body to qualify for federal aid (Hensen & Grecco, 1968), thus centralizing power and creating the appearance of a balanced system. Intuitively, this concept should result in all regions and various subregions getting proper representation and access to transportation funding relative to the area's population. However, this is not done in practice. Due to strained resources, cities regularly have to consider cutting spending to other policy objectives or addressing the transportation needs in only select areas. This often results in routing highways and other major roadways through areas with low socio-economic status and high occupancy of racial minorities — predominately impacting black citizens (Houston et al., 2004).

Race and the Highway System

There is no denying the distinct advantages afforded by the highway system; interstate highways enable the acceleration of suburbanization, making a longer daily commute possible for a steadily growing slice of the workforce (Baum-Snow, 2007). However, issues began to emerge with the placement of these highways. Although the construction of highways enabled the suburbanization of the workforce, it also contained the consequences of preventing inner-city minorities from reaping the benefits of the increased suburbanization. Writing about the disproportionate gains of suburbanization in the 1970s, Rabin (1973) expressed concern about the expansion of the highway system, claiming that the vast majority of the inner-city population that will or may be displaced by the highway system have little means to utilize it (Bullard et al., 2000).

Various perspectives have been put forward in efforts to explain why residents who live in urban areas tend to not have a prevailing voice in determining the location of these interstate and local highways. Leavitt (1970) argues that citizen participation is often impeded due to the vested interest in the successful completion of roadways. To provide evidence for this view, Leavitt references how influential the three largest city developers and contractors in Boston were in the process of getting the extension of the Massachusetts Turnpike into the center of Boston. These actors in effect bought off various constituencies by trading concessions, which ultimately allowed for the highway to be built, in-turn greatly benefiting these city developers and contractors. Bullard et al. (2000) takes a more defeatist outlook, asserting that due to the market demands for less congestion and more viable roadways, urban cores will always be less hospitable due to an excess of car traffic and aggregated accessibility to the interstates. Wright (1997) expresses that many construction projects take the willingness of the local constituencies, but these groups may not always be motivated or properly informed to make prudent decisions. Wright discusses New Orleans's interstate highway 10 extension as an example. During the initial plans, the interstate extension was going to be placed down the Vieux Carre but was successfully contested by a well-organized group of local residents of the French Quarter (Foresta, 1983). Due to this resistance, the project was relocated to be placed down Claiborne Avenue, the heart of the Black Business District (Wright, 1997). This avenue is heavily involved with the historical Black Mardi Gras celebration and was utilized for various community activities. This was permitted due to the route of the highway being placed in neutral ground, which although not being officially used, was heavily involved in local activities for the local black community.

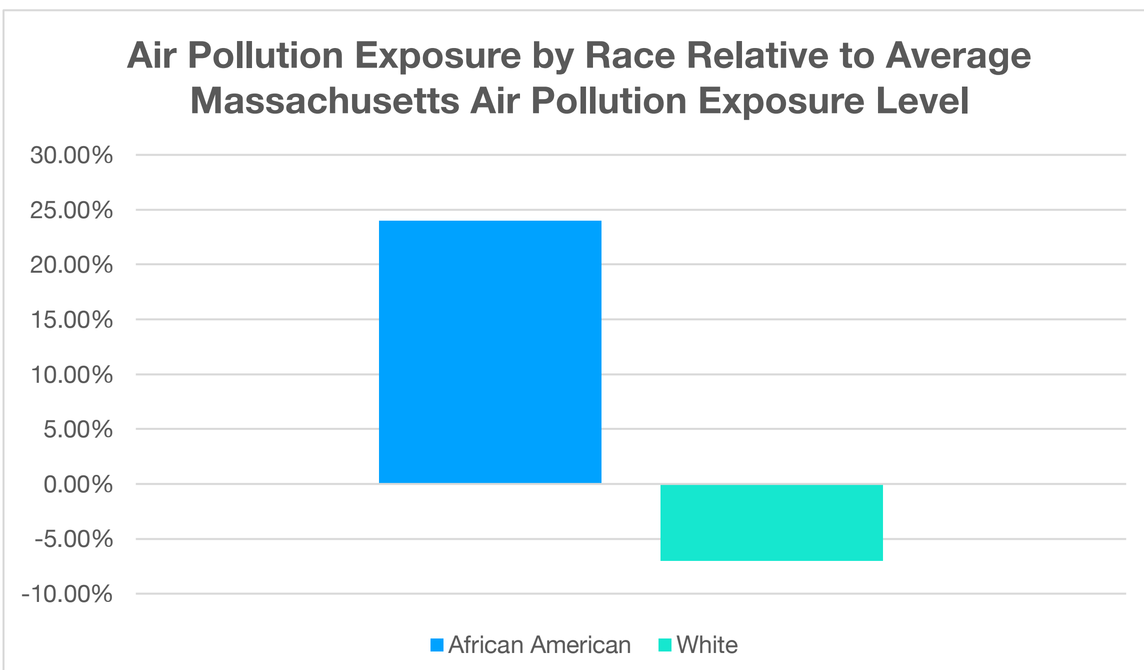
Although providing a presumably utilitarian resource designed to aid movement, much of the negative effects of major roadway and highway placement has been suffered by those in the black community (Boehmer et al., 2013). As mentioned previously, due to residential segregation in the United States (Marshall et al., 2014), black citizens are frequently forced to dwell in areas situated in close proximity to a major roadway or highway (Boehmer et al., 2013; Clark et al., 2014). Living in close proximity to a major roadway or highway significantly increases the overexposure to CO from vehicle exhaust (Strosnider et al., 2017), which is the primary source of CO and accounts for over half of all air pollution in the United States. A recent study by Pratt et al. (2015) confirmed these links while assessing traffic flows in metropolitan areas. During their research, Pratt et al.

(2015) found that air pollution significantly impacts health outcomes of populations with lower socioeconomic status. Interestingly, owning more vehicles and driving alone were linked to a decrease in exposure to air pollution health-related risks, while individuals that owned no vehicles and heavily relied on public transportation or walking as their primary form of transportation experienced higher household exposure levels to air pollution.

Various recent studies have confirmed this overexposure, finding that air pollution in black communities is significantly higher than in non-black communities. Studies dating back to the 1970s have alluded to the consistent trend of black and poor communities living closer to waste sites, landfills, and congested highways due to a lack of affordable alternatives (United Church of Christ, 1987). In a more recent study, assessing structural disparities of urban traffic in Southern California, Houston et al. (2004) found a substantive relationship between vehicle-related air pollution exposure and minority populations. Specifically, Houston et al. (2004) found that minority and high poverty neighborhoods experienced over two times the traffic density when compared to other areas in Southern California, thus exposing those groups to higher levels of vehicle exhaust. These locations also contained higher rates of multifamily housing and a higher proportion of the elderly population.

A recently released analysis by the Union of Concerned Scientists (2019) examined the state of Massachusetts, using the state to exemplify how poor city planning has resulted in routing highways through minority communities. In this analysis, the Union of Concerned Scientists (2019) came to several informative conclusions: tailpipe emissions from motor vehicles were the leading source of air pollution in Massachusetts, and the impact that pollution had on residents differed significantly geographically — African Americans and other minority groups were disproportionally exposed to higher pollution from cars, trucks, and buses when compared to White residents. Furthermore, in zones where air pollution concentrations were more than 200 percent of the Massachusetts average, White residents accounted for 56 percent of the population, despite the fact that white residents constitute about three-fourths of the state's population. In contrast, areas that had air pollution concentrations below the state average had white residents accounting for roughly 81% of the population. Figure 3 visually represents the racial disparity in air pollution exposure.

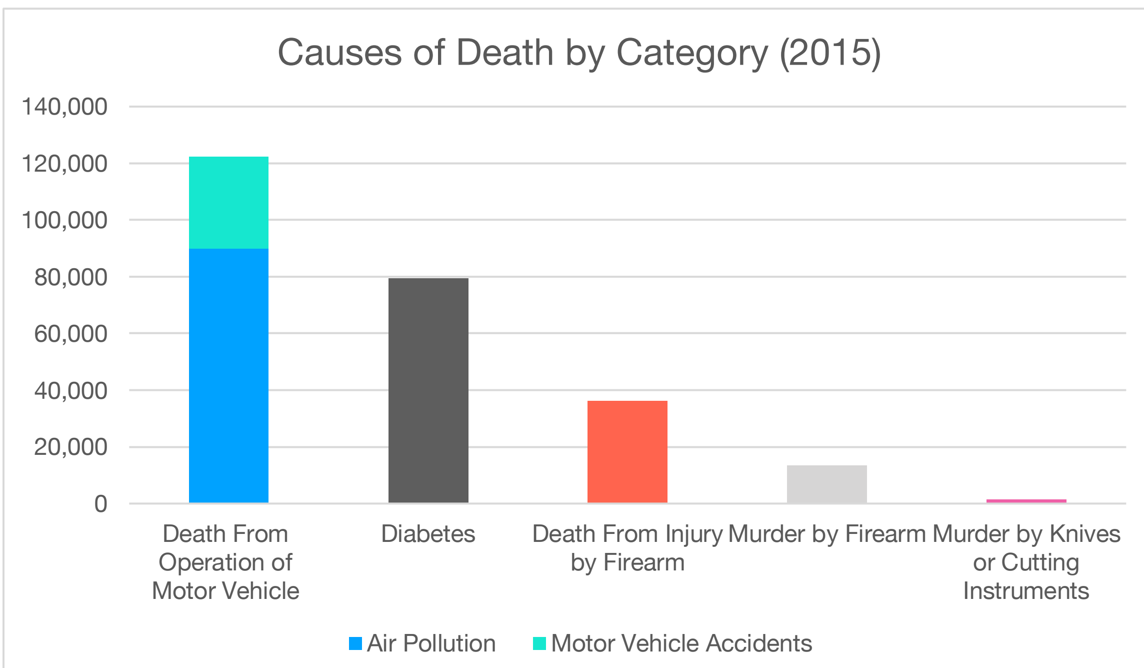
Figure 3. Air Pollution Exposure by Race Relative to Average Massachusetts Air Pollution Exposure Level.



These racial disparities in air pollution exposure have also been demonstrated on a national scale. Utilizing 2000 block group data, Clark et al. (2014) demonstrated that air pollution concentrations varied significantly throughout block groups, largely depending on race and income. This pattern was consistent throughout the United States but was more pronounced in large city areas. Clark et al. (2014) found that environmental inequality levels (levels of exposure to air pollution) were greater than income inequality levels. Furthermore, the authors estimated that reducing the air pollution exposure that nonwhites received to equal the amount experienced by Whites across the United States would decrease Ischemic Heart Disease mortality by 7,000 deaths per year. This would be the equivalent of changing the physical activity status of 16 million Americans from inactive to sufficiently active (Clark et al., 2014).

Thus, given this disparity, it would appear that due to a culmination of racial and economic biased highway construction practices and the externalities of car exhaust, black residents and those who work predominantly outdoors in urban areas are being exposed to a myriad of health risks associated with air pollution, despite many not being able to effectively utilize highways. The incongruity in exposure levels relative to highway utilization alludes to the concept of environmental racism — the notion that one is overexposed to the effects of pollution for no other reason than the immutable factor of race (Pulido, 2016). Weighing the costs and benefits that automotive vehicles provide the nation is usually a typical calculus for those driving; driving provides unparalleled convenience for traveling short distances, but the cost of owning a vehicle can be high, and driving is one of the most dangerous forms of transportation. The direct risk of operating and driving a car in the United States are well known to most drivers — 32,166 people died in car accidents in 2015 (National Highway Traffic Safety Administration, 2017). However, most drivers do not consider the externalities of car exhaust on both drivers and non-drivers. Residents in urban areas, disproportionately minority populations, bear the brunt of these indirect costs. Research done by the Institute for Health Metrics and Evaluation (2018) estimated that 90,000 deaths in the United States could directly be attributed to air pollution in 2015. Although all 90,000 deaths are likely not wholly a direct result of motor vehicle exhaust, it is probable that a large portion of these deaths are related to vehicle exhaust given the firmly documented link between urban pollution due to vehicle exhaust and mortality rates (Clark et al., 2014). Combining these figures would make the operation of motor vehicles more deadly than diabetes, firearms, and knives. Figure 4 displays this disparity in greater detail.

Figure 4. Possible Death Total Due to Motor Vehicle Operation Compared to Other Forms of Death (2015).



The Effect of Air Pollution on Behavior

A large and diverse body of literature has enumerated a range of effects that air pollution has on human behavior. Air pollution is reported to be correlated with psychotic disturbances and mental health illness (Chen et al., 2018). Research also evinces a relationship between air pollution and increased suicide attempts (Biermann et al., 2009; Yang et al., 2011), increased accounts of depression (Guo & Barnett, 2015), and elevated incidents of psychiatric emergencies (Rotton & Frey, 1985). Notably, Yang et al. (2011) found that after controlling for relevant weather and labor market variables, air pollution could explain roughly 23% of the variation in suicides. This effect was strikingly pronounced in suicides via violent methods. It is proffered that air pollution may induce suicidal thoughts because it precipitates various biological as well as psychological effects such as fatigue, an adverse influence on the immune system, and alterations to a person's neurotransmitter system such as serotonin, which influences impulsivity and aggression (Biermann et al., 2009). The relationship between air pollution and mood/mental state alternations can also be explained partially by air pollution possessing the ability to elevate a person's anxiety by raising mortality salience (Greenberg et al., 2003). Although the research covering the effect of air pollution on anxiety is not extensive, it is consistent with other literature concerning the cognitive altering properties of air pollution. For example, Lu et al. (2018) report that the presence of air pollution predicted unethical behavior and higher anxiety levels generally, particularly among women. Power et al. (2015) also produced evidence showing that exposure to air pollution was associated with the occurrence of high anxiety symptoms.

Air pollution is also reported to be linked with poor performance on cognitive ability tests (Forns et al., 2016). Amitai et al. (1998) observed that individuals exposed to CO in Israel had lower scores on memory tests, a decreased ability to learn new skills, a lack of abstract thinking, attention deficiencies, and a dearth of tracking skills. Ebenstein et al. (2016) found that exposure to air pollution was associated with a significant decline in student performance, postsecondary educational attainment, and earnings. A recent study by Heissel et al. (2019) utilized microclimates that exist within zip codes and wind patterns to assess school attendance after controlling for school policies. Their analysis found that children who moved to a school downwind of a major highway had a higher likelihood of behavioral incidents, possessed lower test scores, and had an increased chance of missing school when compared to children that attended schools with similar school characteristics that were not downwind of a major highway (Heissel et al., 2019). Furthermore, a similar analysis found that high levels of CO were associated with reduced school attendance (Currie et al., 2009). Work by Aizer et al. (2018) found that pollution exposure in preschool adversely impacted test scores, and Persico and Venator (2019) demonstrated that residing near industrial plants lowers test scores and increases suspensions. Adverse links between air pollution and cognitive performance in the context of standardized exam grades among students were also documented (Bharadwaj et., 2017).

Other studies show that exposure to air pollution is linked with lower productivity among agricultural workers (Zivin & Neidell, 2012), and call center workers (Chang et al., 2016, 2019). Sager (2016) evinced a relationship in the United Kingdom between pollution and road safety. Recent literature has also documented air pollutions adverse effects in the athletic sports community. Research by Lichter et al. (2017) found that elevated levels of air pollution are negatively associated with the number of passes made by players per match in the German professional soccer league. Moreover, Archsmith et al. (2018) demonstrated that baseball umpires make errors more frequently on days with higher levels of air pollution.

Research further suggests a potential connection between air pollution and aggressive behavior (American Lung Association, 2019a; Biermann et al., 2009; Kelishadi et al., 2015; Pagani et al., 2017). A multi-city analysis by Mapou et al. (2017) found that when accounting for exposure levels and daily crime rates, elevated levels of CO were significantly associated with an increase in assaults. In a multi-year analysis in Columbia, Reyes (2007) found that the elasticity of violent crime regarding childhood pollutant exposure from 1985-2002 was .8 — a very high score indicating a strong relationship. Research by Nevin (2007) evinced a strong correlation between violent crime and preschool pollutant exposure when analyzing high-income countries.

Literature also supports a positive relationship between secondhand cigarette smoke and aggression (American Lung Association, 2019a). Research finds that exposure to secondhand cigarette smoke can elevate antisocial behavior such as skipping school in early childhood (Pagani et al., 2017), fighting, gang affiliation, anger, aggression, and bully-like tendencies in adolescence (Kelishadi et al., 2015). Interestingly, research further finds that exposure to air pollution from secondhand smoke can amplify aggression when an individual is confronted with a problem-solving situation related to interacting with others (Pagani et al., 2017). Research by Rotton et al. (1979) also found that when tasked with shocking fellow research confederates, electric shocks were more often distributed to participants when administrators were exposed to moderately unpleasant odors.

The behavioral modifying effects of air pollution have also been documented in animals, although most of the research is a bit dated. Research by Musi et al. (1993) on adult mice found that short term one-hour exposure to elevated levels of air pollution triggered their fight response far more often than their flight response when paired. Similar findings were revealed by Petruzzi et al. (1995), documenting that the period between attack episodes was shortened and that subordinate mice had an increased likelihood of exhibiting aggressive-defensive rejoinders. Essentially, subordinate mice were standing up to dominate mice rather than retreating — thus also triggering the fight rather than flight response. More recent studies can lend limited support to this research. Soulage et al. (2004) found that short-term air pollution exposure elevates stress levels and aggressive behavior in rats. Similarly, Allen et al. (2013) observed a link between exposure to air pollution and increased impulsivity among mice. Lastly, research by Chen et al. (2003) found that exposing infant rhesus monkeys to air pollution increased their readiness to be roused into a state of excitement.

Air Pollution, Mechanisms, and Possible Explanations

How air pollution influences the likelihood of aggressive behavior transpiring is rather difficult to state definitively, as the reported relationship between these elements can be the result of a multitude of causal mechanisms. These pathways include fostering inflammation in the brain, psychological distress, altering brain chemistry, impeding oxygen transport, and damaging specific regions of the brain.

First, neuroinflammation has been linked to elevated aggressive traits in humans (Beurel & Jope, 2014) and amplified aggressive behavior in animals (Rammal et al., 2008). The specific routes that air pollution may take to produce neuroinflammation are numerous and difficult to identify. Some of the most common mechanisms include the penetration of lung tissue and capillaries by toxic compounds (Silva, 2006) that are transported via the vascular system (Pope III et al., 2002), oxidative stress (Gurgueira et al., 2002), and by the interaction between toxic compounds with proteins and lipids in the body (Cho et al., 2001).

It is theorized that raised levels of neuroinflammation are associated with elevated levels of aggression (Coccaro et al., 2014) by way of transferable inflammation from other body parts (Block & Calderón-Garcidueñas, 2009; Calderón-Garcidueñas et al., 2009). Inhalation of air pollution may induce pulmonary oxidative stress and precipitate inflammation of nerve tissues in the body and the brain (neuroinflammation) (Brook et al., 2004; Calderón-Garcidueñas et al., 2009). This effect is present even in short-term exposure to air pollution (Levesque et al., 2011; Van Berlo et al., 2010). The effect of air pollution on human lungs produces an inflammatory response that is consistent with studies conducted on animals in cellular models (Brain et al., 1998). Air pollution may also mediate a pulmonary inflammatory response via oxidative stress (Kelly, 2003). Toxicological studies indicate that air pollution can produce oxidative stress and neuroinflammation via the central nervous system, causing nervous system disease (Moulton & Yang, 2012). This inflammation of nerve tissue in the body and the brain is consistent with research on both human and several animal populations including mice, rats, and dogs — all demonstrating that air pollution contains components that cause neuroinflammation (Levesque et al., 2011).

Air pollutions oxidative potential must be highlighted, as it represents one of the mechanisms by which the body's inflammatory response can result in neuroinflammation (Brook et al., 2004). Oxidative stress occurs when the production of pro-oxidant substances, which are found in air pollution (Dergham et al., 2012), overwhelm an individual's natural antioxidant system (Delfino et al., 2011). Oxidative stress is by no means confined only to lung tissue, which makes experiencing this stress on the body problematic and can result in the spreading of inflammation to other organs (Gurgueira et al., 2002). Air pollution exposure is also associated with elevated levels of markers for lipid and protein oxidation in blood (Brook et al., 2004). Air pollution can act as a pro-oxidant for lipids and proteins or act as free radicals within the body after the body's natural antioxidant mechanisms are overwhelmed (Delfino et al., 2011). Pulmonary inflammation and other bodily responses are caused partly by this increased production of free radicals that accompanies oxidative stress (Kelly, 2003). Oxidative stress triggers specific transcription factors such as uclear factorκB and activator protein-1, which control the genes for pro-inflammatory mediators (Brook et al., 2004). Exposure to high concentrations of air pollution can also promote the presence of neocortical hyperphosphorylated tau and frontal cortex plaque using amyloid-β, both of which are indicative of oxidative stress and neuroinflammation (Calderón-Garcidueñas et al., 2012).

In a study on mice, Rammal et al. (2008) demonstrated a causal relationship between oxidative stress and behavior in male mice via the administration of a resident/intruder test. The basic premise of the experiment is to see how the resident/incumbent mouse reacts when a new mouse is introduced into the home cage of the resident mouse (Heyes & Saberian, 2015). This test is administered to assess the intensity of the incumbent's reaction to their space being invaded — in part testing the excitability of the incumbent mouse. The analysis by Rammal et al. (2008) revealed that there was a substantive relationship between induced oxidative stress and both measures of aggression used: time elapsed to the first attack by the incumbent mouse and the number of attacks executed in a five-minute period. In another study on rats, Van Berlo et al. (2010) found that exposing rats to air pollution for a duration of two hours resulted in a precipitous rise in pro-inflammatory factors in the brain.

It is also plausible that air pollution prompts a state of psychological distress due to unpleasant emotional states or physical discomfort accompanied with exposure, thereby eliciting aggression. For example, Rotton et al. (1978) found that malodors were correlated positively with negative ratings of paintings and photographs. In a later study, Rotton et al. (1979) documented a curvilinear relationship between malodor and aggression. The slope of the relationship between unpleasant odors and aggression ascended rapidly as the unpleasantness of the smell increased, peaked when the air was moderately poor smelling, and declined as the air became more noxious. Literature from various disciplines documents the link between physical discomfort and aggression (Alzheimer's Association, 2019).

Although a less direct connection, it is possible that air pollution can induce psychological distress through its documented causal link with depression (Perera, 2016; Wang et al., 2014). There is a strong correlation of emergence between depression and anxiety (Anderson & Hope, 2008) — which is noteworthy because anxiety has been documented to be positively associated with aggression (Neumann et al., 2010). Research by Neumann et al. (2010) suggests that the link between anxiety and aggression is likely derived from overlap between circuitries and neurochemical systems that govern the brain. When emotional regulation is disturbed, it manifests with stark oscillations in anxiety levels. These spikes in anxiety often result in elevated levels of aggression (Neumann et al., 2010). Thus, it can be reasonable to assume that a precipitously high amount of air pollution can cause induced aggression via the causal link between air pollution and depression — which often results in elevated levels of anxiety. Although not well documented, air pollution has the potential to directly increase anxiety levels, without the need of depression acting as a mediator (Power et al., 2015).

Air pollutions impact on psychological distress may also be related to its ability to impact monoamine neurotransmitters. For instance, an analysis conducted by Kinawy (2009) exposed rats to the fumes of either leaded or unleaded gasoline, finding that both groups exposed to gasoline exhibited more aggressive behavior than the control group. An ensuing inspection of the rat brains revealed that the rats exposed to the gasoline fumes showed variations in the levels of serotonin, dopamine, and norepinephrine. Uboh et al. (2007) provides some evidence that air pollution may be causally linked to elevated levels of testosterone among male rats. This is relevant given testosterones link to aggression (McDermott et al., 2007).

A third possible pathway considers air pollution's documented ability to influence brain chemistry - particularly serotonin levels - which can result in aggressive behavior. The effect of air pollution on serotonin has varied, being documented to both decrease (Łopuszańska & Makara-Studzińska, 2017) and increase its presence in the body (Wallach, 1986).[4] Serotonin is a vital neurotransmitter that helps regulate information transfer between the brain and nervous system (University of Cambridge, 2011). One of serotonins primary function is the regulate impulsive and aggressive behavior (Coccaro et al., 2011). Lower levels of serotonin in the bloodstream are associated with a diminished capacity to control impulsive and aggressive behaviors (Hennig et al., 2005). The

[4] Even short periods of exposure to air pollution have been documented to cause fluctuations of serotonin levels in the bloodstream (Krueger et al., 1963; Krueger & Kotaka, 1969).

literature suggesting that air pollution can lower serotonin levels is moderately developed. Exposure to air pollution is reported to cause a decrease in the neuro-transfer of serotonin (Łopuszańska & Makara-Studzińska, 2017), specifically between serotonin receptors (Ahangari, 2015), thereby decreasing levels of serotonin and elevating the likelihood of aggressive behavior (Hennig et al., 2005).

A decrease in serotonin seems likely to prompt aggressive behavior, as the phenomenon is well documented (Ahangari, 2015; Łopuszańska & Makara-Studzińska, 2017) and has an extensive body of literature supporting the link between low levels of serotonin and incidents of aggression (Dennis et al., 2013; van Honk et al., 2010). It is speculated that low levels of serotonin not only make information transfer between various brain regions of the emotional limbic system and the frontal lobes weaker when compared to normal serotonin levels, but that low levels of serotonin also impedes the ability of the brains prefrontal cortex to regulate emotional responses such as anger (University of Cambridge, 2011).

In an analysis conducted by Crockett et al. (2013), human subjects had serotonin levels manipulated within a social experimental setting. The analysis evinced that serotonin-depleted participants were more likely to be retributive, punishing those whom they perceived to have treated them unfairly and took longer than the control group to accept what the researchers labeled as fair exchanges. Siegel and Crockett (2013) conducted a meta-analysis containing 175 samples on the relationship between serotonin and human behavior, highlighting that there is a reliable and documented relationship between serotonin and aggression. Hansenne et al. (1999) state that serotonin levels are positively correlated with risk-adverse behavior in humans. This suggests that individuals with low serotonin levels have a lower probability of attempting to avoid or retreat from an aggressor given a flight or fight scenario. The increased proclivity towards aggression with decreased serotonin levels has been documented among children (Frankle et al., 2005) and rhesus monkeys (Faustman et al., 1993).

Air pollution has also been documented to have the ability to increase levels of serotonin (Wallach, 1986), thereby potentially causing serotonin irritation syndrome.[5] Serotonin irritation syndrome is associated with heightened levels of serotonin in the brain and can induce behavioral changes, especially in the form of agitation, hypomania, and anxiety (Volpi-Abadie et al., 2013). It is possible that this state of anxiety can induce a flight or fight response (Zinzow & Jeffirs, 2018), wherein an individual faced with fear or perceived danger can exhibit aggression given this state of arousal. This increase of serotonin can also disturb emotional regulation, which has been documented to increase aggression and acts of violence (Neumann et al., 2010).

Lastly, exposure to an air pollutant such as CO can damage specific parts of the brain by hindering oxygen transport. The inhalation of CO by the lungs enables CO to be absorbed into the blood, which in turn can engender hypoxia by inhibiting oxygen transport (Blumenthal, 2001). This oxygen deficiency can impair attention, concentration, visual processing, and disrupt the brain and other vital organs from functioning properly (Hopkins & Woon, 2006). For example, Amitai et al. (1998) found that study participants exposed to CO had attenuated scores on neuropsychological tests that assessed memory, lacked the ability to learn new skills, possessed shorter attention spans, had reduced

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[5] Serotonin irritation syndrome is sometimes referred to as serotonin syndrome.

tracking skills, and showed decreased abstract thinking when compared to an unexposed control group. Empirical evidence derived from toxicological studies suggest that exposure to high levels of air pollution can damage various parts of the brain including tissues from the frontal cortex region, which is an area of the brain that is responsible for executive functions such as judgment, decision-making, and inhibition (Barrash et al., 2018).

Chapter Summary

Air pollution is comprised of mostly gases, particulate matter, organic compounds, and metals. The World Health Organization considers air pollution to be a carcinogen, being empirically linked to several health maladies including respiratory disease, cardiovascular disease, immune system deficiencies, and congenital disabilities. Air pollution exposure has also been documented to increase instances of psychotic disturbances, mental health illness, suicide attempts, accounts of depression, and criminal activity. Extant literature has inferred a link between air pollution exposure and a prospective criminal's decision-making process, which in turn elevates criminal activity. The state of air emissions in the U.S. has changed significantly in the last 50 years, with aggregate national emissions declining by 73% from 1970 to 2017. Despite this decrease, as of 2019 roughly 141.1 million Americans currently live in cities across the United States with unhealthy levels of air pollution. This number represents a substantial increase from the 125 million Americans living in such conditions in 2017 and accounts for four in every ten people (41%) in the United States. Thus, due to air pollutions ubiquity in urban areas, identifying its primary source and where it is most concentrated is of great importance.

Although the sources of urban air pollution are diverse, exhaust produced by cars, trucks, buses, and other vehicles account for over half of all air pollution generated in the United States. Due to persistent residential racial and economic segregation in our society, black citizens are frequently compelled to dwell in areas situated near a major roadway or highway. Living adjacent to a major roadway or working predominantly outdoors is problematic because it enhances the likelihood that an individual will be overexposed to CO from vehicle exhaust.

Research suggests a potential connection between air pollution and aggressive behavior. How air pollution influences the likelihood of aggressive behavior transpiring is rather difficult to state definitively, as the reported relationship between these elements can be the result of a multitude of causal mechanisms. These pathways include fostering inflammation in the brain, psychological distress, altering brain chemistry, impeding oxygen transport, and damaging specific regions of the brain.

CHAPTER II

AIR POLLUTION AND CRIME

Building on research suggesting that air pollution can influence behavior—specifically aggressive behavior—researchers have begun to investigate the possibility that exposure to air pollution is causally related to the occurrence of crime. Lu et al. (2018) evaluated the relationship between air pollution and several crime types as a means to produce a more nuanced understanding of the connection between air pollution and mortality. This analysis was comprised of three studies. The first two studies examined data from the Uniform Crime Report (UCR) and assessed seven major crime categories: murder and non-negligent manslaughter, forcible rape, robbery, aggravated assault, burglary, larceny-theft, and motor vehicle theft. The crime data was combined with concentrations of various air pollutants from the Environmental Protection Agency, and several germane control variables: city population, law enforcement officers per capita, economic indicators, and city-level demographic variables. The final study combined observation data with self-reported participant journal data.

Following work conducted in previous studies, Lu et al. (2018) postulated that due to air pollution's documented causal link with high anxiety levels (Power et al., 2015), air pollution might be able to produce unethical behavior. This is due to high levels of anxiety being a documented facilitator of unethical behavior; both violent (Corrigan & Watson, 2005) and non-violent (Kouchaki & Desai, 2015). After conducting three separate analyses, Lu et al. (2018) found air pollution to be positively predictive of unethical behavior —with anxiety mediating this effect— and be positivity related to various crime types including murder, rape, robbery, assault, larceny, and motor vehicle theft.

Work conducted by Stretesky and Lynch (2004) also directly contributes to the purported link between air pollution and violent crime. Similar to research by Lu et al. (2018), Stretesky and Lynch (2004) utilized a combination of UCR data, United States Census Bureau data, and air pollution concentration data from the EPA to test the effect that air pollution has on behavior. In particular, Stretesky and Lynch (2004) wanted to assess if air pollution had any impact on violent crime and if air pollution's influence was felt disproportionally higher in areas that suffered from resource deprivation. Resource deprivation was represented as a principal component index that was comprised of several indicators associated with community disadvantage: black population percentage, natural log of median family income, and a Gini index that consisted of income inequality, percent of families below the poverty line, and the rate of families with females as the head of house (Stretesky & Lynch, 2004).

The analysis investigated the link between air pollution levels and crime rates in 2,772 U.S. counties and utilized air-lead levels to represent air pollution. Stretesky and Lynch were able to get nation-wide coverage by using a cumulative exposure projected lead measure. Air-lead level data was generated in the contiguous United States for the year 1990 utilizing the Assessment System for Population Exposure Nationwide (ASPEN), which is based on a Gaussian dispersion model. The generation of air-lead level data allows for a theoretical analysis of the whole United States but may yield less accurate results due to the underlying assumptions of the model. In accordance with their hypotheses, air pollution influenced both violent and property crime. Specifically, they found that air pollution concentrations accounted for 32% of the variance in violent crime rates. Their findings also showed that the association between elevated violent and property crime rates and air pollution concentrations were most active in counties that have high levels of resource deprivation. This suggests that racial minorities and those living in poverty are experiencing the most severe adverse effects of air pollution, possibly due to higher overall levels of air pollution exposure.

Also attempting to expand the literature on air pollution and behavior, Younan et al. (2018) conducted a longitudinal study to examine if increased exposure to air pollution influenced the trajectories of delinquent behavior. The behavior data was recorded as part of a more extensive study aimed to measure risk factors for antisocial behavior among adolescents. The dataset contained almost 700 children, ages 9-18, from a cohort of twins from 1990-1995. Air pollutant data represented monthly ambient air concentrations in Southern California. Utilizing multilevel mixed-effects models, Younan et al. (2018) found that air pollution exposure was significantly associated with increased delinquent behavior after adjusting for within-family/within-individual correlations. The authors go on to suggest that if these results are replicated in other samples, air pollution may be serving as a confounding factor in criminal behavior that may go unnoticed due to high levels of air pollution exposure being linked to poverty, neighborhood quality of life, and criminal violence (Younan et al., 2018).

In an analysis of the cap-and-trade market, Li (2018) attempts to make a case that employing a cap-and-trade system can attenuate the adverse effects of air pollution that are experienced by cities and save cities money in crime-related costs. Although Li (2018) remains unsure as to what mechanism within the body causes air pollution to affect criminality, the author speculates that the relationship may have its roots potentially found in psychological, biological, or economic literature. This analysis utilizes UCR crime data and air pollutant data from the National Oceanic and Atmospheric Administration (NOAA) from 1998-2008. In total, this sample covered 1,412 counties in 37 states. Although the effect sizes were modest for most violent crime types, Li (2008) demonstrated that air pollution does have some predictive ability regarding violent crime. For example, Li's (2008) analysis found that the cap-and-trade program was associated with a 2.5% decrease in assaults, a 7.9% decrease in robberies, a 6.6% decrease in rape occurrences, and no statistically discernible effect on murder. Informal estimates are presented in the article, which indicated that air pollution is potentially costing the Eastern States in the United States over one billion USD in societal costs per year.

Rotton and Frey (1985) also inquired as to how air pollution — and more broadly atmospheric conditions— influence the prevalence of violent episodes. This analysis was also undertaken, in part, to test the generalizability of laboratory studies that documented social effects of air pollution. Several previous studies (Rotton et al., 1978; Rotton et al., 1979; Rotton, 1983) documented adverse effects that foul-smelling chemicals had on undergraduates. For example, in comparison to students that were not exposed to foul-odors, students that were exposed were more likely to describe their moods in more gloomy terms, indicating a disliking for those in the control group, rated their surroundings more poorly, exhibited discontent towards opinions on social stimuli, and opted to spend less time in the testing environment (Rotton & Frey, 1985).

To conduct their analysis, Rotton and Frey (1985) utilized dispatch data from the Dayton, Ohio police department for the years 1975 and 1976. This data was combined with air pollution data from a local environmental protection agency and several meteorological conditions published in the form of monthly summaries by the NOAA: temperature, relative humidity, percentage of sunshine, barometric pressure, wind speed, fog, heavy fog, thunderstorms, and smoke/haze. The analysis employed a two-stage regression structure, utilizing a combination of ordinary least squares (OLS) and generalized least squares (GLS). Subsequently distributed lag (Box-Jenkins) analyses were conducted to construct an Autoregressive integrated moving average (ARIMA) model. The analysis indicated that higher levels of air pollution, along with several atmospheric conditions, were positively related to violent episodes.

In a study on the relationship between traffic and crime, Beland and Brent (2017) analyzed the effects of traffic jams on police incident report data in Los Angeles from 2011- 2015. This study is of particular importance, as it expands on previous work that discusses the costs associated with areas most affected by motor vehicle travel — primarily the psychological and health costs. Also, considering that the leading producer of CO is the combustion engine, it is reasonable to assume that the traffic exhaust that these individuals are presumably exposed to can serve as a proxy for likely exposure to air pollution. Beland and Brent's (2017) study intended to assess if traffic is predictive of domestic violence — a specific violent crime that has been documented to have its prevalence influenced by unexpected adverse stimuli (Card & Dahl, 2011). The police incident data utilized in this study was obtained from the Los Angeles Police Department (LAPD) and the Los Angeles Sheriff Department (LASD); allowing for the analysis to account for the crime incidents in the City of Los Angeles as well as all incorporated cities and unincorporated areas of Los Angeles County. The incident data contained measures of assault, domestic violence, property crime, homicide, and an aggregate measure for all other crime. The Los Angeles traffic data was obtained from the California Department of Transportation. The Los Angeles County area has over 500 unique stations that collect traffic data, enabling a study like this to be conducted. Several weather-related variables were controlled for: rain, maximum temperature, and wind speed.

Through the use of a Poisson count model, Beland and Brent (2017) found that extreme traffic conditions increase the occurrence of domestic violence by approximately 6%. Extreme traffic conditions were also predictive of the overall crime rate, but not of homicides or assaults. This finding is similar to Bondy et al. (2018), which found that air pollution was predictive of the overall crime rate, but not most violent crime types.

Bondy et al. (2018) analyzed London's air quality, as a means to assess the predictive power that air pollution may possess in provoking criminal behavior. This analysis leverages ambient air pollution concentrations in the form of the Air Quality Index (AQI)[6]. The analysis also accounted for over 1.8 million criminal offenses recorded in London during the years 2004-2005. The study included several relevant atmospheric and social variables and utilized a panel fixed effects model and an instrumental variable model. The use of the instrumental variable model sets this analysis apart from the

[6] The AQI is a composite score assessing the presence of various air pollutants: carbon monoxide, ground-level ozone, particle pollution (PM), sulfur dioxide, and nitrogen dioxide (Environmental Protection Agency, 2019b). The AQI produces a score ranging from 0-500, with 0-50 representing good air quality, 51-100 representing moderate air quality, 101- 150 being unhealthy for sensitive groups, and anything exceeding 150 being considered unhealthy (Environmental Protection Agency, 2019b).

previously mentioned studies due to the use of wind direction as an exogenous indicator to determine which areas may be most impacted by the presence of air pollution. The influence of wind direction is constructed based on wind flow direction between five different regions: Central, North, South, East, and West. Bondy et al. (2018) constructed the variable this way due to the large geographical size of London. Due to the large area, wind patterns may carry air pollution from different sources originating in various locations from both in and around the city, which should presumably precipitate the wind to have meaningful impacts on air pollution concentrations. Although not without its limitations, a handful of other notable studies have utilized some form of a novel wind-direction based model to test the effect of air pollution on the general public (Herrnstadt et al., 2016; Heyes & Saberian, 2015).

The analysis by Bondy et al. (2018) found that exposure to elevated levels of air pollution was associated with elevated crime rates. Specifically, the research revealed that for every additional 10 Air Quality Index (AQI) points, the overall crime rate increases by about 1%. Further, areas exposed to an AQI above 35 (good air quality) have about, on average 3% more crime. To stress the link between air pollution and crime, Bondy et al. (2018) highlight that on London's most polluted day (AQI = 103.6; unhealthy for sensitive groups), crime rates were about 8.5% higher than London's days with the lowest level of air pollution (AQI=9.3). However, it should be noted that while the aggregate crime rate was positively correlated with the AQI, these predictive qualities were not present for the violent offenses that were tested: murder, assault causing severe bodily harm, and robbery. These findings seem to indicate that while air pollution may increase non-violent criminal offenses — whether it be due to physiological or psychological induced change — air pollution does not provide the impetus to commit bodily harm. This finding coupled with Beland and Brent's (2017) research seems to suggest that while air pollution may have a measurable impact on human behavior related to general criminality, its effects may be limited regarding the calculus that determines if a violent act should be committed. Alternatively, this may also suggest a fundamental difference in the way prospective criminals view violent and non-violent criminal activities.

Heyes and Saberian (2015) also utilized a wind direction method of exposure in Los Angeles to assess the relationship between air pollution and violent crime. In short, this analysis aimed to establish support for a causal link between short-term variation in air pollution levels and the commission of violent crime. The analysis used daily crime data from the FBI that covered law enforcement agencies within Los Angeles County. Due to the interest of testing the aggression inducing properties that are documented by other disciplines (Coccaro et al., 2011; Petruzzi et al., 1995; Soulage et al., 2004), Heyes and Saberian (2015) only focus on two crime types: assault and larceny-theft. The assault category is an aggregate count of all aggravated and non-aggravated assaults. Air pollution data were obtained from the South Coast AIR Quality Management District (SCAQMD), an air pollution control agency that covers all of Orange County and the urban areas of Los Angeles (Heyes & Saberian, 2015). Several weather conditions were collected from the NOAA: maximum temperature, minimum temperature, humidity, percentage of cloud coverage from sunrise to sunset, and wind speed.

Utilizing ordinary least squares regression (OLS) and an instrumental variables method, Heyes and Saberian (2015) found that when using wind direction as the method of specification, assaults increased by 17%, but no corresponding discernible effect was documented for larceny-theft. These results led the authors to reason that the findings are likely due to a fundamental difference between violent and non-violent crimes. Heyes and Saberian (2015) claim that violence and aggression are akin to a sudden loss of temper — a sudden spike of aggression, impulsivity, and irritability that should inhibit self-control. This immediate and unpremeditated loss of control is primarily subjected to swings in emotion and mood —the faculties that air pollution has been documented to be able to affect adversely. Conversely, larceny is much less impulsive and far more likely to be planned and thus, less likely to be subjected to impulses.

While their analysis is well written, insightful, and soundly reasoned, Heyes and Saberian (2015) may have potentially erred in their theoretical presuppositions due to their reliance on assaults to represent aggression levels. It can be reasonably argued that the use of non-aggravated assault to partially represent aggression is problematic, as unlike aggravated assault and other violent crime types, there is no actual readily perceived display of physical aggression in non-aggravated assaults. The use of crime incidents that distinctly do not contain actual violence can be misrepresentative if the crime incidents in question are being used as a proxy for aggression. Although often used interchangeably and as synonyms in several studies (Herrnstadt et al., 2016; Heyes & Saberian, 2015; Tiihonen et al., 2017), aggression, impulsiveness, and a general loss-of-control are not exact proxies for one another— but rather closely related. For example, while it is reasonable to assume that non-aggravated assaults involve the presence of increased impulsiveness as highlighted by Heyes and Saberian (2015); it does not definitively suggest an abnormally high level of aggression.

Presumably, the underlying rationale that Heyes and Saberian (2015) used for combining both assault crime types into one category is as follows: both crime types are very similar and, in all likelihood, require some abnormal level of aggression. However, If we are to assume that an air pollution-induced spike in aggression caused the crime to be committed, then the following question presents itself: how can it be assured that air pollution provided the imputes for non-aggravated assaults to occur if the main distinction between aggravated and non-aggravated assault is the level of injury sustained (or potential injury) by the victim —which is arguably the best indicator for actual violence/aggression. The combination of both assault types highlights a possible missed opportunity to test an arguably more direct measure of aggression and could have inadvertently provided inaccurate results. It is also worth noting that the use of aggravated assault as a surrogate measure of aggression is likely also problematic, as roughly seven in every ten aggravated assaults involve the use of a weapon (Uniform Crime Report, 2016a). Although the presence of a weapon increases the potential for harm to occur, a victim physical injury is much less likely to occur when an offender uses a weapon because victims are more likely to acquiesce to the offender's demands (Cook, 1980; Kleck, 1997; Kleck & McElrath, 1991). Thus, there is no actual display of violence — arguably the most direct measure of aggression. This relationship will be discussed further in a later section.

Herrnstadt et al. (2016) completed what is likely the most comprehensive analysis to date on the relationship between air pollution and the commission of violent crime. Motivated by extant literature in various disciplines, Herrnstadt et al. (2016) set out to generate support that causally binds day-to-day fluctuations in air pollution levels to violent crime. This analysis examines the relationship between air pollution and crime in Los Angeles and Chicago —the second and third most populated cities in the United States respectively. This analysis also utilizes wind direction as a form of quasi-random variation in pollution exposure. As in Bondy et al. (2018), it is assumed that areas downwind of pollution sources are exposed to higher levels of air pollution. Thus, as the daily wind direction changes, the collection of areas that are overexposed to air pollution change.

The analysis utilizes crime data from the Chicago police department and the Los Angeles County Sheriff's Department. Both agencies supply either the street address of the reported crime or the exact geocode coordinates. This provides an extremely detailed account of where the crime incident took place, surpassing the traditional use of aggregate crime counts at the census tract level. Due to the inclusion of precise geolocations for incidents of crime, Herrnstadt et al. (2016) were able to contrast the amount of crime in two different neighborhoods that were both downwind. This allowed the authors to utilize wind direction data more effectively. The research design leverages daily, within-study-area variation in air pollution, which enables the research design to disregard correlated citywide economic or weather variables. Herrnstadt et al. (2016) highlight that the usage of wind direction should also alleviate any issues associated with under-reporting of crime, as it is unlikely that underreporting is systematically linked to the wind direction.

The study utilizes multi-year crime data from both cities. All crimes reported to the Chicago police department from 2001 - 2012 and all crimes reported to the Los Angeles County Sheriff's Department from 2005 - 2013 were used in these analyses. Due to the vast array of crimes reported, the authors elected to focus on FBI type I crimes: homicide, forcible rape, robbery, assault, battery, burglary, larceny, arson, and grand theft auto. Pollution data was collected from a combination of monitoring stations in both cities. Weather variables were collected from the National Climatic Data Center (NCDC). The weather variables consist of daily maximum temperature, precipitation, dew point, air pressure, wind speed, and cloud cover. The analysis revealed that elevated air pollution exposure resulted in a 2.2% increase in violent crime in Chicago and a 6.1% increase in Los Angeles. This provides support for the notion that there is a causal link between violent crime and same-day pollution spikes. The effect was also documented to persist from one day to the next, although the result was limited. Also, air pollution had no impact on property crime.

These findings suggest that air pollution has a measurable effect on violence, but not general criminality. Thus, these findings are consistent with the literature in several disciplines on the impact of air pollution and aggression. However, similar to the limitations mentioned in the analysis done by Heyes and Saberian (2015), this analysis may also be subjected to the same potential shortcomings associated with trying to accurately produce an appropriate proxy for aggression. Specifically, many crimes that are labeled violent crimes by the FBI involve the use of a weapon, which while increases the potential for harm to occur in fact decreases the likelihood of actual physical harm occurring (Cook, 1980; Kleck, 1997; Kleck & McElrath, 1991).

Criminological Underpinnings

Several criminological theories can aid in disentangling the relationship between air pollution and violent crime. Although not conclusive, a handful of researchers have speculated on how air pollution affects the thought process through a rational choice framework (Bondy et al., 2018; Heyes et al., 2016). Since its initial inception, rational choice theory has embraced the belief that humans are actors of reason, weighing the costs and benefits associated with an action (Akers, 1990). Following this framework, potential criminals will always act in a manner that maximizes self-interest and minimizes potential cost (Matsueda et al., 2006). Rational choice theory can find its roots in the 18th-century writings of Cesare Beccaria and Jeremy Bentham. Although not the primary purpose of his writing, Beccaria outlined desire seeking as the primary driving force of humans – asserting that humans are by default self-seeking and motivated to gain all they can from one another (Beccaria, 1963). Bentham's work was more of a general theory of behavior (Tomlinson, 2016). Bentham's most influential idea is centered around the notion of hedonism, where he surmised that pleasure and pain were the primary drivers that motivate human action (Bentham et al., 1996). This insight into what are some of the primary drivers of human action provided ample material for debate and insight into the development of criminological theory.

Air Pollution, Aggression, and Rational Choice Theory

Rational choice theory has the potential to provide some insight into the relationship between air pollution and aggressive behavior— air pollution may impact the naturally occurring calculus that transpires in the human-mind when weighing the positives and negatives of a decision. Although appearing as a rather general yet straightforward theory, several presuppositions are tacitly inferred. For rational choice theory to be applicable, it must be assumed that humans are aware of their actions and that their behavior is grounded in the informed probable consequences of their actions.

For instance, for rational choice theory to be appropriate, a criminal must be aware that their behavior is likely prohibited and must have a firm understanding that what they are doing will likely have consequences.

Bondy et al. (2018) attempted to elucidate a possible relationship between air pollution and aggressive behavior by applying an underlying rational choice theory mechanism to the decision-making process of those affected by air pollution. In their analysis, Bondy et al. (2018) outline that the effect of air pollution may be mediated through three avenues: (1) the overall rewards of crime increasing relative to the cost of future punishment (now being discounted or underestimated), (2) the likelihood of being punished is decreased, or (3) the preferences of the prospective offender become more accepting to risk taking. While it is difficult to definitively prove any of these three-potential modes of mediation, all three are plausible and thus warrant further discussion.

Risk Preference and Perception

Theoretically, air pollution introduces a new and presumably salient influence in how potential criminals weigh their actions, — exposure to air pollution can lead to more risk taking, either in the form of changing how one perceives risk or altering one's risk preferences (avenues 2 and 3). Currently there is no existing literature supporting the claim that changes in risk perception or preference is an observable consequence of exposure to air pollution. There is, however, limited research that may suggest that the relationship may be in the opposite direction. Research by Heyes et al. (2016) found that risk taking in financial markets was lower on days with higher levels of air pollution. Although the thought process of investing is substantively different than that of criminal behavior, this research can be mildly interpreted as air pollution possessing a dampening effect on risk taking. To combat the dearth of relevant literature, Bondy et al. (2018) set out to test how fluctuations in England and Wales AQI impacted lottery sales. Their research suggests that a 10-point increase in the national average AQI on the day of a draw was associated with a 1.5% decrease in lottery sales after controlling for weather conditions, day of the week, month, and year of draw. Lastly, there is a negative association between air pollution and risk taking found in medical literature. Experimental evidence documents that people tend to be more risk averse when administered the stress hormone cortisol (Kandasamy et al., 2014), which may be relevant considering that extensive air pollution exposure has been associated with elevates levels of cortisol (Li et al., 2017). Thus, due to limited but consistent multidisciplinary evidence, it is reasonable to propose that air pollution is unlikely to be suitable to explain the relationship between air pollution and violent crime through its suspected effects on risk preference and perception.

Payoff and Punishment

If rational choice theory is applicable, then air pollution would have to increase the pleasure or gain from the action relative to the punishment. For such a change, there would need to be an increase in the perceived benefit of a violent act, and/or a substantive decrease in the perceived costs. Although likely a consequence of researchers not specifically focusing on this issue, no literature to date discusses if air pollution would increase the perceived benefit of a crime. Considering that various studies have found air pollution to increase the occurrence of both violent crime (Herrnstadt et al., 2016; Li, 2018; Rotton & Frey, 1985) (crimes of aggression) and non-violent crimes like theft (Bondy et al., 2018) (economically motivated crimes), it seems unlikely that a change in emotional state due to air pollution will have this intended effect considering the differing motivating factors between violent and economically motivated crime. While it can be speculated that air pollution may impact the perceived benefit of committing a violent act, it is improbable that exposure to air pollution would impact the perceived gain of an economically driven crime. For example, research done by Heyes and Saberian (2015) was able to demonstrate that in Los Angeles, exposure to air pollution was estimated to increase the amount of assaults 17%, but air pollution had no corresponding effects on larceny-theft related crimes.

There is some, although limited, literature suggesting that air pollution may modify the perceived costs of a crime by effectively disregarding long-term outcomes, which can align with a decrease in the perceived cost of future punishment. As mentioned previously, Li et al. (2017) found that high exposure to air pollution can result in a significant increase in cortisol, along with cortisone, epinephrine, and norepinephrine. Elevated concentrations of stress hormones in the blood are expected to result in a behavioral change, particularly altering reward-seeking preferences (Bondy et al., 2018). In a small experiment, Riis-Vestergaard et al. (2018) found that subjects that were administered cortisol 15 minutes before doing an experimental task demonstrated a strong preference for small instantaneous rewards over larger but delayed rewards. In a similar study, subjects exposed to pain —which induces the release of cortisol (Porcelli & Delgado, 2009) — were more likely to appear impatient when compared to control groups (Koppel et al., 2017). Thus, grave exposure to air pollution can engender high levels of stress hormones in the blood, which can potentially discount the costs associated with potential future punishment. If true, this can theoretically increase the occurrence of criminal offenses.

Significance and Hypothesis

The purpose of the current study is to expand on the existing literature covering the effect of air pollution on violent crime. This analysis utilizes 2015 data drawn from 109 U.S. cities and a Hierarchical Generalized Linear Model (HGLM)[7] to ascertain the strength of the effect of CO levels on violent criminal behavior. In contrast to previous research that focused on the relationship between air pollution and the occurrence of violent crime, this study gauges the effect of air pollution by assessing if an offender exhibited aggressive behavior during the commission of a criminal offense. Specifically, aggressive behavior is defined as whether a crime victim suffered any physical injury during the commission of a crime. Physical victim injury encompasses apparent broken bones, possible internal injury, loss of teeth, severe laceration, unconsciousness, and other major and apparent minor injuries. This dependent variable is theoretically relevant because while there is ample evidence suggesting that air pollution has the potential to amplify aggressive behavior (Barrash et al., 2018; Calderón-Garcidueñas et al., 2009; Coccaro et al., 2014; Hopkins & Woon, 2006; Łopuszańska & Makara-Studzińska, 2017; Rotton et al., 1979; Wallach, 1986), there is no strong clear-cut rationale for why air pollution would be the precipitating factor in determining why an individual commits a crime.

[7] The HGLM model was created utilizing the scientific software HLM7.

Thus, the use of whether a crime victim suffered a physical injury during a crime incident as an outcome variable rather than using the rate of violent crime provides two main benefits: the indicator is theoretically relevant in that it captures actual displays of physical violence, and this theoretical framing aids in circumventing problems associated with the use of weapons inflating the perception of violence in violent crime statistics. While violent crime in the FBI's UCR Program is comprised of four offense categories (aggravated assault, robbery, murder and nonnegligent manslaughter, and rape), just two of these offenses (aggravated assault and robbery) represented approximately 90% of the violent crimes reported to police in 2015 (UCR, 2016b). Moreover, most incidents of aggravated assault (71%) and robbery (51%) involved the presence of a weapon (UCR, 2016a)[8]. While robberies involving the use of a firearm are considered by the law to be more severe than other types of robberies, victim physical injury is much less likely to occur when an offender uses a firearm because victims are more likely to acquiesce to the offender's demands (Cook, 1980; Kleck, 1997; Kleck & McElrath, 1991). In contrast, despite being punished less severely, non-firearm crimes often illicit greater offender aggression because the victim is much more apt to be physically injured during these types of crimes. The likelihood of physical contact is enhanced without the use of a firearm because the criminal offender is forced to close on his or her victim. The conflating of violent crime and offender aggression may have vitiated the results of previous research, as prior studies relied on the frequency or rate of violent crime as a proxy measure of individual aggression. Thus, when one considers that the violent crime

[8] Weapon usage statistics include the use of a firearm, knife or cutting instrument, and a catch-all category labeled other instruments. The categories strong-arm and hands, fists, feet, etc. were excluded from the percentage that represents weapons used.

rate is not necessarily synonymous with the amount of aggression exhibited by a criminal offender, it becomes readily apparent that researchers need to employ a better indicator of aggressive behavior to determine the effect of air pollution on violent crime.

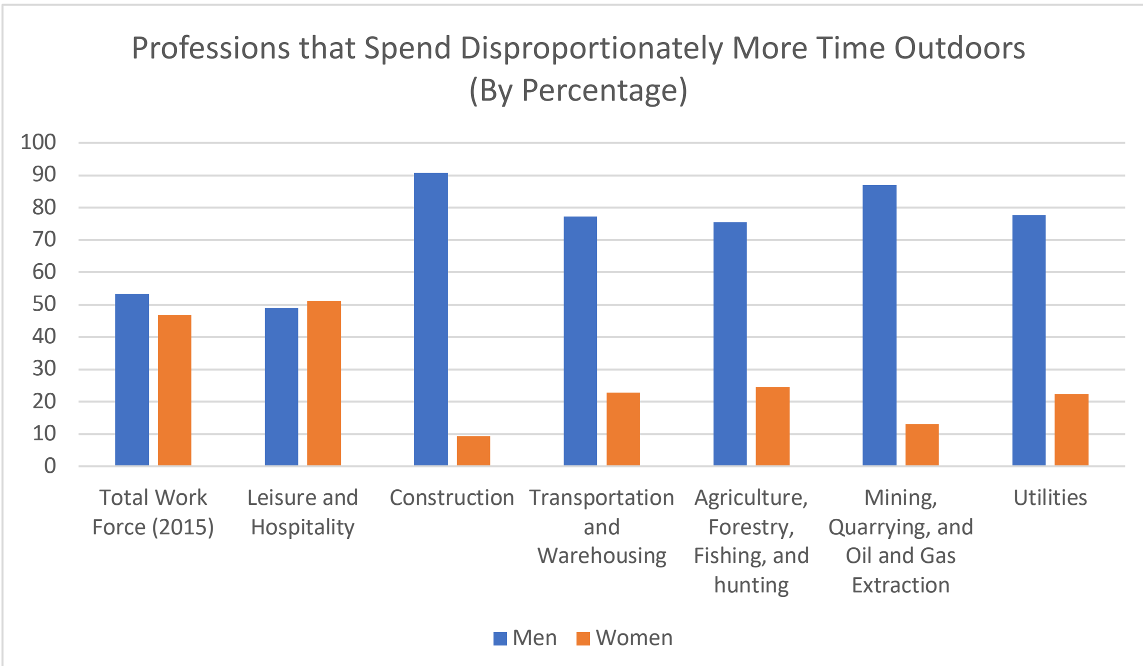
Second, every study conducted to date that examines the effect of air pollution on crime relies exclusively on aggregate data. No study has assessed the impact that air pollution has on violence while controlling for potentially salient factors at the microlevel, nor have they been able to determine whether an individual's demographic characteristics condition the relationship between air pollution and crime. This omission from the literature is surprising when one considers that research suggests that both the sex and race of the individual may moderate the relationship between air pollution and violence.

Several studies find that females are physically more negatively impacted by air pollution when compared to men (Oftedal et al., 2008; Rosenlund et al., 2009), although some question the veracity of this finding because social factors are not typically accounted for in these studies (Clougherty, 2010). In a study of atherosclerosis risk, Kan et al. (2007) found that women living near a major roadway had a diminished breathing capacity that was not present among men. Luginaah et al. (2005) further observed that prolonged exposure to air pollution was more predictive of respiratory hospitalizations for women than for men. They argued that biological sex differences in hormonal induced inflammation, smooth muscle vascular functions, and different airway sizes accounted for their findings. The airways of women have also been found to be more sensitive to cigarette smoke when compared to men (Carlsen et al., 2006).

Although less frequently documented, a few empirical studies have noted that diminished air quality impacts men more adversely than women. In a study that focused on Yale University freshmen, Galizia and Kinney (1999) found that men who grew up in areas with low air quality had diminished lung functionality. Similar attenuation in respiratory functionality was not observed among women living in similar areas. Zavorsky et al. (2014) examined the rate of CO elimination in males and females and noted that half-time of elimination was consistently longer in men than in women. Chen et al. (2017) found that exposure to air pollution impeded verbal and math scores for both genders. However, the effect was more prevalent among men. Granados-Canal et al. (2005) observed that elevated levels of air pollution were predictive of hospital admissions among men but not women in Paris, but in contrast to other researchers they theorized that this effect was the result of sex differences in exposure to air pollution rather than being biologically triggered.

The assertion that the effect of air pollution on observed sex differences in health-related outcomes may be due to societal factors rather than to biological differences between men and women made by Granados-Canal et al. (2005) has also been advanced by other social scientists (Clougherty, 2010). One societal factor that may be salient in this regard is gender-related work circumstances. Job placement is often stratified by gender, with men having an enhanced proclivity to work outdoors (Statista, 2019). The most common outdoor occupations include construction, agriculture and forestry, leisure and hospitality, mining and quarrying, transportation and warehousing, and utility jobs (Torpey, 2017). Data derived from the Bureau of Labor Statistics, which are depicted in Figure 5, show that men represent 90.7% of the construction workforce, 75.4% of the agriculture, forestry, fishing, and hunting workforce, 48.9% of the leisure and hospitality workforce, 77.3% of the transportation and warehousing workforce, 86.9% of the mining, quarrying, and oil and gas extraction workforce, and 77.6% of all utilities jobs (Torpey, 2017).

Figure 5. Professions that Spend Disproportionately More Time Outdoors (By Percentage).



The greater likelihood of men working in outdoor occupations has important implications for the effect of air pollution on violent behavior because air pollution tends to be present in higher concentrations outdoors (Chatoutsidou, et al., 2015). Indoor air pollution can sometimes exceed the levels of outdoor pollution, but in the U.S. this situation typically requires poor ventilation and already poor outdoor air quality (Environmental Protection Agency, 2018d). The most prominent sources of indoor air pollution in the U.S. come from the misuse or by-products of household items/equipment and are small in comparison to outdoor producers (Environmental Protection Agency, 2017). Thus, outdoor air pollution tends to be more severe and concentrated than indoor air pollution (Chatoutsidou et al., 2015). In addition to men being more likely to be employed in outdoor industries, men are also much less apt than women to seek medical assistance for a physical or mental illness (Matheson et al., 2014). This situation helps elevate the likelihood that air pollution will have a greater detrimental effect on men when compared to women.

It is also reasonable to speculate that race conditions the relationship between air pollution and violent criminal behavior. Racial disparities in exposure to air pollution have been documented in several studies (Stretesky, 2003). For example, Pirkle et al. (1994) utilized data from the National Health and Nutrition Examination Survey and found that black citizens had higher concentrations of air toxins in their system compared to whites. Research by Hird and Reese (1998) on industrial release patterns of environmental hazards across U.S. counties found that exposure levels were positively related to racial composition, disproportionately impacting blacks. Similar findings were made by Stretesky (2003). He found that counties with the largest proportion of black youth under 16 years of age had about eight percent more air pollution than counties with relatively few black youths. Additionally, air pollution emitting industries tend to be concentrated in areas occupied by black citizens (Mohai et al., 2009). This issue is further exacerbated by the documented unequal enforcement of air emission regulations in areas primarily inhabited by racial minorities (Mohai et al., 2009).

Due to persistent residential racial segregation in our society (Marshall et al., 2014), black citizens are also frequently obligated to dwell in areas situated in close proximity to a major roadway or highway (Boehmer et al., 2013; Clark et al., 2014). Living adjacent to a major roadway or highway is problematic in that it can enhance the likelihood that an individual will be overexposed to CO from vehicle exhaust (Strosnider et al., 2017). The vehicle exhaust generated by cars, trucks, buses, and other vehicles accounts for over half of all the air pollution in the U.S. (National Park Service, 2018). Thus, because blacks are more likely than whites to reside near or adjacent to a major roadway or highway due to residential segregation, they should be more vulnerable than whites to the adverse effects of CO.

Guided by the theoretical rationale discussed above, this analysis broadens the scope of previous inquiry on the influence of air pollution on violence by empirically testing the following three hypotheses:

Hypothesis (1)

(1) As carbon monoxide levels rise in a city, there will be an increase in the likelihood that a crime victim will be physically injured by a criminal offender in a crime incident.

Hypothesis (2)

(2) The sex of the criminal offender will condition the relationship between carbon monoxide levels in a city and the likelihood that a crime victim will be physically injured by a criminal offender in a crime incident.

Hypothesis (3)

(3) The race of the criminal offender will condition the relationship between carbon monoxide levels in a city and the likelihood that a crime victim will be physically injured by a criminal offender in a crime incident.

Chapter Summary

Building on research suggesting that air pollution can influence behavior—specifically aggressive behavior—researchers have begun to investigate the possibility that exposure to air pollution is causally related to the occurrence of crime. Most of the extant literature is consistent — an abundance of air pollution is predictive of elevated violent crime rates. A sparse number of analyses state that air pollution does not affect violent crime, and an even smaller amount claim that air pollution influences both violent crime and non-violent crime.

Trying to establish a theoretical relationship between air pollution exposure and violent crime is difficult because most researchers are agnostic as to what effects brought about by air pollution exposure precipitates criminal activity. Some researchers have elected to apply rational choice theory, claiming that humans are actors of reason, weighing the costs and benefits associated with an action. When applying rational choice theory, three potential causal mechanisms emerge: (1) the overall rewards of crime increasing relative to the cost of future punishment (now being discounted or underestimated), (2) the likelihood of being punished is decreased, or (3) the preferences of the prospective offender become more accepting to risk-taking. Limited prior literature seems to reject mechanisms two and three but provides potential support for mechanism one. Significant exposure to air pollution can engender high levels of stress hormones in the blood, which can potentially discount the costs associated with potential future punishment. If true, this can theoretically increase the occurrence of criminal offenses.

The purpose of this study is to extend previous work and current theoretical explanations of the effects that air pollution has on criminal behavior. Specifically, this study aims to measure the impact air pollution has on the likelihood of a physical injury occurring during the commission of a violent crime. This is in direct contrast with other studies, which use violent crime types as a proxy for aggression rather than actual displays of violence that occur during the offense. This study contributes to the field by providing a possible theoretical explanation for the effects that air pollution has on aggression. In contrast to most previous research that focused on the relationship between air pollution and the occurrence of violent and or property crime, this study examines the effects of air pollution on whether the offender exhibits aggressive behavior during the commission of the criminal offense. This dependent variable is theoretically germane because while there is ample evidence to suggest that air pollution amplifies aggressive behavior, there is no strong theoretical rationale for why air pollution would be a precipitating factor in the determination for why an individual commits a crime. Also, this study assesses if demographic characteristics of the individual condition the relationship between air pollution and crime. No current study has controlled for sex and race. However, several studies have documented how biological sex conditions how the body reacts to pollution. Also, job placement is often stratified by gender, with men having an enhanced proclivity to work outdoors. Lastly, several city areas are segregated by race, which is problematic as black citizens are frequently forced to live in areas located near a major roadway or highway.

CHAPTER III

DATA AND METHODOLOGY

The micro-level data were obtained from the National Incident-Based Reporting System (NIBRS) for 109 cities in 22 states[9] for the year 2015 (National Archive of Criminal Justice Data, 2018). All the cities analyzed here possess a population of at least 50,000 people. The NIBRS data are distinctively advantageous for the purposes of this study because unlike the UCR, the NIBRS provides an extensively large collection of factors associated with each crime incident. The NIBRS data are also useful because information on micro-level factors associated with a crime incident are provided along with geocode information that identifies the city where each crime incident transpired. These geographic identifiers can be employed to match crime incidents within a given city with an air pollution concentration variable and with other city-level variables theorized to be associated with the likelihood of an offender displaying aggressive behavior during the commission of a criminal offense.

Dependent Variable

In contrast to previous research that utilized the occurrence of violent crime interchangeably with aggressive behavior (Coccia, 2017; Kamaluddin et al., 2016), the current study uses the likelihood of a crime victim sustaining a physical injury during the commission of a criminal offense as its outcome variable. This strategy for measuring aggressive behavior is beneficial because it captures actual displays of physical violence by the criminal offender. Aggressive behavior is defined as a crime incident where the

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[9] The 22 states include Arkansas, Arizona, Colorado, Delaware, Iowa, Idaho, Kansas, Kentucky, Massachusetts, Montana, North Dakota, New Hampshire, Ohio, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Utah, Virginia, Washington, and Wisconsin.

criminal offender physically injured the crime victim (physical injury = 1 and no physical injury = 0).

Physical victim injury encompasses apparent broken bones, possible internal injury, loss of teeth, severe laceration, unconsciousness, and other major and apparent minor injuries. The violent crimes analyzed include rape, robbery, and aggravated assault. Simple assault was also included in the analysis but was used as the reference category for analyzing the violent crime variables. In these types of confrontational crimes, the victim is able to identify basic demographic characteristics of the offender. Research finds that crime victims are fairly accurate in their identification of these basic offender demographic characteristics (Hindelang, 1981). Data pertaining to the physical injury of the crime victim were derived from the 2015 NIBRS dataset.

Crime Incident Variables

Several crime incident variables, which are expected to influence the likelihood of offender aggression during the commission of a criminal offense, are included as controls in the multilevel analysis. These variables include the age, race, sex of both the offender and victim, the ethnicity of the victim, the relationship between the offender and victim, and the specific criminal offense committed. The age of the offender and victim are coded as interval variables. The race (1 = black and 0 = white), sex (1 = male and 0 = female), ethnicity (1 = Hispanic and 0 = non-Hispanic), offender/victim relationship (1 = stranger and 0 = non-stranger), firearm use (1 = firearm and 0 = no firearm), and specific criminal offense (1 = rape and 0 = no rape; 1 = robbery and 0 = no robbery; and 1 = aggravated assault and 0 = no aggravated assault) are all coded as dichotomous variables. Simple assault serves as the reference category for the other criminal offenses. Research finds that the age of the offender (Bureau of Justice Statistics, 1994), age of the victim (Bureau of Justice Statistics, 2018), race of the offender (Bureau of Justice Statistics, 2019), race of the victim (Bureau of Justice Statistics, 2017), sex of the offender (Lauritsen et al., 2009), sex of the victim (Lauritsen et al., 2009), ethnicity of the victim (Morgan & Kena, 2018b), and the relationship between the victim and offender (Black, 1976) all influence the frequency of violent crime. For instance, although individuals ages 12-34 represent 38% of the population, they account for roughly 58% of all serious violent crime victims (Oudekerk & Truman, 2017). Empirical studies that rely on official data (Bureau of Justice Statistics, 2019), victimization surveys (Morgan & Kena, 2018b), or self-report questionnaires (Lochner & Moretti, 2004) also show that black citizens tend to commit violent crime more frequently than their white counterparts. Additionally, because most crime is intraracial rather than interracial, black citizens bear the brunt of criminal victimization (Becker, 2007). According to the National Crime Victimization Survey (2016), the rate of violent victimization committed against black citizens (24.1 victimizations per 1,000 persons age 12 or older) is substantially higher than the rate committed against whites (20.5 victimizations per 1,000 persons age 12 or older). Ethnicity is also related to violent criminal activity and influences the occurrence of violent crime victimization similar to race (Morgan & Kena, 2018a).

With regards to biological sex, over 80% of violent crimes are perpetrated by men (Uniform Crime Reports, 2013). In contrast, violent victimization rates are relatively similar between the sexes. In 2015, the violent victimization rate for males was 15.9 per 1,000 males and 21.1 per 1,000 for females (Morgan & Kena, 2018b). This small but notable difference is consistent among most crime types except for robbery, where 2.2

males per 1,000 were victimized compared to 2.1 females per 1,000. The relationship between the victim and offender is relevant in predicting violent criminal behavior. Although roughly 46% of violent victimization occurs between strangers, an increase of familiarity between an offender and a victim elevates both the frequency and severity of violent offenses (Oudekerk & Truman, 2017).

This analysis also controls for the possibility that firearm use has a tempering effect on an offender's aggression during the commission of a crime. Controlling for firearm use is theoretically germane because research finds that victim injury is less likely to occur when an offender uses a firearm in a crime (Cook, 1980; Kleck, 1997; Kleck & McElrath, 1991). Victims are simply less apt to resist an offender's demands when the offender possesses a firearm.

Lastly, this research also considers the effect that different crimes may have on offender aggression displayed during a criminal offense. Accounting for violent crime types such as rape, robbery, and aggravated assault aids in controlling for the manifestations of offender aggression in certain crime types.

Macro-Level Variables

The data are aggregated at the city-level because this is the smallest geographical unit for which NIBRS and air pollution data are made available to the public. The use of multilevel data not only allows for an assessment of the effect of air pollution concentration on offender aggression, but it also enables a determination of whether the sex or race of the offender conditions the relationship between air pollution and violent behavior. The city-level variables used in the multilevel analysis include air pollution concentration, percent police officers, racial residential segregation, population density, southern city, percent population ages 15-24, percent male population, economic inequality, average annual temperature, percent of civilian labor force unemployed, percent of households headed by a single female with children, and percent of population living below the poverty line in 2009. Data for these aggregate variables were derived from the U.S. Census Bureau, the Environmental Protection Agency, and from the commercial weather service company Weather Underground. The inclusion of these variables in the multilevel analysis allows for a comprehensive appraisal of the factors that may potentially influence the likelihood of a victim being physically injured during the commission of a crime.

Carbon monoxide (CO) is the air pollutant of theoretical interest in this study because unlike other air pollutants that have a variety of possible origins, approximately 95% of CO emissions emanate directly from motor vehicle exhaust (Environmental Protection Agency, 2008). Prior research suggests that CO exposure can engender aggressive behavior (American Lung Association, 2019a; Mapou et al., 2017; Pagani et al., 2017) by disrupting the human brain and other vital organs from functioning properly, impairing attention, diminishing concentration, and by hindering visual processing (Amitai et al., 1998; Hopkins & Woon, 2006). CO also tends to be concentrated outdoors (Chatoutsidou, et al., 2015), disproportionally impacting those who work outside in cities (Strosnider et al., 2017), and affecting large swathes of the black population that live in close proximity to major roadways or highways due to the effects of residential segregation (Boehmer et al., 2013; Clark et al., 2014). Average annual CO concentrations for each city were collected for 2015. These CO concentrations are represented in parts per million (ppm) and are gathered, stored, and maintained by the EPA (Environmental

Protection Agency, 2018c). Currently, the EPA utilizes more than 4,000 monitoring stations around the U.S. to record emission data (Environmental Protection Agency, 2018c).

The multilevel analysis also includes a variable measuring law enforcement officers per capita to capture the impact that law enforcement presence in a city has on aggressive criminal behavior. Studies report that violent crime decreases as the quantity of law enforcement officers in an area increases (Mello, 2018). Data on the percent of sworn police officers per 1,000 city population were obtained from the United States Census Bureau (2015a; 2015c).

Residential racial segregation is measured using the dissimilarity index and is included in the analysis as a control variable because of the robust correlation between residential segregation and crime rates (Krivo et al., 2009). This positive relationship has been observed in cities (Phillips, 2002), as well as in neighborhoods (Capowich, 2003). Racial residential segregation is speculated to be a contributor to violence due to the structural disadvantage and isolation that prevails in majority-minority areas (Krivo et al., 2009). The dissimilarity index measures the distribution of one racial group among geographical units to the distribution of another racial group among the same geographical units. This comparison is typically undertaken at the city-level, with the distribution being calculated across census tracts. The index scores range from 0 to 1, with 0 representing an equally integrated geographical unit and 1 indicating a completely segregated geographical unit. Black and white populations are compared for this study, with the scores converted to percentages. For example, if the dissimilarity index in a given city is 40%, it means that 40% of the white population would need to relocate to another geographical unit to achieve uniform distribution of the population by race. The dissimilarity index was calculated in each city utilizing information from 2015 demographic data of white and black populations from the United States Census Bureau (2015d), ArcMap software, and from the following formula:

$$\text{Dissimilarity} = \frac{1}{2}\sum_{i=1}^{N}\left|\frac{a_i}{A} - \frac{b_i}{B}\right|$$

In this equation, n = the number of census block groups, ai = the number of whites in block group i, A = total number of whites in the city, bi = the number of blacks in block group i, and B = total number of blacks in the city. ArcMap software is a geographic information system used for manipulating and managing geographic and spatial information. For this analysis, ArcGIS (Version 10.7.1) was utilized to compile geographic data at the Census block group level to most accurately calculate the dissimilarity index. Census block groups generally contain between 600 and 3,000 people, do not cross the boundaries of counties or states, and are the smallest geographical unit permitted for the release of tabulated data to the public for confidentiality reasons. Census tracts consist of one or more of these block groups.

Calculating the dissimilarity scores using census block groups rather than census tracts yields slightly different index scores, which are arguably more accurate. In an analysis examining residential housing patterns, Iceland and Steinmetz (2003) found that when calculating dissimilarity scores, the use of census block groups rather than census tracts yielded slightly higher but similar scores. The observed difference in index scores may be the result of census block groups being smaller and more racially homogeneous. The smaller sizes of census block groups also alleviated some issues associated with calculating the dissimilarity index. Although census tracts are not large geographical units, they can sometimes be unusually shaped. When pieced together, they do not typically possess the same spatial borders with most cities and often capture unrelated surrounding areas or do not entirely capture city boundaries (Clapp & Wang, 2006). Thus, a reliance on potentially inaccurate demographic information derived from census tracts to calculate the dissimilarity index may attenuate the accuracy of the dissimilarity index score. In contrast, census block groups are smaller and can be amalgamated with greater ease to represent a city more precisely. Through the utilization of ArcGIS, the census block groups that fell within or significantly intersected the border of a city were used when calculating each dissimilarity score. This methodology helps to alleviate much of the precision issues associated with the traditional calculation of the dissimilarity index. Figures 6 and 7 contrast the two approaches.

Figure 6. Using Census Tracks to Outline the City Boundaries of Lewisville, TX.

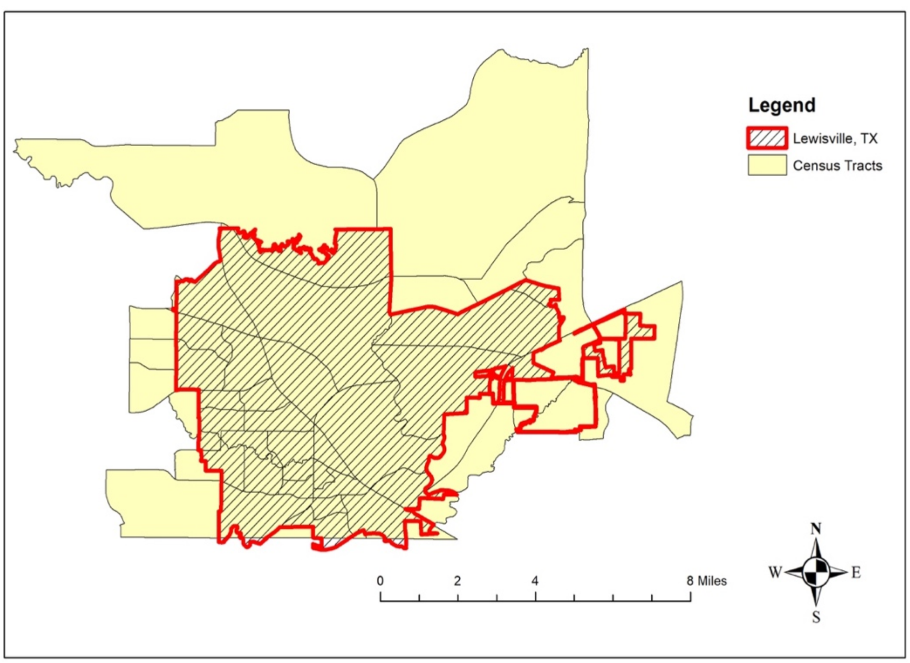
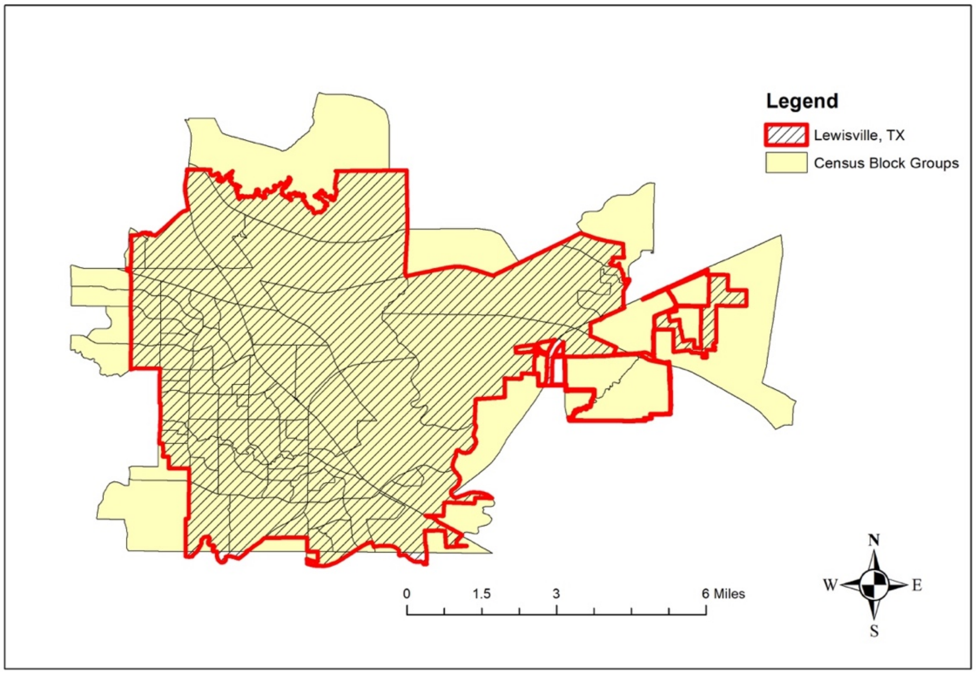


Figure 7. Using Census Block Groups to Outline the City Boundaries of Lewisville, TX.



Population density per square mile is also controlled for in the analysis. The literature is mixed on the effect that population density has on violent crime and criminal activity generally, which may be symptomatic of a lack of consistency regarding the specific control variables used in prior analyses (Battin & Crowl, 2017). Nolan (2004) and Sampson (1983) found that population density was associated positively with violent crime rates. However, when disaggregating violent crimes, Sampson (1983) observed that this effect was dependent on the specific crime analyzed. While population density was predictive of robbery victimization, no effect was evinced for assault victimization. Research by Li and Rainwater (2000) did not find population density to be a salient predictor of crime, whereas Christens and Speers (2005) demonstrated a negative relationship between population density and criminality. Data on the 2015 population for each city was collected from the United States Census Bureau (2015a). Total population data were then imported into ArcMap software and combined with 2015 shapefiles from the Census Bureau that contained the spatial boundaries of every block group that comprised each city. Using the same established spatial boundaries from the dissimilarity index variable, the population density values were generated and represent population density per square mile of land area.

This analysis also accounts for a city's position in reference to the Mason-Dixon line. This variable allows for a city to be categorized as northern or southern. The Mason-Dixon line has been used in previous work to delineate northern regions from southern regions, both culturally and geographically (Boyd, 2015). The primary purpose for the inclusion of this variable is to account for the proclivity of southern populations within the U.S. to have higher violent crime rates (Snell, 2011) and elevated levels of aggressive behavior (Erlanger, 1975). This variable was coded dichotomously, with 1 = south of Mason-Dixon line and 0 = north of Mason-Dixon line.

The tendency for youth to be involved in violent altercations is well-documented (Mesquida & Wiener, 1999). Although criminality on the aggregate level has declined in recent years, the age-crime curve distribution with youth being overrepresented in criminal activity remains robust. Individuals between the ages of 15 to 25 comprise 14% of the population (United States Census Bureau, 2015a), but are responsible for about 33% of the violent crime (UCR, 2016b). Because of this relationship between age and crime, a variable representing the percent of the city population ages 15-24 was included in the analysis.

A variable measuring the percent of the population in a city that is male was also included in the analysis. Men are overrepresented in offender crime statistics generally and possess an even greater disproportionate presence in violent criminal activity (Douglas et al., 2013). Men account for over 80% of the arrests for violent crime (UCR, 2013), despite representing roughly half of the general population (United State Census Bureau, 2015). Data on the total male population for each city in 2015 were derived from the United State Census Bureau (2015).

A control for economic inequality is included in the analysis because several studies report that income inequality is a strong predictor of violence (Lee et al., 2014; United Nations Office on Drugs and Crime, 2011). Although there are several different ways to measure economic inequality, the Gini Index is the most frequently utilized assessment tool (Bornmann et al., 2008). A city's Gini Index score is a composite score ranging from 0 to 1. A value of 0 indicates perfect equality, and 1 implies absolute inequality. The formula for the Gini coefficient is shown below:

$$G = \frac{1}{2n^2\mu} \sum_{j=1}^{m} \sum_{k=1}^{m} n_j \, n_k \, |\gamma_j - \gamma_k|$$

n = total number of people
n_i = number of people in income class i
y_i = income class i
u = mean income

Data on the 2015 Gini Index for each city were derived from the United States Census Bureau (2015b).

A robust body of literature has accumulated through the years linking high temperatures to violent crime rates (Schinasi & Hamra, 2017). This association has been demonstrated when temperature was assessed daily (Michel et al., 2016), monthly (Tiihonen et al., 2017), or annually (Habibullah, 2017). It is often theorized that high temperatures are associated with elevated violent crime rates because uncomfortable levels of heat engender feelings of hostility and agitation (Krenzer & Splan, 2018). However, it is also plausible that high temperatures provoke impulsive aggressive behavior by eliciting the release of the adrenaline and noradrenaline hormones into the body (Simister & Cooper, 2005). Tiihonen et al. (2017) further argue that high temperatures can impact the serotonergic system, thereby modulating serotonergic transmission and possibly increasing impulsivity. A control for average annual city temperature is included in the analysis for these reasons. Data on average annual temperature for each city for 2015 were collected from the Weather Underground, a commercial weather company that reports accurate weather data internationally (Weather Underground, 2019).

Lastly, a city disadvantage variable was included in the analysis. This composite variable was calculated using factor scores from a principal component analysis of three variables: (1) the percent of the civilian labor force that is unemployed, (2) the percent of households headed by a single female with children, and (3) the percent of the population living below the poverty line in 2009. High levels of city disadvantage are analogous to areas of concentrated disadvantage, which possess a constellation of factors that have been associated with higher rates of aggression (Sampson et al., 1997). A high score on this variable indicates a high level of city disadvantage. The results from the principal component analysis for the city disadvantage variable are shown in Table 1. The means, standard deviations, and definitions for all the variables used in this study are presented in Table 2.

Table 1. Principal Component Analysis for Community Disadvantage

	Percent of Variance	Component
Percent of civilian labor force that is unemployed	82.530	.941
Percent of households headed by a single female with children	11.504	.896
Percent of population living below the poverty line in 2009	5.966	.888

Note: N = 109 cities.

Table 2. Means, Standard Deviations, and Definitions for the Variables Used in the Analysis

Variable	Mean	Standard Deviation	Definition
Injury	.55	.50	Coded 1 if the victim was injured, 0 not injured.
Black offender	.53	.50	Coded 1 if the offender is black, 0 white.
Black victim	.46	.50	Coded 1 if the victim is black, 0 white.
Hispanic victim	.11	.32	Coded 1 if the victim is Hispanic, 0 non-Hispanic.
Male offender	.76	.43	Coded 1 if the offender is male, 0 female.
Male victim	.31	.46	Coded 1 if the victim is male, 0 female.
Offender age	32.31	12.76	Age of the offender in years.
Victim age	32.24	14.12	Age of the offender in years.
Stranger	.08	.27	Coded 1 if the victim was a stranger, 0 no.
Firearm use	.04	.19	Coded 1 if a firearm was involved in the incident, 0 no.
Rape	.03	.16	Coded 1 for rape incident, 0 no.
Robbery	.03	.17	Coded 1 for robbery incident, 0 no.
Aggravated assault	.16	.36	Coded 1 for aggravated assault incident, 0 no.
CO	.29	.15	Carbon monoxide (CO) parts per million level.
Temperature	56.48	6.49	Fahrenheit temperature scale.
Officers	3.12	2.03	Sworn police officers per 1,000 population.
Population density	1,853.32	1,465.95	Population per square mile of land area.
Southern city	.30	.46	Coded 1 if the city is in the South, 0 otherwise. Controls for the possibility of a southern subculture of violence and crime.
Percent 15-24	14.84	4.58	Percent of the population prone to criminal activity (ages 15-24).
Percent male	48.98	1.19	Percent of the population that is male.
Inequality	.45	.05	A measure of the distribution of household income for all residents (Gini coefficient). Ranges from 0 = perfect equality to 1 = total inequality.
Racial segregation	49.92	9.45	The white-black dissimilarity index ranges from 0 = complete integration to 100 = complete segregation.
Community disadvantage	0.00	1.00	Factor scores from a principal component analysis of three variables: a) percent of civilian labor force that is unemployed, b)

	percent of households headed by a single female with children, and c) percent of population below the poverty line in 2009. A high score indicates greater disadvantage.

Note: N = 117,924 incidents in 109 cities.

Chapter Summary

This analysis utilized 2015 data drawn from 109 U.S. cities and a Hierarchical Generalized Linear Model (HGLM) to ascertain the strength of the effect of CO levels on violent criminal behavior. Data from the FBI's National Incident-Based Reporting System (NIBRS), the Environmental Protection Agency (EPA), the United States Census Bureau, and the commercial weather service provider Weather Underground were utilized to create the incident-level and city-level variables. The incident-level variables were comprised of if the victim sustained a physical injury during the criminal incident, offender race, victim race, victim ethnicity, biological sex of the offender, biological sex of the victim, victim age, familiarity level between victim and offender, and violent crime type. The city-level variables consisted of the CO parts per million concentration, average daily temperature, population density, the geographical orientation of the city, sworn police officers per capita, percentage of the population ages 15-24, percentage of the population that is male, an inequality measure, racial segregation level, and a community disadvantage score.

In contrast to previous research that focused on the relationship between air pollution and the occurrence of violent crime, this study gauged the effect of air pollution by assessing if an offender exhibited aggressive behavior during the commission of a criminal offense. Aggressive behavior is defined as whether a crime victim suffered any physical injury during the commission of a crime. Physical victim injury encompasses apparent broken bones, possible internal injury, loss of teeth, severe laceration, unconsciousness, and other major and apparent minor injuries. The use of whether a crime victim suffered a physical injury during a violent criminal incident as an outcome variable rather than using the rate of violent crime provides two main benefits: the indicator is theoretically relevant in that it captures actual displays of physical violence, and this theoretical framing aids in circumventing problems associated with the use of weapons inflating the perception of violence in violent crime statistics. An HGLM was utilized to address all three research questions. Hierarchical models are ideal for measuring cross-level effects due to all estimates being adjusted for the covariates, allowing for assessment of the predictive power of both the incident and city level variables.

CHAPTER IV

MULTILEVEL ANALYSIS

This study employs a nonlinear hierarchical modeling methodology because the dependent variable is a dichotomy and because the data are multilevel (Bryk et al., 1996). A penalized quasi-likelihood (PQL) technique was utilized to produce parameter estimates for the binary outcome (Agresti & Kateri, 2011). Using a multilevel model to establish if air pollution concentrations influence the probability of physical injury being sustained by a victim during a violent criminal act is methodologically useful for several reasons. First, notwithstanding whether the variables are measured at the individual or aggregate level, hierarchical models are ideal for measuring cross-level effects due to all estimates being statistically adjusted for the covariates. Second, because multilevel models explicitly account for the clustering of subjects within a given context, they avoid violating the assumption of statistical independence among the observations. Ignoring the clustering of observations in an analysis could result in the regression coefficients being underestimated, which in turn could engender an overestimation of their statistical significance (Osborne, 2000). Finally, hierarchical models can identify the variance between levels and separate individual-level variance parameters from sampling variance (Raudenbush, 1995). A researcher's failure to separate sampling variance when analyzing nested data can result in an underestimation of the explanatory power of the variables included in the model.

Within-City Results

A within-city regression model using the crime incident variables to predict the likelihood of victim physical injury in a crime incident was estimated to begin the multilevel analysis. Except for the intercept and the variables representing the offender's sex and race, all remaining crime incident variables were constrained (fixed effects) to have the same effect across the cities in the sample. These three variables of interest were permitted to vary among the different cities (random effects) to determine whether air pollution and the other contextual variables have the ability to predict between-city differences in their slopes. The following equation was employed for the within-city model:

$$\log\left[\rho_{ij}/(1-\rho_{ij})\right] = \beta_{0j} + \beta_{1j} Black\ Offender_{ij} + \beta_{2j} Black\ Victim_{ij} + \beta_{3j} Hispanic\ Victim_{ij} + \beta_{4j} Male\ Offender_{ij} + \beta_{5j} Male\ Victim_{ij} + \beta_{6j} Offender\ Age_{ij} + \beta_{7j} Victim\ Age_{ij} + \beta_{8j} Stranger_{ij} + \beta_{9j} Firearm_{ij} + \beta_{10j} Rape_{ij} + \beta_{11j} Robbery_{ij} + \beta_{12j} Aggravated\ Assault_{ij} + \varepsilon_{ij}$$

where ρ_{ij} is the probability that crime i from city j resulted in the physical injury of the victim, β_{ij} represents the coefficients for the crime incident variables, and ε is the error term.

The results for the within-city analysis are reported in Table 3. These results indicate that at their grand means, several of the variables have a statistically discernible effect on the likelihood of a victim being physically injured during a violent criminal offense. These noteworthy variables include the offender's race, victim's race, victim's sex, offender's age, victim's age, relationship between the offender and victim, firearm use, and type of violent crime committed. The odds ratios are included in Table 3 because they are easier to interpret than the coefficients themselves. These odds ratios can also be converted into a percent change by using the following formula: (odds ratio - 1) * 100.

Table 3. Within-City Probability of Injury Results

Outcome Predictor	Coefficient	Standard Error	Odds Ratio
Intercept	.175	.045	1.191
Black offender	.155***	.020	1.168
Black victim	-.189***	.020	.828
Hispanic victim	.097***	.020	1.102
Male offender	.007	.016	1.007
Male victim	.078***	.018	1.081
Offender age	-.002**	.001	.998
Victim age	.002**	.001	1.002
Stranger	-.467***	.034	.627
Firearm use	-1.767***	.078	.171
Rape	-1.088***	.077	.337
Robbery	-.179*	.079	.836
Aggravated assault	.713***	.056	2.041

Notes: *p ≤ .05; **p ≤ .01; ***p ≤ .001 (two-tailed tests). Results from population-average model with robust standard errors.

The results displayed in Table 3 show the likelihood of victim physical injury is impacted by the race of the offender and the race/ethnicity of the victim. A crime victim is 16% more likely to be physically injured if the offender is black. Hispanic victims are 10% more apt to be injured, whereas black victims are about 17% less likely to be injured during the commission of a violent crime. Interestingly, while the sex of an offender does not possess predictive ability, the sex of the victim provides a salient relationship – male victims are about 8% more likely to be physically injured. Both the age of the offender and victim are also statistically substantive. The effect for the variable representing the offender-victim relationship showed that if the victim and offender are strangers, the likelihood of a physical injury occurring decreased by 37%.

The remaining salient variables in the equation are firearm use and the type of violent crime committed by the offender. Findings show that the use of a firearm by the offender decreases the likelihood of physical injury occurring by about 83%. This finding coincides with prior research showing that the use of a firearm by an offender reduces the possibility that a victim will be physically injured. Examination of the violent crime types reveals that while physical injuries are twice as likely to occur during aggravated assaults, the occurrence of rape or robbery decreases the likelihood of physical injury by 66% and 16% respectively. Prior research also finds that in contrast to crimes such as robbery and assault, the crime of rape rarely results in serious bodily injury to the victim (Thornhill & Palmer, 2000). These findings suggest that the amalgamation of several different violent crimes to measure aggression in prior research studies may have muddied the relationship between air pollution and aggressive behavior.

Between-City Results

The purpose of the between-city analysis is to use the city-level variables to determine whether CO concentration among the different cities can explain aggressive offender behavior, even after accounting for the microlevel crime incident variables. One question of theoretical relevance being addressed in the between-city model is whether CO concentration in a city influences the likelihood of a victim being physically injured by an offender during the commission of a crime. The between-city analysis also assesses empirically whether the sex or race of the offender moderates the relationship between CO concentration and the likelihood of victim injury. The between-city model is written as:

$$\beta_{0j} = \gamma_{00} + \gamma_{01} Carbon\ Monoxide + \gamma_{02} Temperature_j + \\ \gamma_{03} Police\ Officers_j + \gamma_{04} Population\ Density_j + \gamma_{05} Southern\ City_j + \\ \gamma_{06} Percent\ Population\ 15 - 24_j + \gamma_{07} Percent\ Male_j + \\ \gamma_{08} Economic\ Inequality_j + \gamma_{09} Racial\ Segregation_j + \\ \gamma_{10} Community\ Disadvantage_j + u_{0j},$$

where, for each city j, β_0 represents the intercept from the crime incident model, γ_0 represents the city contextual variables, and u is the error term. The estimated coefficients for this model are reported in Table 4.

Table 4 shows the estimates pertaining to the influence of CO concentration and the other contextual variables on the overall probability of physical injury occurring during a violent crime. The results also indicate whether the relationship between CO concentration and victim injury is conditioned by the sex or race of the offender. A visual examination of Table 4 reveals that when controlling for other relevant contextual variables, the concentration of CO is not predictive of whether a victim is physically injured during the commission of a violent crime. In cities with higher concentrations of CO, a crime victim does not have a greater chance of being physically injured by a criminal offender when controlling for other factors. Such a finding stands in marked contrast to the findings generated in several previous studies. However, while violent crime rates have been linked to air pollution in several prior studies (see Herrnstadt et al., 2016; Heyes & Saberian, 2015; Li, 2018; Lu et al., 2018; Rotton & Frey, 1985; Stretesky & Lynch, 2004), these research endeavors are methodologically problematic making any relationship evinced between air pollution and violent behavior in these studies tentative at best. Methodological problems afflicting these studies include the failure to distinguish between violent crime and actual displays of physical violence by the offender, small or unrepresentative samples, and the absence of important statistical controls.

First, while much of what we currently know about the effect of air pollution on violent behavior is derived from studies that examine air pollution concentration and vacillations in violent crime rates, these types of analyses cannot easily identify the specific causal processes at work because they all fail to make an empirical distinction between violent crime and the actual display of physical violence by the offender. Such a distinction as discussed previously is salient because in many violent crimes, such as when an offender uses a firearm, the offender does not typically show any physically aggressive behavior toward the victim. Thus, without explicitly measuring the amount of physical aggression shown by a criminal offender, there is a clear theoretical disconnect in prior research as to why air pollution would impact violent crime rates when in many of these crimes the offender exhibited little if any aggressiveness toward the victim.

Current literature also possesses other problematic features — prior research documenting a relationship between air pollution and aggressive behavior typically analyzed unrepresentative samples that diminished their general applicability. For instance, Younan et al. (2018) found a substantive link between delinquent behavior and air pollution. However, this analysis drew its conclusion from data gathered only from Southern California. The utilization of rich but geographically limited data is a common trend among several seminal studies that elucidate the relationship between air pollution and aggression. Research done by Rotton & Frey (1985), Beland & Brent (2017), Bondy et al. (2018), and Heyes & Saberian (2015) all use data derived from a single city. Herrnstadt et al. (2016) analyzed data from only two cities, while Li (2018) scrutinized seven cities. Over half of the aforementioned studies also examined data drawn solely from California, which further hinders their ability to inform the public as to whether air pollution influences aggressive behavior in cities throughout the U.S. Apart from a few notable exceptions, the dearth of nationwide representative empirical studies necessitated the undertaking of the current analysis.

Additionally, an important oversight in prior research pertains to the general failure of researchers to include relevant control variables in their analyses. This situation not only obstructs a researcher's ability to generate estimates for these omitted variables, but the exclusion of relevant variables can also bias the estimates for the variables included in the analysis. Although there is a fair amount of literature informing on the effect of air pollution on deviant behavior — particularly purported violent behavior — most of this work did not originally intend to examine this relationship exclusively. Therefore, much of the extant literature is missing relevant control variables at the city and individual level. For example, several studies do not control for different violent crime types (Li, 2018; Rotton & Frey, 1985; Stretesky & Lynch, 2004; Younan et al., 2018), law enforcement density (Stretesky & Lynch, 2004; Younan et al., 2018), inequality (Beland & Brent, 2017; Bondy et al., 2018), percentage of male youth (Beland & Brent, 2017; Bondy et al., 2018), and corresponding offender and victim level demographics (Bondy et al., 2018; Beland & Brent, 2017; Herrnstadt et al., 2016; Heyes & Saberian, 2015; Li, 2018; Lu et al., 2018; Stretesky & Lynch, 2004; Younan et al., 2018) in their respective regression models. These omissions may have influenced outcomes due to the vast literature suggesting that these variables are strongly predictive of violent crime.

In contrast to CO concentration, two contextual variables did show some relevancy in predicting the likelihood of victim injury. Both population density and percent male population achieve statistical significance in the equation. A crime victim is more apt to be physically injured in cities that have a low population density or a large male population.

Examination of the results presented in Table 4 also reveals a statistically discernible effect of air pollution on the black-white offender injury differential. This effect is equivalent to an interaction effect in a logistic regression analysis. While black offenders are typically more likely than white offenders to physically injure their victims in a violent crime (18% more likely in the between-city model), this 18% racial difference between blacks and whites in the likelihood to physically injure victims increases by 28% with a one-unit increase in a city's CO concentration. This cross-level interaction effect is compelling when one considers the large number of incident and contextual control variables included in the analysis. This finding buttresses the argument that air pollution is more impactful on the aggressiveness of black offenders when compared to similarly situated white offenders. Such a finding may be explained to a large degree by the elevated concentrations of CO that racial minorities are exposed to due to their common living areas being clustered near heavily traveled roadways with large amounts of vehicle exhaust. None of the other contextual variables are salient in explaining the black-white victim injury differential.

Results in Table 4 show that CO concentration also has a discernible effect on the male-female offender injury differential. In cities with higher CO concentrations, male offenders are more apt than women offenders to physically injure their crime victims. Results show that despite existing literature stating that male offenders are more physically aggressive than female offenders (Ramirez et al., 2001), the male-female offender injury differential did not yield statistical significance. However, the likelihood of male offenders physically injuring a victim when compared to female offenders is greater in cities with a higher level of CO concentration. More specifically, the gender difference in the likelihood of a victim being physically injured in a crime (between-city model) rises about 22% for a one-unit increase in a city's CO concentration. Thus, while male offenders were not on average more physically aggressive than females, they were more apt to injure their victims when exposed to higher concentrations of CO. This result is likely due to males having a greater propensity than women to work outdoors (Statista, 2019; Torpey, 2017).

Further review of the between-city results reveals that several other incident-level variables have predictive power regarding if an injury will occur during a violent crime – most of which confirm prior literature. While these variables are not related to addressing the hypotheses of this study directly, an examination of these outputs can provide insight for future research endeavors. The offender and victim race demographics yielded salient results. Injuries were more likely to occur if the offender was black, while black victims were less likely to be injured when compared to similarly situated white victims. Thus, it would appear that although most crime is intra-racial and blacks typically suffer from higher violent victimization rates when compared to whites (Truman et al., 2013), black victims are substantively less likely to sustain physical injuries during a violent crime. Also, victims were more likely to be injured during a violent criminal offense if they were Hispanic. These findings may result from a multitude of idiosyncrasies associated with intra-racial and inter-racial crime. The remaining salient variables all yielded almost identical results to the within-city model. If the victim and offender were strangers, the likelihood of a physical injury occurring decreased by 37%. The use of a firearm by the offender reduced the probability of a physical injury occurring by about 83%. Lastly, the violent crime category aggravated assault doubled the likelihood of a victim physical injury occurring, while rape or robbery decreased the likelihood of physical injury by 66% and 16% respectively.

Table 4. Between-City Probability of Injury Results

Outcome Predictor	Coefficient	Standard Error	Odds Ratio
Injury probability differential			
Intercept	.178	.045	1.195
CO	-.260	.232	.771
Temperature	-.007	.011	.993
Officers	.002	.031	1.002
Population density	-.072e-3*	.036e-3	1.000
Southern city	.107	.158	1.113
Percent 15-24	-.005	.013	.995
Percent male	.103**	.034	1.109
Inequality	.853	1.102	2.347
Racial segregation	-.001	.005	.999
Community disadvantage	.014	.057	1.014
Black-white offender injury differential			
Intercept	.165***	.024	1.180
CO	.247*	.123	1.281
Temperature	.001	.004	1.001
Officers	-.006	.011	.994
Population density	.006e-3	.018e-3	1.000
Southern city	-.076	.048	.927
Percent 15-24	-.002	.005	.998
Percent male	.027	.023	1.028
Inequality	.572	.717	1.772
Racial segregation	.021e-2	.181e-2	1.000
Community disadvantage	-.001	.021	.999
Black victim	-.186***	.020	.830
Hispanic victim	.099***	.019	1.105
Male-female offender injury differential			
Intercept	-.012	.016	.988
CO	.196**	.064	1.216
Temperature	-.032e-2	.361e-2	1.000
Officers	-.020**	.008	.980
Population density	-.015e-3	.011e-3	1.000
Southern city	.056	.037	1.058
Percent 15-24	-.001	.004	.999
Percent male	.001	.015	1.001
Inequality	.176	.445	1.192
Racial segregation	.002	.002	1.002
Community disadvantage	.006	.017	1.006
Male victim	.078***	.018	1.081
Offender age	-.002**	.001	.998
Victim age	.002**	.001	1.002

Outcome Predictor	Coefficient	Standard Error	Odds Ratio
Stranger	-.468***	.033	.626
Firearm use	-1.763***	.069	.171
Rape	-1.088***	.077	.337
Robbery	-.180*	.079	.835
Aggravated assault	.713***	.059	2.039

NOTES: *p ≤ .05; **p ≤ .01; ***p ≤ .001 (two-tailed tests). Results from population-average model with robust standard errors.

Chapter Summary

The results of the within-city analysis indicate that several variables have predictive power regarding the likelihood of a victim physical injury occurring: offender race, victim ethnicity, victim biological sex, familiarity level between victim and offender, if a firearm was used during the violent criminal offense, and the type of violent crime committed. Firearm use had the most significant effect, with a physical injury being about 83% less likely to occur if a firearm was used during the violent criminal offense. Other notable variables included offender race and victim ethnicity, where a victim was 16% more likely to be physically injured if the offender was black. Hispanic victims were 10% more likely to be injured, whereas black victims are about 17% less likely to be injured during the commission of a violent crime. Interestingly, while male victims were about 8% more likely to be physically injured, no effect was found on the sex of the offender.

The between-city analysis revealed that when controlling for several relevant contextual variables, the concentration of CO is not predictive of whether a victim is physically injured during the occurrence of a violent crime. Such a finding stands in marked contrast with most existing research documenting a tangible association between aggression and air pollution. It is speculated that this discrepancy in findings is likely the consequence of several factors. These factors include the failure of prior research to differentiate between actual displays of physical violence by the offender and violent crime incidents, small or unrepresentative samples, and a lack of theoretically relevant control variables.

However, an examination of the black-white victim injury differential and the male-female victim injury differential evinced statistical significance for CO in predicting a victim injury. Interpreting these differentials as interaction effects resulted in black offenders being 28% more likely to injure their victims when compared to similarly situated white offenders when CO levels are high. Analogously, men are about 22% more likely to injure victims when compared to similarly situated female offenders when CO levels are elevated. The statistical significance of these demographic differentials is likely due to a consequence of disproportionate exposure levels of air pollution to both groups. Men hold the vast majority of labor positions that spend considerable periods outdoors, thus increasing their levels of air pollution exposure. Black citizens are often forced to live in communities that are near and adjacent to major roadways and highways, systematically overexposing black citizens to vehicle exhaust generated by cars, trucks, buses, and other vehicles — which accounts for over half of all air pollution generated in the U.S.

CHAPTER V

DISCUSSION

A considerable catalog of quantitative literature documenting the effects of air pollution on criminal behavior has amassed in recent years. The relevant literature detailing the effects of air pollution on violent crime follows a similar thread of reasoning. This logic suggests that air pollution has a physiological and or psychological impact on the human body, altering a criminal offender's usual condition by prompting an amplified frequency of aggressive criminal activity. The designation of air pollution as a facilitator of violent behavior remains an issue in the criminological landscape because prior studies make the explicit but untested assumption that violent crime can be employed as a suitable proxy for aggressive behavior. However, this commonly made supposition is problematic because the specific type of criminal offense committed by an offender is not necessarily synonymous with the amount of physical aggression displayed by the offender during the commission of a crime. Such a situation makes it abundantly clear that researchers need a better indicator of aggressive criminal behavior to more clearly articulate the relationship between air pollution and violent crime.

This study used multilevel data to assess the relationship between air pollution and the amount of physical violence displayed by a criminal offender during the commission of the criminal offense. Results generated in the analysis show that when controlling for relevant crime incident and contextual variables, air pollution has little impact on the likelihood of a victim being physically injured during the commission of a crime. This finding casts doubt on the assertion that high levels of CO are predictive of the likelihood of a crime victim suffering a physical injury (Hypothesis 1). This finding is relevant and telling when one considers that not only does it conflict with the empirical literature linking air pollution to violent crime (Herrnstadt et al., 2016; Heyes & Saberian, 2015; Li, 2018; Lu et al., 2018; Rotton & Frey, 1985; Stretesky & Lynch, 2004), but that it is also incongruous with the underlying premise that air pollution is linked to violent crime due to its physical aggression inducing properties. If air pollution is associated with elevated occurrences of violent crime but not actual displays of aggression by the individual, then another unspecified variable is likely responsible for this positive relationship. Omitted variable bias is implied because there is no readily interpretable reason for why air pollution would motivate a person to commit a crime without magnifying aggressive behavior. For example, one might ponder why air pollution would motivate a person to commit a rape if it has little influence on increasing the aggressiveness of the offender. It simply wouldn't. Other unidentified factors would have to be responsible for the offender's behavior.

However, while the lack of an overall relationship between air pollution and aggressive offender behavior is noteworthy based on the findings generated in prior research, such a null finding fails to provide any insight into populations disproportionately overexposed to air pollution. Previous literature demonstrates that CO is heavily concentrated outdoors (Chatoutsidou, et al., 2015) and in black and other minority neighborhoods (Boehmer et al., 2013; Clark et al., 2014; Strosnider et al., 2017). The results produced in the multilevel analysis support Hypotheses 2 and 3 by showing that the effects of the sex and race of the offender on aggression are conditioned by the amount of CO in a city. In cities with higher levels of CO, both male and black offenders are much more apt to physically injure their victims during the commission of a criminal offense.

Given the mixed literature on whether air pollution has a greater influence on males or females, it was not a forgone conclusion that air pollution would moderate the relationship between an offender's sex and aggressive behavior. One plausible explanation for this sex difference is rooted in labor proclivities. Men tend to be overrepresented in jobs that require workers to spend most of the workday outdoors, thereby increasing the probability and intensity of their exposure to air pollution (Statista, 2019; Torpey, 2017). It is also conceivable that biological differences between men and women may be salient in explaining why male offenders are more inclined to be influenced by air pollution. However, this study is unable to identify the specific causal mechanisms by which air pollution influences the human body. A variety of causal pathways may be operative.

The conditioning effect that air pollution has on the relationship between an offender's race and victim physical injury is entrenched in the fact that racial minorities face overexposure to air pollutants (Stretesky, 2003), particularly black citizens (Mohai et al., 2009; Stretesky, 2003). This overexposure is due to black communities frequently being clustered around busy roadways and major highways (Boehmer et al., 2013; Clark et al., 2014). This situation amplifies an individual's exposure to motor vehicle exhaust, which is the main contributor of CO in a given geographical location (National Park Service, 2018).

Environmental Racism

The physical aggression inducing properties of air pollution being disproportionately experienced by black communities in urban settings can be viewed as another instance of environmental racism. These areas are not only plagued by concentrated environmental hazards such as air pollution (Mohai et al., 2009), but also by low performing schools (Peske & Haycock, 2006), high violent crime rates (Pattavina et al., 2006), a lack of safe outdoor space for children to play (Babey et al., 2007), reduced economic mobility (Chetty et al., 2019), a small number of large supermarkets that stock inexpensive and healthy foods (Walker et al., 2010), scarce pharmacies (Qato et al., 2014), elevated rates of mortality, morbidity, and other unfavorable health outcomes (Deaton & Lubotsky, 2003).

Environmental racism can be defined as the disproportionate burdening of environmental hazards on minorities, both unintentional and intentional (United Church of Christ, 1987). Environmental racism finds its roots in purposeful discrimination and indifference. The genesis of environmental racism research began with an analysis conducted by the United States General Accounting Office (GAO) in 1983. In this report, the GAO made the first significant attempt to examine the socio-economic and racial demographics of communities near four hazardous landfills in the Southeast region of the United States (United States General Accounting Office, 1983). This report discusses the 1982 decision by the EPA, where the agency decided to relocate soil contaminated with industrial products and chemicals in North Carolina to an area within the state that was predominantly populated by black residents. In a legal battle to halt the relocation of the landfill to their county, Warren County lost its lawsuit, which was built primarily on the claim of racial discrimination, because the court ruled that race was not referenced as a motivating factor in the relocation of the landfill. This ruling was made even though the African American population was significantly overrepresented in all the neighboring townships. For example, Judkins Township was 48% black and Fishing Creek Township was 44% black and 47% American Indian. The GAO (1983) argued that this disproportionate treatment of minorities was due to a lack of adequate protective policies from federal and local governments and from purposeful neglect on behalf of private corporations.

The 1983 GAO study was then followed by the United Church of Christ Commission for Racial Justice (UCC) study, which was the first national analysis of communities that contained hazardous waste dumps (United Church of Christ, 1987). The UCC study found that race was the most consistent factor in determining the location of commercial waste treatment facilities and uncontrolled toxic waste sites. Areas with one operating facility had about twice the percentage of minorities when compared to areas without an operating facility. Furthermore, the UCC study observed that locations with more than one operating facility had over three times the percentage of racial minority residents when compared to areas without facilities.

Several other research studies published slightly after the UCC investigation added empirical support to the findings generated in the GAO and UCC investigations. Work by Bullard (1990) found that in southern states, African American communities contained about 60% of the hazardous waste disposal capacity but only constituted about 20% of the population. Bullard (1990) also noted that about 60% of the nation's largest waste landfills were situated in predominately African American or Latino communities.

In an evaluation of 15 studies assessing the distribution of environmental dangers, Mohai and Bryant (1992) found that there was a noteworthy relationship between race and to a lesser extent income regarding the distribution of environmental hazards. In a study of New Jersey communities, Greenberg and Anderson (1984) observed that most hazardous sites were situated in areas with high proportions of African Americans when compared to other communities. Additionally, in an examination of Los Angeles County, Cole (1992) demonstrated that the zip code with the largest amount of chemical discharge was about 60% African American.

Despite these early studies bringing national attention to the consequences of environmental racism, the disproportionate levels of racial exposure to air pollution and environmental hazards persist in the U.S. In a recent research article examining white supremacy, white privilege, and environmental racism, Pulido (2015) investigated troubling issues surrounding Exide. Exide is a battery recycling facility located in Vernon, an industrial city situated adjacent to Los Angeles. Exide uses heavily regulated chemicals, with lead and arsenic posing the most significant hazards. Although Exide had violated state and local environmental regulations for decades, it was afforded the opportunity to operate with a temporary permit from the California Department of Toxic Substances and Control (DTSC) for around 40 years (Garrison, 2013). The extent of Exide's pollution is reported to be substantial. According to a health risk assessment undertaken in 2010, over 100,000 residents were estimated to be at an elevated risk level of contracting cancer due to Exide's activity (Environ International Corporation, 2013). This high risk of contracting cancer is 44 times the legal limit (Environ International Corporation, 2013). Certain racial groups disproportionately shoulder these risks because the neighboring cities of Bell, Maywood, and Huntington Park are predominantly non-white. Approximately four in every five residents exposed to these elevated risk levels are racial minorities. Exide has been issued over 100 citations, with several regulatory agencies attempting to close the facility down (Garrison & Christensen, 2013). However, Exide has countersued and won several times and has often reached settlements to avoid losing their business. In sum, Exide knowingly pollutes and threatens the livelihood of neighboring residents but has chosen not to comply because state and local regulations have failed to stop them. These citizens of color are often left without recourse — lacking the means to relocate or proper political representation (Pulido, 2015). Several other recent studies also document environmental racism by showing that while racial minorities disproportionately bear the burden of pollutants, they often do not equally benefit from the structures, such as highways and waste sites, that produce the environmental hazards (Ash & Fetter, 2004).

Identifying racial animus as the chief underlying rationale for why hazardous waste sites and highways are located near poor minority neighborhoods is often difficult. It is not customary for politicians, state officials, and private companies to overtly reference race as a motivating factor for the locating of highway or waste sites (Pulido, 2017; Sherman, 2014; United States General Accounting Office, 1983). The modern-day manifestation of environmental racism has bested most of our legal and societal safety valves. Cases of intentional discrimination are sporadic, while examples of racial disparity and inequality are pervasive (Glenn, 2017). One substantial issue resides in legislation at the federal and state level that typically ignores subliminal, structural, and unconscious discrimination by requiring some form of overt discrimination (Dane, 2016).

Thus, environmental racism need not be committed by ill-willed individuals. It may simply be the result of decisions being made by those who do not properly account for the impact of their behavior or do not fully consider the ramifications of historic structural discrimination (Pincus, 1996).

Several realities of societal norms underscore why combating environmental racism is difficult without reasonable legal protections. First and foremost is a lack of personal awareness due to an unclear connection between behavior and negative environmental externalities (Moore, 2016). Roughly 80% of Americans believe that they are living a sustainable lifestyle and that their behavior is either neutral or positively contributes to the physical health of the environment (YouGov, 2016). Consider the choices many urban and suburban residents face in their daily lives. Opting for green or eco-friendly labeled products is an excellent method to demonstrate that one is a conscious consumer (D'Souza et al., 2006), but most consumers do not want to fundamentally change what products they use daily. Most citizens also already recycle (Ipsos, 2011). Thus, asking residents to drastically change how they consume resources will likely be ineffective because most Americans do not see their consumption as wasteful. Campaigns to reduce driving will likely fail. Economic incentives to curb driving patterns will likely amount to a small inconvenience and may persuade a marginal amount to decrease their travel frequency to urban areas for leisure. However, it will not change that most suburban and urban residents work in densely populated urban areas (Boone, 2018). Disincentivizing car travel will also likely have a small but negative effect on local businesses that depend on customers routinely traveling to their stores.

Second, due to the consistent growth in the population (United States Census Bureau, 2019) and the number of registered vehicles (Statista, 2019), demand for new highways and roadways in the U.S. will likely increase in the foreseeable future. This same type of growth is also projected for waste facilities (Wang, 2018). The amplified demand for highways/roadways and for waste facilities in the U.S. naturally fosters issues pertaining to location selection. The determination of specific locations ultimately bleeds into another factor that inadvertently perpetuates environmental racism — a lack of political representation. If a newly selected highway/roadway or waste facility location were in or near an affluent neighborhood, the Not in My Back Yard (NIMBY) effect would likely organically take hold (Schively, 2007). Affluent concerned locals and environmental conservationists would make it increasingly difficult for local developers or state officials to build these structures, which makes building in predominantly poor minority communities advantageous (Stromberg, 2016). Low-income minority communities have less natural resistance to such structures, and generally possess lower amounts of political representation (Glenn, 2017). Poor communities are also more economically vulnerable (Woolf et al., 2015), which makes these areas more susceptible to offers of compensation in exchange for accepting fixtures that produce environmentally hazardous conditions (Bullard, 1993).

Third, segregated housing patterns also influence why racial minorities — particularly the black population — are overburdened by environmental risks (Park & Kwan, 2017). Non-Hispanic blacks generally reside in more impoverished neighborhoods than the average American (Firebaugh & Acciai, 2016). In metropolitan areas, blacks are about four times more likely than other residents to live in areas where the poverty rate is at least 40% (Firebaugh & Acciai, 2016). Research by Logan (2011) found that on average black households with annual earnings of $75,000 reside in areas with higher poverty rates than white households with annual earnings of less than $40,000. Thus, because poor whites are more likely to live in economically diverse areas, they possess a higher chance of receiving political representation from the middle and upper-middle-class communities (Godsil, 1991). Additionally, due to the black median household income being less on average than the white median household income (Fontenot et al., 2018), black citizens are far less likely to have political influence on both the state and federal levels (Stephanopoulos, 2015). Due to these compounding factors, remedies to address environmental racism would probably be more effective if pursued at the federal rather than the state level.

Federal, State, and Local Policies to Address Environmental Racism

Legal battles combating environmental racism customarily arise in two forms: a private citizen sues as a victim of discrimination or by public enforcement — when a federal agency either brings a case to court or examines a claim through an administrative procedure (Glenn, 2017). Both of the potential remedies at the federal level stem from Title VI of the Civil Rights Act of 1964 (Environmental Protection Agency, 2017a), which mandates that no one in the U.S. should be denied benefits, face discrimination, or be denied participation in a program receiving federal assistance based on race, color, or national origin (United States Equal Employment Opportunity Commission, 2000). Seeking remedies at the Federal level can be difficult for two reasons. First, protections at the Federal level are significantly limited by precedent established in civil rights litigation (Powell & Supreme Court of The United States, 1977). Secondly, the court's ability to act is predicated on how the court or various federal government agencies interpret purposeful discrimination (Glenn, 2017). For example, in Alexander v. Sandoval, the Supreme Court specified that Title VI of the Civil Rights Act of 1964 created a protected class and provides legal remedies only for claims of intentional discrimination (Scalia & Supreme Court of The United States, 2000). In other words, Title VI confirmed the authority of an agency to prohibit actions that will unintentionally yield disproportionate negative externalities for some groups but ruled that disparate impact does not provide private parties the ability to bring a lawsuit because there is no remedy explicitly offered under Title VI.

Given the barriers that private citizens confront in federal court, administrative remedies created by federal government agencies offer the best option for those seeking solutions on the federal level (Yang, 2001). The U.S. federal government has taken various legal and administrative steps to minimize environmentally harmful conditions. The EPA has established regulations based on Title VI that forbid discrimination in programs that receive or benefit from EPA assistance, primarily concentrating on complaint investigation (Yang, 2001). The National Environmental Policy Act (NEPA) requires government agencies to account for how any major project will impact the environment (Environmental Protection Agency, 2017c). Similarly, the U.S. transportation conformity program mandates that any plan, program, or project related to transportation must conform to goals that are pre-established in State Implementation Plans by the National Ambient Air Quality Standards (Environmental Protection Agency, 2018a). These standards ensure that transportation activities will not cause any new air quality violations or degrade the current state of air quality. Both the NEPA and the project-level conformity analyses utilize dispersion models to project air quality (Baldauf et al., 2009). The use of dispersion models can identify local populations who are at risk for overexposure to air pollutants because of the initiation of new projects.

However, some remain skeptical of the validity of these dispersion models because the algorithms for assessing impact are simplistic and do not adequately account for roadside features (Abhijith et al., 2017; Baldauf et al., 2009). Additional research on downwind patterns and full consideration of various roadside designs would likely augment the reliability of the models. This shortcoming significantly limits the reach of the NEPA and other laws that allow federal government agencies to intervene if the potential risk is not being distributed equally along racial lines. Thus, considering that federal administrative remedies come with their own set of inefficiencies, seeking recourse at the federal level is likely not feasible without congress explicitly passing a law that both prohibits actions under the environmental racism umbrella and provides an appropriate cause of action.

Most state departments of transportation (DOT) and various local governments in the U.S. share concurrent jurisdiction over land use along major roads (Vanka et al., 2005). These different sources of authority frequently have different objectives. State DOT's often seek to further highway maintenance and expansion (United States Department of Transportation, 2012) while municipal governments tend to focus their attention on economic development and have authority over zoning and permitting (Vanka et al., 2005). Collaboration between these two entities can help facilitate optimal roadway design, which would allow for the further expansion of highways and a net-decrease of air pollutants in areas immediately adjacent to major roadways and highways after modifications. These activities would be beneficial to those most impacted by urban air pollution.

Roadside Walls and Vegetation

One well-studied and relatively non-intrusive method that can be employed by local governments to diminish air pollutants is to use roadside features (Abhijith et al., 2017; Baldauf, 2017; Gallagher et al., 2015). Roadside features such as noise barriers and vegetation offer a mitigation plan for air pollutants that accumulate in areas directly adjacent and downwind of major roadways (Bowker et al., 2007). Noise barriers are a common roadside feature along busy roadways and highways that can aid in air pollution concentration mitigation (Baldauf et al., 2008; Heist et al., 2009). Noise barriers are walls that reside on the sides of highways that impede and deflect sound waves (United States Department of Transportation, 2017b). Aside from deflecting sound generated by traffic, noise barriers encourage air pollutant dispersion by vertical mixing via increased vertical airflow (Bowker et al., 2007; Finn et al., 2010; Heist et al., 2009; Ning et al., 2010). Increased vertical airflow is beneficial because it will likely lead to recirculation downwind of the barrier, which will contain mixed and often less potent air pollution concentrations (Ho ̇lscher et al., 1993).

Several studies have investigated the effectiveness of noise barriers at air pollution mitigation. These studies generally find them to be a valuable tool for decreasing air pollution concentrations. For example, research by Baldauf et al. (2008) showed that concentrations of CO and other air pollutants can be reduced anywhere from 15% to 50% behind noise barriers. In an analysis using tracer pollutants, Finn et al. (2010) found that noise barriers have the potential to improve air quality by 50% if atmospheric conditions are stable. A similar study by Hagler et al. (2011) found that noise barriers can lessen air pollutant concentrations anywhere from 15% to 61%, with higher barriers performing the best for downwind pollution reduction. A more recent study by Baldauf (2016) found that noise barriers reduced 50% of air pollution levels within 164 feet of the barrier and 30% within 984 feet of the barrier. Similar findings regarding air pollution concentrations being decreased at long distances from noise barriers were also found by Heist et al. (2009) and Ning et al. (2010). It is recommended that noise barriers be about 13 feet or taller for optimal effectiveness (Heist et al., 2009).

In addition to noise barriers, other non-vegetative solid structures such as low boundary walls and parked cars can influence pollutant dispersion. Low boundary walls and parked cars differ from noise barriers in their height and utility. Effective noise barriers tend to be 13 to 16 feet tall and are used for high-speed highways (Baldauf et al., 2016). In contrast, low boundary walls are much smaller (three to six feet tall) and are used mostly for low-speed roadways and local urban streets. Although not as effective when compared to noise barriers, low boundary walls still have some potential for pollutant dispersion (Gallagher et al., 2015). Research reports that low boundary walls improve air quality and are particularly useful for improving air quality for pedestrians in urban areas (King et al., 2009). For example, McNabola et al. (2008) found that low boundary walls of only six feet in height can decrease up to 57% of the air pollutants pedestrians encounter while walking alongside roadway traffic. Gallagher et al. (2012) also observed that low boundary walls lessened air pollutants by up to 50% in urban windward footpaths.

Due to their relatively small size, low boundary walls are also ideal for combating the formation of street canyons engendered by the design of urban cities (McNabola et al., 2009). Street canyons are urban city areas where air pollution from urban street traffic gets trapped near sidewalks and local houses because of the obstruction of airflow triggered by streets being flanked by buildings on both sides (Vardoulakis et al., 2003). Parked cars are common in urban environments and can also help to mitigate the effects of street canyons. Parked cars furnish a temporary barrier between roadside air pollution and footpaths in urban areas because parked cars are frequently located alongside driving lanes. Research by Gallagher et al. (2011) found that when using projected air pollutant models, parked cars can lower air pollution concentrations by up to 49% on footpaths. Thus, occupied parallel parking spaces on streets can provide a viable option to curtail air pollution concentrations in urban areas (Abhijith & Gokhale, 2015). However, it should be noted that studies on the effectiveness of parked cars are scarce, and while traffic patterns are somewhat predictable, vehicles do not offer a static barrier to nullify air pollution.

Although vegetation does not afford the same level of sound reduction as noise barriers, thick foliage can provide comparable blockage effects and airflow reduction from air pollution plumes by catching particles on leaf surfaces via impaction or deposition (Sæbø et al., 2012). Air pollutants are also absorbed through leaf stoma on the surface of plants (Fantozzi et al., 2015), although this absorption can be harmful to the plants (Gupta et al., 2016). Various studies find the use of vegetation to be a versatile and effective means to attenuate air pollution concentrations (Brantley et al., 2014; Jayasooriya, et al., 2017). For example, Neft et al. (2016) found that vegetation barriers located within 33 feet of pollutant sources improved air quality by curtailing air pollution concentrations in excess of 50%.

One unobtrusive way to leverage vegetation in curtailing air pollution is to incorporate it into noise barriers or low boundary walls to form a green wall. Green walls are structures that have vegetation either partially or entirely covering their surfaces (Manso & Castro-Gomes, 2015). Green walls retain the benefits of impeding air pollutant plumes and increased turbulence (Hölscher et al., 1993), while providing the added benefit of absorbing or catching particles through deposition or impaction (Sæbø et al., 2012). They are more effective at decreasing concentrations of air pollutants than either open fields or noise barriers without vegetation (Baldauf et al., 2008; Bowker et al., 2007). For optimal blockage effects, green walls should be approximately 13 feet or higher (Heist et al., 2009). Short and dense vegetation can also be used instead of walls, as these vegetative structures are reported to have a beneficial impact on urban air quality (Pugh et al., 2012). If used without a wall, the vegetation structure should be roughly 33 feet thick or more to better remove particulates from vehicle exhaust (Neft et al., 2016). Multiple rows of varying types of vegetation is also recommended to maximize pollutant removal (Baldauf, 2017). Work by (Baldauf et al., 2008) and (Brantley et al., 2014) further suggests that vegetative barriers should extend laterally or perpendicularly past the highway, as pollutants can linger around the ends of vegetation barriers.

However, it is important to recognize that despite the notable upside of using vegetation to reduce air pollution, not all foliage provides benefits. Several studies have assessed the impact of trees in urban street canyons. These studies typically find that the presence of trees increases air pollution concentrations (Abhijith & Gokhale, 2015;

Hofman et al., 2016). Factors such as humidity, regional climate, and rain patterns can also act to diminish the effectiveness of vegetation. Notwithstanding these mild limitations, vegetation can be leveraged by policymakers to combat urban air pollution to great effect.

Concluding Thoughts

While the findings generated here are informative and provide a substantive addition to the literature discussing the relationship between air pollution and crime, this study is not without its shortcomings. The most discernible vulnerability of the multilevel analysis is the use of CO as the sole indicator of air pollution, although it is the most commonly used variable by researchers. It is abundant in cities, disproportionate likely exposure exists between demographic groups, and city concentrations are widely measured and recorded by the EPA. Despite these advantages of CO, there are a handful of other air pollutants that could warrant consideration. However, this consideration was not feasible here because reporting for other air pollutants collected by the EPA do not enjoy the same level of coverage as CO. Reducing the number of cities measured to accommodate other less analyzed air pollutants would have severely compromised the generalizability of the results.

Other points of contention may reside in the way aggression was measured and the use of cross-sectional data. While the use of a physical injury of the crime victim to represent offender aggression is intuitive, it is not a comprehensive measure. Physical attacks are not the only form in which aggression can manifest itself. Other more covert and possibly indirect actions can serve the same purpose as displaying physical aggression (Little et al., 2003). However, while there are several avenues to display aggression, it is reasonable to speculate that aggression that is sufficient to provide the impetus to commit a violent crime will likely manifest itself in a direct and noticeable manner, with displays of physical violence being the most likely of indicators to capture this. Additionally, due to the cross-sectional nature of the data, the multilevel analysis is ill-suited to determine the effect of air pollution on aggression over time. However, due to the fluctuations in the Environmental Protection Agency's monitoring stations, gathering data for multiple cities over an extended period for even one air pollutant was not feasible.

Despite these shortcomings, this is the first study to document how disproportionate exposure to air pollution can increase the likelihood of a victim being injured during the commission of a violent criminal offense. This study also adds to the expanding catalog of tangible repercussions sowed into urban areas from decades of decision making guided by racial discrimination and indifference. The visible and ever-present display of environmental racism via established highway systems in urban areas will continue to disproportionately burden minority communities unless action is initiated to help abate the highway and roadside air pollution that pervades urban areas.

This situation is not going to disappear on its own and will likely get worse in the immediate future. The air quality in many urban areas throughout the U.S. has consistently deteriorated in recent years, despite national emissions declining by 73% from 1970 to 2017 (Environmental Protection Agency, 2018d). The American Lung Association (ALA) published its annual report in 2019 estimating that the number of Americans living in cities with unsafe levels of air pollution had reached nearly 141.1 million, which is representative of about four in every ten Americans. This number of

Americans denotes an increase from the ALA's two prior reports with about 133.9 million reported in 2018 (covering the years 2014-2016) and more than the 125 million documented in the 2017 report (covering the years 2013-2015) (American Lung Association, 2019b). According to 2018 metrics provided by the Air Quality Index, days in American Metro areas where the air quality was unhealthy for the young, the elderly, and those with heart and lung disease increased by about 15% when compared to the average for the years from 2013 to 2016 (Borenstein & Forster, 2019). Days categorized as very unhealthy and hazardous also grew by more than 150% from 2013 to 2016 (Borenstein and Forster, 2019).

The stark contrast between national air emissions and urban air quality is likely due to populations growing in urban areas and the continued dependence on motor vehicles for transportation. Although urban and suburban populations were nearly equal in the early 1900s, urban areas now contain over 80% of the population despite occupying about 3% of the nation's land area (United States Census Bureau, 2016b). Additionally, notwithstanding a minor dip in the aftermath of the economic recession of 2008, the number of registered vehicles has steadily increased in the U.S. - increasing by about 41% from 1990 to 2017 (Statista, 2019). Improvements in gas mileage and vehicle fuel technologies (Environmental Protection Agency, 2018d; Environmental Protection Agency, 2018b) and the gradual shift from fossil fuels to natural gas for energy generation (Environmental Protection Agency, 2018b) has dramatically benefited national efforts to diminish air pollution. However, these efforts have had relatively little impact in growing urban areas.

The projected rise in the number of motor vehicles operating in urban areas is believed to be harmful for several reasons. Aside from releasing CO into surrounding areas, motor vehicles also emit other chemicals that are highly volatile and reactive to sunlight (Environmental Protection Agency, 2018a). These harmful chemicals are ubiquitous throughout urban areas and are particularly concentrated near major roadways and highways (American Lung Association, 2018). They can also amplify the quantity and lethality of air pollutants in hot temperatures, which exacerbates the effects of global warming in urban areas (Environmental Protection Agency, 2019a).

Americans are already feeling the effects of prolonged exposure to air pollution. A recent analysis by Goodkind et al. (2019) found that air pollution was responsible for over 100,000 premature deaths in the U.S. in 2011, which cost the country $886 billion in potential output. Densely populated areas bear the brunt of these damages, despite occupying a small percentage of available land. The federal government, state governments, and municipalities need to initiate well-funded and long-term initiatives to address air pollution. Otherwise, urban areas will continue to experience calloused economic and political policies that disproportionately burden minority communities.

Chapter Summary

Although not without its limitations, this is the first analysis to document how disproportionate exposure to air pollution can increase the likelihood of a victim being injured during the commission of a violent criminal offense. This study also adds to the expanding catalog of tangible repercussions sowed into urban areas from decades of decision making guided by racial discrimination and indifference. The visible and ever-present display of environmental racism via established highway systems in urban areas will continue to disproportionately burden minority communities unless action is initiated to help abate the highway and roadside air pollution that pervades urban areas.

To diminish the effects of environmental racism in urban areas, the federal government, state governments, and municipalities need to initiate well-funded and long-term initiatives to address air pollution. Currently, a relatively non-intrusive and proven method to blunt the impact of air pollution is through the implementation of roadside features. Roadside features such as noise barriers, vegetation, low boundary walls, and parked cars can offer a reprieve from air pollutants that accumulate in areas directly adjacent and downwind of major roadways. Optimally, a combination of sound barriers and vegetation will be utilized to flank most major roadways to form green walls, which possess the dispersion properties of sound barriers and the impaction and deposition ability of vegetative surfaces. Low boundary walls can be utilized for smaller roadways, and both low boundary walls and space allocations for parallel parking in busy city streets can help attenuate air pollution that is trapped in urban areas due to street canyons.

REFERENCES

Abhijith, K. V., & Gokhale, S. (2015). Passive control potentials of trees and on-street parked cars in reduction of air pollution exposure in urban street canyons. *Environmental pollution*, *204*, 99-108.

Abhijith, K. V., Kumar, P., Gallagher, J., McNabola, A., Baldauf, R., Pilla, F., ... & Pulvirenti, B. (2017). Air pollution abatement performances of green infrastructure in open road and built-up street canyon environments–A review. *Atmospheric Environment*, *162*, 71-86.

Agresti, A., & Kateri, M. (2011). *Categorical data analysis*. Berlin, Heidelberg: Springer.

Ahangari, G. (2015). The study of negative effects of air pollution on serotonin receptors (5htr2a and 5htr3a) and mono amino oxidase a gene expression alterations in exposed individuals and its association with urban traffic accident. *The Neuroscience Journal of Shefaye Khatam, 2*(4), 29.

Aizer, A., Currie, J., Simon, P., & Vivier, P. (2018). Do low levels of blood lead reduce children's future test scores? *American Economic Journal: Applied Economics*, *10*(1), 307–341.

Akers, R. L. (1990). Rational choice, deterrence, and social learning theory in criminology: The path not taken. *The Journal of Criminal Law and Criminology*, *81*(3), 653.

Akimoto, H. (2003). Global air quality and pollution. *Science*, *302*(5651), 1716-1719.

Allen, J. L., Conrad, K., Oberdörster, G., Johnston, C. J., Sleezer, B., and Cory-Slechta, D. A. (2013). Developmental exposure to concentrated ambient particles and preference for immediate reward in mice. *Environmental Health Perspectives, 121*(1), 32–38.

Alzheimer's Association. (2019). *Stages and behaviors: Aggression and anger.* https://www.alz.org/help-support/caregiving/stages-behaviors/agression-anger

American Lung Association. (2018, April 10). *Healthy air*. https://www.lung.org/our-initiatives/healthy-air/outdoor/air-pollution/highways.html

American Lung Association. (2019a, August 20). *Smoking facts*. http://www.lung.org/stop-smoking/smoking-facts/whats-in-a-cigarette.html

American Lung Association. (2019b). *State of the air 2018*. https://www.lung.org/our-initiatives/healthy-air/sota/key-findings/

Amitai, Y., Zlotogorski, Z., Golan-Katzav, V., Wexler, A., & Gross, D. (1998). Neuropsychological impairment from acute low-level exposure to carbon monoxide. *Archives of Neurology*, *55*(6), 845-848.

Anderson, E. R., & Hope, D. A. (2008). A review of the tripartite model for understanding the link between anxiety and depression in youth. *Clinical Psychology Review*, *28*(2), 275-287.

Archsmith, J., Heyes, A., & Saberian, S. (2018). Air quality and error quantity: Pollution and performance in a high-skilled, quality-focused occupation. *Journal of the Association of Environmental and Resource Economists*, *5*(4), 827-863.

Ash, M., & Fetter, T. R. (2004). Who lives on the wrong side of the environmental tracks? Evidence from the EPA's risk-screening environmental indicators model. *Social Science Quarterly*, *85*(2), 441-462.

Babey, S. H., Hastert, T. A., & Brown, R. E. (2007). *Teens living in disadvantaged neighborhoods lack access to parks and get less physical activity.* UCLA Center for Health Policy Research. https://escholarship.org/content/qt4ww2p7v4/qt4ww2p7v4.pdf

Baldauf, R. (2016). *Recommendations for constructing roadside vegetation barriers to improve near-road air quality*. United States Department of Environmental Protection Agency. https://www.epa.gov/sites/production/files/2016-08/documents/recommendations_for_constructing_roadside_vegetation_barriers_to_improve_near-road_air_quality.pdf

Baldauf, R. (2017). Roadside vegetation design characteristics that can improve local, near-road air quality. *Transportation Research Part D: Transport and Environment*, *52*(11), 354-361.

Baldauf, R., Cahill, T., Bailey, C., Khlystov, A., Zhang, K. M., Cook, R., ... Bowker, G. (2009). Can roadway design air quality impacts be used to mitigate from traffic? *EM: Air and Waste Management Association's Magazine for Environmental Managers*, 6-11.

Baldauf, R. W., Isakov, V., Deshmukh, P., Venkatram, A., Yang, B., & Zhang, K. M. (2016). Influence of solid noise barriers on near-road and on-road air quality. *Atmospheric Environment*, *129*, 265-276.

Baldauf, R., Thoma, E., Khlystov, A., Isakov, V., Bowker, G., Long, T., & Snow, R. (2008). Impacts of noise barriers on near-road air quality. *Atmospheric Environment*, *42*(32), 7502-7507.

Barrash, J., Stuss, D. T., Aksan, N., Anderson, S. W., Jones, R. D., Manzel, K., & Tranel, D. (2018). “Frontal lobe syndrome”? Subtypes of acquired personality disturbances in patients with focal brain damage. *Cortex*, *106*, 65-80.

Battin, J. R., & Crowl, J. N. (2017). Urban sprawl, population density, and crime: an examination of contemporary migration trends and crime in suburban and rural neighborhoods. *Crime Prevention and Community Safety*, *19*(2), 136-150.

Baum-Snow, N. (2007). Did highways cause suburbanization? *The Quarterly Journal of Economics*, 122(2), 775-805.

Beccaria, C. (1963). *On crime and punishments*, trans. Henry Paolucci. Prentice Hall.

Becker, S. (2007). Race and violent offender “propensity”: Does the intraracial nature of violent crime persist on the local level? *Justice Research and Policy*, *9*(2), 53-86.

Beland, L. P., & Brent, D. A. (2018). Traffic and crime. *Journal of Public Economics*, *160*, 96-116.

Bentham, J., Burns, J. H., & Hart, H. L. A. (1996). *An introduction to the principles of morals and legislation*. Oxford University Press.

Beurel, E., & Jope, R. S. (2014). Inflammation and lithium: clues to mechanisms contributing to suicide-linked traits. *Translational Psychiatry*, *4*(12), 1-6.

Bharadwaj, P., Gibson, M., Zivin, J. G., & Neilson, C. (2017). Gray matters: Fetal pollution exposure and human capital formation. *Journal of the Association of Environmental and Resource Economists*, *4*(2), 505-542.

Biermann, T., Stilianakis, N., Bleich, S., Thürauf, N., Kornhuber, J., & Reulbach, U. (2009). he hypothesis of an impact of ozone on the occurrence of completed and attempted suicides. *Medical Hypotheses*, *72*(3), 338-341.

Black, D. (1976). *The behavior of law*. Academic Press.

Block, M. L., & Calderón-Garcidueñas, L. (2009). Air pollution: mechanisms of neuroinflammation and CNS disease. *Trends in Neurosciences*, *32*(9), 506-516.

Blumenthal, I. (2001). Carbon monoxide poisoning. *Journal of the Royal Society of Medicine*, *94*(6), 270–272.

Boehmer, T. K., Stephanie, F. L., Henry, J. R., & Woghiren-Akinnifesi, E. L. (2013). Residential Proximity to Major Highways—United States, 2010. *CDC Health Disparities and Inequalities Report—United States, 2013*, *62*(3), 46.

Bondy, M., Roth, S., & Sager, L. (2018). *Crime is in the air: The contemporaneous relationship between air pollution and crime.* IZA Institute of Labor Economics. https://www.econstor.eu/bitstream/10419/180510/1/dp11492.pdf

Boone, C. (2018, September 20). The U.S. has become a nation of suburbs. *High Country News*. https://www.hcn.org/articles/growth-and-sustainability-the-us-has-become-a-nation-of-suburbs

Borenstein, S., & Forster, N. (2019, July 18). US air quality is slipping after years of improvement. *Associated Press.* https://www.apnews.com/d3515b79af1246d08f7978f026c9092b

Bornmann, L., Mutz, R., Neuhaus, C., & Daniel, H. D. (2008). Citation counts for research evaluation: standards of good practice for analyzing bibliometric data and presenting and interpreting results. *Ethics in Science and Environmental Politics*, *8*(1), 93-102.

Boyd, R. L. (2015). The 'Black Metropolis' in the American Urban System of the Early Twentieth Century: Harlem, Bronzeville and Beyond. *International Journal of Urban and Regional Research*, *39*(1), 129-144.

Bowker, G. E., Baldauf, R., Isakov, V., Khlystov, A., & Petersen, W. (2007). The effects of roadside structures on the transport and dispersion of ultrafine particles from highways. *Atmospheric Environment*, *41*(37), 8128-8139.

Brain, J. D., Long, N. C., Wolfthal, S. F., Dumyahn, T., & Dockery, D. W. (1998). Pulmonary toxicity in hamsters of smoke particles from Kuwaiti oil fires. *Environmental Health Perspectives*, *106*(3), 141.

Brantley, H. L., Hagler, G. S., Deshmukh, P. J., & Baldauf, R. W. (2014). Field assessment of the effects of roadside vegetation on near-road black carbon and particulate matter. *Science of the Total Environment*, *468-469*, 120-129.

Brook, R. D., Franklin, B., Cascio, W., Hong, Y., Howard, G., Lipsett, M., ... & Tager, I. (2004). Air pollution and cardiovascular disease: a statement for healthcare professionals from the Expert Panel on Population and Prevention Science of the American Heart Association. *Circulation*, *109*(21), 2655-2671.

Bryk, A. S., Raudenbush, S. W., & Congdon, R. T. (1996). *Hierarchical linear and nonlinear modeling with the HLM/2L and HLM/3L programs.* Chicago: Scientific Software International.

Bullard, R. (1990). *Dumping in dixie: Race, class, and environmental quality*. Westview.

Bullard, R., Johnson, S. G., & Torres, O. A. (2000) *Sprawl city: Race, politics, and planning in Atlanta*. Island Press.

Bullard, R. D. (1993). Anatomy of environmental racism. In: R. Hofrichter (ed.), *Toxic Struggles: The Theory and Practice of environmental justice*. New Society Publishers.

Bureau of Justice Statistics. (2018). *Criminal victimization, 2017*. https://www.bjs.gov/content/pub/pdf/cv17_sum.pdf

Bureau of Justice Statistics. (2019). *Criminal victimization, 2018*. https://www.bjs.gov/content/pub/pdf/cv18_sum.pdf

Bureau of Justice Statistics. (2017). *Race and Hispanic origin of victims and offenders, 2012-15*. https://www.bjs.gov/content/pub/pdf/rhovo1215_sum.pdf

Bureau of Justice Statistics. (1994). *Violent crime*. https://www.bjs.gov/content/pub/pdf/VIOCRM.PDF

Calderón-Garcidueñas, L., Kavanaugh, M., Block, M., D'Angiulli, A., Delgado-Chávez, R., Torres-Jardón, R., ... & Guo, R. (2012). Neuroinflammation, hyperphosphorylated tau, diffuse amyloid plaques, and down-regulation of the cellular prion protein in air pollution exposed children and young adults. *Journal of Alzheimer's Disease*, *28*(1), 93-107.

Calderón-Garcidueñas, L., Kulesza, R. J., Doty, R. L., D'angiulli, A., & Torres-Jardón, R. (2015). Megacities air pollution problems: Mexico City Metropolitan Area critical issues on the central nervous system pediatric impact. *Environmental Research*, *137*, 157-169.

Calderón-Garcidueñas, L., Mora-Tiscareño, A., Ontiveros, E., Gómez-Garza, G., Barragán-Mejía, G., Broadway, J., ... & Henríquez-Roldán, C. (2009). Air pollution, cognitive deficits and brain abnormalities: a pilot study with children and dogs. *Brain and Cognition*, *68*(2), 117-127.

Capowich, G. E. (2003). The conditioning effects of neighborhood ecology on burglary victimization. *Criminal Justice and Behavior*, *30*(1), 39-61.

Card, D., & Dahl, G. B. (2011). Family violence and football: The effect of unexpected emotional cues on violent behavior. *The Quarterly Journal of Economics*, *126*(1), 103-143.

Carlsen, K. C., Løvik, M., Granum, B., Mowinckel, P., & Carlsen, K. H. (2006). Soluble CD14 at 2 yr of age: Gender-related effects of tobacco smoke exposure, recurrent infections and atopic diseases. *Pediatric Allergy and Immunology*, *17*(4), 304-312.

Centers for Disease Control and Prevention. (2016). *Climate change decreases the quality of the air we breathe*. https://www.cdc.gov/climateandhealth/pubs/air-quality-final_508.pdf

Chang, T., Graff Zivin, J., Gross, T., & Neidell, M. (2016). Particulate pollution and the productivity of pear packers. *American Economic Journal: Economic Policy*, *8*(3), 141– 169.

Chang, T. Y., Graff Zivin, J., Gross, T., & Neidell, M. (2019). The effect of pollution on worker productivity: evidence from call center workers in China. *American Economic Journal: Applied Economics*, *11*(1), 1-10.

Chatoutsidou, S. E., Ondráček, J., Tesar, O., Tørseth, K., Ždímal, V., & Lazaridis, M. (2015). Indoor/outdoor particulate matter number and mass concentration in modern offices. *Building and Environment*, *92*(1), 462-474.

Chen, C.-Y., Bonham, A. C., Plopper, C. G., and Joad, J. P. (2003). Selected Contribution: Neuroplasticity in nucleus tractus solitarius neurons after episodic ozone exposure in infant primates. *Journal of Applied Physiology*, *94*(2), 819–827.

Chen, C., Liu, C., Chen, R., Wang, W., Li, W., Kan, H., & Fu, C. (2018). Ambient air pollution and daily hospital admissions for mental disorders in Shanghai, China. *Science of The Total Environment*, *613*(1), 324-330.

Chen, X., Zhang, X., & Zhang, X. (2017). *Smog in our brains: Gender differences in the impact of exposure to air pollution on cognitive performance*. IZA Institute of Labor Economics, 5-9. http://ftp.iza.org/dp10628.pdf

Chetty, R., Hendren, N., Jones, M. R., & Porter, S. R. (2019). *Race and economic opportunity in the United States: An intergenerational perspective* (No. 24441). The National Bureau of Economic Research, 1-8. http://www.equality-of-opportunity.org/assets/documents/race_paper.pdf

Cho, H. Y., Zhang, L. Y., & Kleeberger, S. R. (2001). Ozone-induced lung inflammation and hyperreactivity are mediated via tumor necrosis factor-α receptors. *American Journal of Physiology-Lung Cellular and Molecular Physiology*, *280*(3), L537-L546.

Christens, B., & Speer, P. W. (2005). Predicting violent crime using urban and suburban densities. *Behavior and Social Issues*, *14*(2), 113-127.

Clapp, J. M., & Wang, Y. (2006). Defining neighborhood boundaries: Are census tracts obsolete? *Journal of Urban Economics*, *59*(2), 259-284.

Clark, L. P., Millet, D. B., & Marshall, J. D. (2014) National patterns in environmental injustice and inequality: outdoor NO 2 air pollution in the United States. *PloS one*, *9*(4), e94431.

Clougherty, J. E. (2010). A growing role for gender analysis in air pollution epidemiology. *Environmental Health Perspectives*, *118*(2), 167.

Coccaro, E. F., Lee, R., & Coussons-Read, M. (2014). Elevated plasma inflammatory markers in individuals with intermittent explosive disorder and correlation with aggression in humans. *JAMA Psychiatry*, *71*(2), 158-165.

Coccaro, E. F., Sripada, C. S., Yanowitch, R. N., and Phan, K. L. (2011). Corticolimbic function in impulsive aggressive behavior. *Biological Psychiatry, 69*(12), 1153–1159.

Coccia M. (2017). A Theory of general causes of violent crime: Homicides, income inequality and deficiencies of the heat hypothesis and of the model of CLASH. *Aggression and Violent Behavior*, 37, 190-200.

Cole, L. W. (1992). Empowerment as the key to environmental protection: The need for environmental poverty law. *Ecology Law Quarterly*, *19(*4), 619-622.

Cook, P. J. (1980). Reducing injury and death rates in robbery. *Policy Analysis*, *6*(1), 21-45.

Corrigan, P. W., & Watson, A. C. (2005). Findings from the National Comorbidity Survey on the frequency of violent behavior in individuals with psychiatric disorders. *Psychiatry Research*, *136*(2-3), 153-162.

Crockett, M. J., Apergis-Schoute, A., Herrmann, B., Lieberman, M. D., Müller, U., Robbins, T. W., and Clark, L. (2013). Serotonin modulates striatal responses to fairness and retaliation in humans. *Journal of Neuroscience, 33*(8), 3505–3513.

Currie, J., Hanushek, E. A., Kahn, E. M., Neidell, M., & Rivkin, S. G. (2009). Does pollution increase school absences? *The Review of Economics and Statistics*, *91*(4), 682–694.

D'Souza, C., Taghian, M., Lamb, P., & Peretiatkos, R. (2006). Green products and corporate strategy: an empirical investigation. *Society and Business Review*, *1*(2), 144-157.

Dane, S. M. (2016). *The Potential Impact of Texas Department of Housing and Community Affairs v. Inclusive Communities Project on Future Civil Rights Enforcement and Compliance*. The Federal Lawyer, 39-40. https://www.relmanlaw.com/assets/htmldocuments/The-Potential-Impact-ofemTexas-Department-on-Housing-and-Community-Affairs-v-Inclusive-Commun.pdf

Deaton, A., & Lubotsky, D. (2003). Mortality, inequality and race in American cities and states. *Social Science & Medicine*, *56*(6), 1139-1153.

Dearing, C. L. (1941): *American highway policy*. Brookings Institution.

Delfino, R. J., Staimer, N., & Vaziri, N. D. (2011). Air pollution and circulating biomarkers of oxidative stress. *Air Quality, Atmosphere & Health*, *4*(1), 37-52.

Dennis, R. L., Fahey, A. G., & Cheng, H. W. (2013). Alterations to embryonic serotonin change aggression and fearfulness. *Aggressive Behavior*, *39*(2), 91-98.

Dergham, M., Lepers, C., Verdin, A., Billet, S., Cazier, F., Courcot, D., ... & Garçon, G. (2012). Prooxidant and proinflammatory potency of air pollution particulate matter (PM2. 5–0.3) produced in rural, urban, or industrial surroundings in human bronchial epithelial cells (BEAS-2B). *Chemical Research in Toxicology*, *25*(4), 904-919.

Douglas, J., Burgess, A. W., Burgess, A. G., & Ressler, R. K. (2013). *Crime classification manual: A standard system for investigating and classifying violent crime*. John Wiley & Sons.

Dutta, A., Khramstova, G., Brito, K., Alexander, D., Mueller, A., Chinthala, S., ... & Adigun, K. (2018). Household air pollution and chronic hypoxia in the placenta of pregnant Nigerian women: A randomized controlled ethanol Cookstove intervention. *Science of the Total Environment*, *619*(1), 212-220.

Ebenstein, A., Lavy, V., & Roth, S. (2016). The long-run economic consequences of high-stakes examinations: Evidence from transitory variation in pollution. *American Economic Journal: Applied Economics, 8*(4), 36-65.

Energy Information Administration. (2018, February 8). *U.S. energy-related CO2 emissions expected to rise slightly in 2018, remain flat in 2019*. https://www.eia.gov/todayinenergy/detail.php?id=34872

Environ International Corporation. (2013). *Revised AB2588 Health Risk Assessment.* ENVIRON International Corporation. http://www.aqmd.gov/docs/default-source/planning/risk-assessment/exide-hra.pdf

Environmental Defense Fund. (2018). *Health impacts of air pollution*. https://www.edf.org/health/health-impacts-air-pollution

Environmental Protection Agency. (2019a, November 21). *Air quality and climate change research*. https://www.epa.gov/air-research/air-quality-and-climate-change-research

Environmental Protection Agency. (2019b, June 18). *Air quality index (AQI) basics*. https://airnow.gov/index.cfm?action=aqibasics.aqi

Environmental Protection Agency. (2018a, May 10). *General Information for Transportation and Conformity*. https://www.epa.gov/state-and-local-transportation/general-information-transportation-and-conformity

Environmental Protection Agency. (2018b, January 20). *History of reducing air pollution from transportation in the United States*. https://www.epa.gov/transportation-air-pollution-and-climate-change/accomplishments-and-success-air-pollution-transportation

Environmental Protection Agency. (2008, January). *Latest findings on national air quality: status and trends through 2006*. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=60000MXE.PDF

Environmental Protection Agency. (2018c, July 20). *Outdoor air quality data*. https://www.epa.gov/outdoor-air-quality-data/air-data-basic-information

Environmental Protection Agency. (2018d, August 7). *Progress cleaning the air and improving people's health*. https://www.epa.gov/clean-air-act-overview/progress-cleaning-air-and-improving-peoples-health

Environmental Protection Agency. (2017a, January 17). *Title VI and environmental justice*. https://www.epa.gov/environmentaljustice/title-vi-and-environmental-justice

Environmental Protection Agency. (2017b, March 2017). *Vehicle certification and compliance testing*. https://www.epa.gov/vehicle-and-fuel-emissions-testing/vehicle-certification-and-compliance-testing

Environmental Protection Agency. (2017c, January 24). *What is the national environmental policy act?* https://www.epa.gov/nepa/what-national-environmental-policy-act

Erlanger, H. S. (1975). Is There a" Subculture of Violence" in the South? *The Journal of Criminal Law and Criminology*, *66*(4), 483-490.

Fainstein, N. I., & Fainstein, S. S. (1987). Economic restructuring and the politics of land use planning in New York City. *Journal of the American Planning Association, 53*(2), 237-248.

Fantozzi, F., Monaci, F., Blanusa, T., & Bargagli, R. (2015). Spatio-temporal variations of ozone and nitrogen dioxide concentrations under urban trees and in a nearby open area. *Urban Climate*, *12*, 119-127.

Faustman, W. O., Ringo, D. L., and Faull, K. F. (1993). An association between low levels of 5-HIAA and HVA in cerebrospinal fluid and early mortality in a diagnostically mixed psychiatric sample. *British Journal of Psychiatry, 163*(4):519–521.

Federal Highway Administration. (2018, November 7). *Moving ahead for progress in the 21st century.* https://www.fhwa.dot.gov/map21/.

Finn, D., Clawson, K. L., Carter, R. G., Rich, J. D., Eckman, R. M., Perry, S. G., ... & Heist, D. K. (2010). Tracer studies to characterize the effects of roadside noise barriers on near-road pollutant dispersion under varying atmospheric stability conditions. *Atmospheric Environment*, *44*(2), 204-214.

Firebaugh, G., & Acciai, F. (2016). For blacks in America, the gap in neighborhood poverty has declined faster than segregation. Proceedings of the National Academy of Sciences, *113*(47), 13372-13377.

Fontenot, K., Semega, J., & Kollar, M. (2018). *Income and poverty in the United States: 2017.* United States Census Bureau. https://www.census.gov/content/dam/Census/library/publications/2018/demo/p60-263.pdf

Forns, J., Dadvand, P., Foraster, M., Alvarez-Pedrerol, M., Rivas, I., López-Vicente, M., ... & Grellier, J. (2016). Traffic-related air pollution, noise at school, and behavioral problems in Barcelona schoolchildren: a cross-sectional study. *Environmental Health Perspectives, 124*(4), 529.

Frankle, W. G., Lombardo, I., New, A. S., Goodman, M., Talbot, P. S., Huang, Y., ... & Laruelle, M. (2005). Brain serotonin transporter distribution in subjects with impulsive aggressivity: a positron emission study with [11C] McN 5652. *American Journal of Psychiatry*, *162*(5), 915-923.

Foresta, R. A. (1983). The second battle of New Orleans: A history of the Vieux Carre Riverfront Expressway controversy. *Annals of the Association of American Geographers*, *73*(3), 457-460.

Galizia, A., & Kinney, P. L. (1999). Long-term residence in areas of high ozone: associations with respiratory health in a nationwide sample of nonsmoking young adults. *Environmental Health Perspectives*, *107*(8), 675.

Gallagher, J., Baldauf, R., Fuller, C. H., Kumar, P., Gill, L. W., & McNabola, A. (2015). Passive methods for improving air quality in the built environment: a review of porous and solid barriers. *Atmospheric Environment*, 100(120), 61-70.

Gallagher, J., Gill, L. W., & McNabola, A. (2011). Optimizing the use of on-street car parking system as a passive control of air pollution exposure in street canyons by large eddy simulation. *Atmospheric environment*, *45*(9), 1684-1694.

Gallagher, J., Gill, L. W., & McNabola, A. (2012). Numerical modelling of the passive control of air pollution in asymmetrical urban street canyons using refined mesh discretization schemes. *Building and Environment*, *56*, 232-240.

Garrison, J. (2013) Exide plant ordered to clean up lead. *Los Angeles Times*. https://www.latimes.com/local/la-xpm-2013-dec-18-la-me-exide-20131219-story.html

Garrison, J., & Christensen, K. (2013) Uproar swells over toxic sites. *Los Angeles Times*. https://www.latimes.com/local/la-me-toxic-oversight-20131226-dto-htmlstory.html

Garza, A., Vega, R., & Soto, E. (2006). Cellular mechanisms of lead neurotoxicity. *Medical Science Monitor*, *12*(3), RA57-RA65.

Ghorani-Azam, A., Riahi-Zanjani, B., & Balali-Mood, M. (2016). Effects of air pollution on human health and practical measures for prevention in Iran. *Journal of Research in Medical Sciences: The Official Journal of Isfahan University of Medical Sciences, 21*(5)*,* 1-4.

Glenn, C. (2017). Upholding Civil Rights in Environmental Law: The Case for Ex Ante Title VI Regulation and Enforcement. *Review of Law & Social Change*, *41*(1).

Godsil, R. D. (1991). Remedying environmental racism. *Michigan Law Review*, *90*(2), 394-427.

Goodkind, A. L., Tessum, C. W., Coggins, J. S., Hill, J. D., & Marshall, J. D. (2019). Fine-scale damage estimates of particulate matter air pollution reveal opportunities for location-specific mitigation of emissions. *Proceedings of the National Academy of Sciences*, *116*(18), 8775-8780.

Granados-Canal, D. J., Chardon, B., Lefranc, A., & Gremy, I. (2005). Air pollution and respiratory hospital admissions in greater Paris: exploring sex differences. *Archives of Environmental & Occupational Health*, *60*(6), 307-313.

Greenberg, M. R., & Anderson, R. F. (1984). *Hazardous waste sites--the credibility gap: Center for Urban Policy Research*. Routledge.

Greenberg, J., Martens, A., Jonas, E., Eisenstadt, D., Pyszczynski, T., & Solomon, S. (2003). Psychological defense in anticipation of anxiety: Eliminating the potential for anxiety eliminates the effect of mortality salience on worldview defense. *Psychological Science*, *14*(5), 516-519.

Guo, Y., & Barnett, A. G. (2015). Invited commentary: assessment of air pollution and suicide risk. *American Journal of Epidemiology*, *181*(5), 304-308.

Gupta, R. B., Chaudhari, P. R., & Wate, S. R. (2008). Overview on attenuation of industrial air pollution by greenbelt. *Journal of Industrial Pollution Control*, *24*(1), 1-8.

Gurgueira, S. A., Lawrence, J., Coull, B., Murthy, G. K., & González-Flecha, B. (2002). Rapid increases in the steady-state concentration of reactive oxygen species in the lungs and heart after particulate air pollution inhalation. *Environmental Health Perspectives*, *110*(8), 749.

Habibullah, M. S. (2017). The effects of weather on crime rates in Malaysia. *International Journal of Business & Society*, *18*(2), 263–270.

Hagler, G. S., Tang, W., Freeman, M. J., Heist, D. K., Perry, S. G., & Vette, A. F. (2011). Model evaluation of roadside barrier impact on near-road air pollution. *Atmospheric Environment*, *45*(15), 2522-2530.

Hansenne, M., Reggers, J., Pinto, E., Kjiri, K., Ajamier, A., and Ansseau, M. (1999). Temperament and Character Inventory (Tci) and Depression. *Journal of Psychiatric Research, 33*(1), 31–36.

Health Effects Institute. (2010). *Traffic-related air pollution: A critical review of the literature on emissions, exposure, and health effects*. https://www.healtheffects.org/system/files/SR17TrafficReview_Exec_Summary.pdf

Health Effects Institute. (2017). *State of global air /2017 a special report on global exposure to air pollution and its disease burden*. https://ccacoalition.org/en/resources/state-global-air-2017-special-report-global-exposure-air-pollution-and-its-disease-burden

Heissel, J., Persico, C., & Simon, D. (2019). *Does Pollution Drive Achievement? The Effect of Traffic Pollution on Academic Performance*. Institute of Labor Economics. http://ftp.iza.org/dp12745.pdf

Heist, D. K., Perry, S. G., & Brixey, L. A. (2009). A wind tunnel study of the effect of roadway configurations on the dispersion of traffic-related pollution. *Atmospheric Environment*, *43*(32), 5101-5111.

Hennig, J., Reuter, M., Netter, P., Burk, C., & Landt, O. (2005). Two types of aggression are differentially related to serotonergic activity and the A779C TPH polymorphism. *Behavioral Neuroscience*, *119*(1), 16.

Hensen, R. J., & Grecco, W. L. (1968). *An informational manual on the urban transportation planning process for technical committees in smaller urban areas*. Purdue University. https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=2087&context=jtrp

Herrnstadt, E., Heyes, A., Muehlegger, E., & Saberian, S. (2016). *Working Papers: Air pollution as a cause of violent crime.* Erich Muehlegger. http://www.erichmuehlegger.com/Working%20Papers/crime_and_Pollution_fv.pdf

Heyes, A., & Saberian, S. (2015). *Air pollution causes violent crime*. University of Ottawa. https://pdfs.semanticscholar.org/174e/cdd4542a8fcde8d2c1d0d116e15960358b08.pdf

Hindelang, Michael J. (1981). Variations in sex-race-age-specific incidence rates of offending. *American Sociological Review*, *46*(4), 461-74.

Hird, J., & Michael, R. (1998). The distribution of environmental quality: An empirical analysis. *Social Science Quarterly*, 79(4), 693–716.

Hofman, J., Bartholomeus, H., Janssen, S., Calders, K., Wuyts, K., Van Wittenberghe, S., & Samson, R. (2016). Influence of tree crown characteristics on the local PM10 distribution inside an urban street canyon in Antwerp (Belgium): A model and experimental approach. *Urban Forestry & Urban Greening*, *100*(20), 265-276.

Hölscher, N., Höffer, R., Niemann, H. J., Brilon, W., & Romberg, E. (1993). Wind tunnel experiments on micro-scale dispersion of exhausts from motorways. *Science of the Total Environment*, *134*(1-3), 71-79.

Hopkins, R. O., & Woon, F. L. M. (2006). Neuroimaging, cognitive, and neurobehavioral outcomes following carbon monoxide poisoning*. Behavioral and Cognitive Neuroscience Reviews, 5*(3), 141-155.

Houston, D., Wu, J., Ong, P., & Winer, A. (2004). Structural disparities of urban traffic in Southern California: implications for vehicle-related air pollution exposure in minority and high-poverty neighborhoods. *Journal of Urban Affairs*, *26*(5), 565-592.

Iceland, J., & Steinmetz, E. (2003). *The effects of using census block groups instead of census tracts when examining residential housing patterns*. United State Census Bureau. https://www.census.gov/hhes/www/housing/housing_patterns/pdf/unit_of_analysis.pdf

Institute for Health Metrics and Evaluation. (2018). *GBD compare*. https://vizhub.healthdata.org/gbd-compare/

Ipsos. (2011). *Nine in ten adults recycle, but only half do so daily.* https://www.ipsos.com/sites/default/files/news_and_polls/2011-07/5285.pdf

Jayasooriya, V. M., Ng, A. W. M., Muthukumaran, S., & Perera, B. J. C. (2017). Green infrastructure practices for improvement of urban air quality. *Urban Forestry & Urban Greening*, *21*, 34-47.

Kamaluddin, M. R., Othman, A., Ismail, K., & Saat, G. A. M. (2016). Aggression profiles of incarcerated Malaysian male murderers. *Akademika*, *86*(2), 137.

Kan, H., Heiss, G., Rose, K. M., Whitsel, E., Lurmann, F., & London, S. J. (2007). Traffic exposure and lung function in adults: the atherosclerosis risk in communities study. *Thorax*, *62*(10), 873-879.

Kandasamy, N., Hardy, B., Page, L., Schaffner, M., Graggaber, J., Powlson, A. S., ... & Coates, J. (2014). Cortisol shifts financial risk preferences *Proceedings of the National Academy of Sciences*, *111*(9), 3608-3613.

Kelishadi, R., Babaki, A. E. S., Qorbani, M., Ahadi, Z., Heshmat, R., Motlagh, M. E., ... & Mohammadi, R. (2015). Joint association of active and passive smoking with psychiatric distress and violence behaviors in a representative sample of Iranian children and adolescents: the CASPIAN-IV Study. *International Journal of Behavioral Medicine*, *22*(5), 652-661.

Kelly, F. J. (2003). Oxidative stress: Its role in air pollution and adverse health effects. *Occupational and Environmental Medicine*, *60*(8), 612-616.

Kinawy, A. A. (2009). Impact of gasoline inhalation on some neurobehavioural characteristics of male rats. *BMC Physiology*, 9(1), 21–31.

King, E. A., Murphy, E., & McNabola, A. (2009). Reducing pedestrian exposure to environmental pollutants: A combined noise exposure and air quality analysis approach. *Transportation Research Part D: Transport and Environment*, *14*(5), 309-316.

Kleck, G. (1997). *Targeting guns*. Routledge.

Kleck, G., & McElrath, K. (1991). The effects of weaponry on human violence. *Social Forces*, *69*(3), 669-692.

Koppel, L., Andersson, D., Morrison, I., Posadzy, K., Västfjäll, D. and G. Tinghög (2017). The effect of acute pain on risky and intertemporal choice. *Experimental Economics*, *20*(4), 878-893.

Kouchaki, M., & Desai, S. D. (2015). Anxious, threatened, and also unethical: How anxiety makes individuals feel threatened and commit unethical acts. *Journal of Applied Psychology*, *100*(2), 360.

Krenzer, W. L. D., & Splan, E. D. (2018). Evaluating the heat-aggression hypothesis: The role of temporal and social factors in predicting baseball related aggression. *Aggressive Behavior*, *44*(1), 83–88.

Krivo, L. J., Peterson, R. D., & Kuhl, D. C. (2009). Segregation, racial structure, and neighborhood violent crime. *American Journal of Sociology*, *114*(6), 1765-1802.

Krueger, A. P., Andriese, P. C., & Kotaka, S. (1963). The biological mechanism of air ion action: The effect of CO 2+ in inhaled air on the blood level of 5-hydroxytryptamine in mice. *International Journal of Biometeorology*, *7*(1), 3-16.

Krueger, A., & Kotaka, S. (1969). The effects of air ions on brain levels of serotonin in mice. *International Journal of Biometeorology*, *13*(1), 25-38.

Lauritsen, J. L., Heimer, K., & Lynch, J. P. (2009). Trends in the gender gap in violent offending: New evidence from the National Crime Victimization Survey. *Criminology*, 47(2), 361-399.

Leavitt, H. (1970). *Superhighway--Superhoax*. Doubleday.

Levesque, S., Lull, M. E., Taetzsch, T., Kodavanti, U., Stadler, K., Wagner, A., Johnson, J. A., Duke, L., Kodavanti, P., Surace, M. J., et al. (2011). Diesel exhaust activates and primes microglia: air pollution, neuroinflammation, and regulation of dopaminergic neurotoxicity. *Environmental Health Perspectives*, *119*(3), 1149–1155.

Lee, B. J., Kim, B., & Lee, K. (2014). Air pollution exposure and cardiovascular disease. *Toxicological research*, *30*(2), 71-75.

Lee, B. X., Marotta, P. L., Blay-Tofey, M., Wang, W., & de Bourmont, S. (2014). Economic correlates of violent death rates in forty countries, 1962–2008: a cross-typological analysis. *Aggression and Violent Behavior*, *19*(6), 729-737.

Li, T. (2018). *The effect of air pollution on criminal activities: Evidence from the NOx budget trading program.* Social Science Research Network. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3212525

Li, H., Cai, J., Chen, R., Zhao, Z., Ying, Z., Wang, L., ... & Kan, H. (2017). Particulate matter exposure and stress hormone levels: a randomized, double-blind, crossover trial of air purification. *Circulation*, *136*(7), 618-627.

Li, J., & Rainwater, J. (2000). *The real picture of land-use density and crime: A GIS application*. http://proceedings.esri.com/library/userconf/proc00/professional/papers/PAP508/p508.htm

Lichter, A., Pestel, N., & Sommer, E. (2017). Productivity effects of air pollution: Evidence from professional soccer. *Labour Economics*, *48*, 54-66.

Little, T. D., Henrich, C. C., Jones, S. M., & Hawley, P. H. (2003). Disentangling the "whys" from the "whats" of aggressive behaviour. *International Journal of Behavioral Development*, *27*(2), 122-133.

Liu, B. (2016). *Bad weather, safe day? the effect of weather and pollution on crime*. Georgia State University. https://aysps.gsu.edu/files/2016/10/B.Liu-JMP.pdf.

Lochner, L., & Moretti, E. (2004). The effect of education on crime: Evidence from prison inmates, arrests, and self-reports. *American Economic Review, 94*(1), 155-189.

Logan, J. R. (2011). *Separate and unequal: The neighborhood gap for blacks, Hispanics and Asians in Metropolitan America*. Brown University. *https://s4.ad.brown.edu/Projects/Diversity/Data/Report/report0727.pdf*

Łopuszańska, U., & Makara-Studzińska, M. (2017). The correlations between air pollution and depression. *Current Problems of Psychiatry*, *18*(2), 100-109.

Lu, J. G., Lee, J. J., Gino, F., & Galinsky, A. D. (2018). Polluted morality: Air pollution predicts criminal activity and unethical behavior. *Psychological Science*, 29(3), 340-355.

Luginaah, I. N., Fung, K. Y., Gorey, K. M., Webster, G., & Wills, C. (2005). Association of ambient air pollution with respiratory hospitalization in a government-designated "area of concern": the case of Windsor, Ontario. *Environmental Health Perspectives*, *113*(3), 290.

Manso, M., & Castro-Gomes, J. (2015). Green wall systems: A review of their characteristics. *Renewable and Sustainable Energy Reviews*, *41*, 863-871.

Mapou, A. M., Shendell, D., Ohman-Strickland, P., Madrigano, J., Qingyu, M., Whytlaw, J., & Miller, J. (2017). Environmental factors and fluctuations in daily crime rates. *Journal of Environmental Health*, *80*(5), 8-23.

Marshall, J. D., Swor, K. R., & Nguyen, N. P. (2014). Prioritizing environmental justice and equality: diesel emissions in Southern California. *Environmental Science & Technology*, *48*(7), 4063-4068.

Matheson, F. I., Smith, K. L., Fazli, G. S., Moineddin, R., Dunn, J. R., & Glazier, R. H. (2014). Physical health and gender as risk factors for usage of services for mental illness. *Journal of Epidemiology and Community Health, 68(10), 971-978*.

Matsueda, R. L., Kreager, D. A., & Huizinga, D. (2006). Deterring delinquents: A rational choice model of theft and violence. *American Sociological Review*, *71*(1), 95-122.

McDermott, R., Johnson, D., Cowden, J., & Rosen, S. (2007). Testosterone and aggression in a simulated crisis game. *The Annals of the American Academy of Political and Social Science*, *614*(1), 15-33.

McNabola, A., Broderick, B. M., & Gill, L. W. (2008). Reduced exposure to air pollution on the boardwalk in Dublin, Ireland. *Environment International*, *34*(1), 86-93.

McNabola, A., Broderick, B. M., & Gill, L. W. (2009). A numerical investigation of the impact of low boundary walls on pedestrian exposure to air pollutants in urban street canyons. *Science of the Total Environment*, *407*(2), 760-769.

Mello, S. (2018). *More COPS, less crime.* Princeton University, Industrial Relations Section. http://www.princeton.edu/~smello/papers/cops.pdf

Mesquida, C. G., & Wiener, N. I. (1999). Male age composition and severity of conflicts. *Politics and the Life Sciences*, *18*(2), 181-189.

Michel, S. J., Wang, H., Selvarajah, S., Canner, J. K., Murrill, M., Chi, A., ... & Schneider, E. B. (2016). Investigating the relationship between weather and violence in Baltimore, Maryland, USA. *Injury*, *47*(1), 272-276.

Mohai, P., & Bryant, B. (1992). Environmental injustice: weighing race and class as factors in the distribution of environmental hazards. *University of Colorado Law Review*, *63*, 921.

Mohai, P., Pellow, D., & Roberts, J. T. (2009). Environmental justice. *Annual Review of Environment and Resources*, *34*, 405-430.

Moore, P. (2016, April 20). Only 13% of Americans think they have a negative impact on the environment. YouGov. https://today.yougov.com/topics/politics/articles-reports/2016/04/20/earth-day

Morgan, R. E., & Kena, G. (2018a). *Criminal victimization, 2016*. Bureau of Justice Statistics. https://www.bjs.gov/content/pub/pdf/cv16.pdf

Morgan, R. E., & Kena, G. (2018b). *Criminal victimization, 2017*. Bureau of Justice Statistics. https://www.bjs.gov/content/pub/pdf/cv17.pdf

Moulton, P. V., & Yang, W. (2012). Air pollution, oxidative stress, and Alzheimer's disease. *Journal of Environmental and Public Health*, *2012*, 2-5.

Musi, B., Dell'Omo, G., Ricceri, L., Santucci, D., Laviola, G., Bignami, G., and Alleva, E. (1993). Effects of acute and continuous ozone (O3) exposure on activity/exploration and social behavior of CD-1 mice. Neurotoxicology, *15*(4), 827–835.

National Archive of Criminal Justice Data. (2018). *National incident-based reporting system, 2015: Extract files* [Data set]. https://www.icpsr.umich.edu/icpsrweb/NACJD/studies/36851

National Highway Traffic Safety Administration. (2017, October). *Traffic safety facts.* https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812376

United States Equal Employment Opportunity Commission. (2000). *Title VII of the civil rights act of 1964.* https://www.eeoc.gov/laws/statutes/titlevii.cfm

National Oceanic and Atmospheric Administration. (2020, January 7). *Trends in atmospheric carbon dioxide*. https://www.esrl.noaa.gov/gmd/ccgg/trends/ff.html

National Park Service. (2018, January 17). *Where does air pollution come from*? https://www.nps.gov/subjects/air/sources.htm

Neft, I., Scungio, M., Culver, N., & Singh, S. (2016). Simulations of aerosol filtration by vegetation: Validation of existing models with available lab data and application to near-roadway scenario. *Aerosol Science and Technology*, *50*(9), 937-946.

Nevin, R. (2007). Understanding international crime trends: The legacy of preschool lead exposure. *Environmental Research, 104*(3), 315–336.

Neumann, I. D., Veenema, A. H., & Beiderbeck, D. I. (2010). Aggression and anxiety: Social context and neurobiological links. *Frontiers in Behavioral Neuroscience*, *4*, 12.

Ning, Z., Hudda, N., Daher, N., Kam, W., Herner, J., Kozawa, K., ... & Sioutas, C. (2010). Impact of roadside noise barriers on particle size distributions and pollutants concentrations near freeways. *Atmospheric Environment*, *44*(26), 3118-3127.

Nolan, J. J. (2004). Establishing the statistical relationship between population size and UCR crime rate: Its impact and implications. *Journal of Criminal Justice*, *32*(6), 547-555.

Oftedal, B., Brunekreef, B., Nystad, W., Madsen, C., Walker, S. E., & Nafstad, P. (2008). Residential outdoor air pollution and lung function in schoolchildren. *Epidemiology*, *19*(1), 129-137.

Osborne, J. W. (2000). Advantages of hierarchical linear modeling. *Practical Assessment, Research & Evaluation*, 7(1), 3-7.

Oudekerk, B. A., & Truman, J. L. (2017). *Violent victimization, 2005-14*. Bureau of Justice Statistics. https://www.bjs.gov/content/pub/pdf/rvv0514.pdf

Pagani, L. S., Lévesque-Seck, F., Archambault, I., & Janosz, M. (2017). Prospective longitudinal associations between household smoke exposure in early childhood and antisocial behavior at age 12. *Indoor Air*, *27*(3), 622-630.

Park, Y. M., & Kwan, M. P. (2017). Multi-contextual segregation and environmental justice research: Toward fine-scale spatiotemporal approaches. *International Journal of Environmental Research and Public* Health, *14*(10), 1205.

Pattavina, A., Byrne, J. M., & Garcia, L. (2006). An examination of citizen involvement in crime prevention in high-risk versus low-to moderate-risk neighborhoods. *Crime & Delinquency*, *52*(2), 203-231.

Perera, F. P. (2016). Multiple threats to child health from fossil fuel combustion: impacts of air pollution and climate change. *Environmental Health Perspectives*, *125*(2), 141-148.

Persico, C. L., & Venator, J. (2019). The effects of local industrial pollution on students and schools. *Journal of Human Resources*, 54(3), 518-525.

Petruzzi, S., Fiore, M., Dell'Omo, G., & Alleva, E. (1995). Exposure to ozone inhibits isolation-induced aggressive behavior of adult CD-1 male mice. Aggressive Behavior, 21(5), 387–396.

Peske, H. G., & Haycock, K. (2006). *Teaching inequality: How poor and minority students are shortchanged on teacher quality*. Education Trust. https://files.eric.ed.gov/fulltext/ED494820.pdf

Phillips, J. A. (2002). White, black, and Latino homicide rates: Why the difference? *Social Problems*, *49*(3), 349-373.

Pincus, F. L. (1996). Discrimination comes in many forms: Individual, institutional, and structural. *American Behavioral Scientist*, *40*(2), 186-194.

Pirkle, J. L., Brody, D. J., Gunter, E. W., Kramer, R. A., Paschal, D. C., Flegal, K. M., & Matte, T. D. (1994). The decline in blood lead levels in the United States: the National Health and Nutrition Examination Surveys (NHANES*). The Journal of the American Medical Association, (4), 284*.

Powell, L. F. & Supreme Court of The United States. (1977) *U.S. Reports: University of California Regents v. Bakke, 438 U.S. 265*. Library of Congress. https://www.loc.gov/item/usrep438265/.

Pope III, C. A., Burnett, R. T., Thun, M. J., Calle, E. E., Krewski, D., Ito, K., & Thurston, G. D. (2002). Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *The Journal of the American Medical*, *287*(9), 1132-1141.

Porcelli, A. J., & Delgado, M. R. (2009). Acute stress modulates risk taking in financial decision making. *Psychological Science*, *20*(3), 278-283.

Power, M. C., Kioumourtzoglou, M.-A., Hart, J. E., Okereke, O. I., Laden, F., & Weisskopf, M. G. (2015). The relation between past exposure to fine particulate air pollution and prevalent anxiety: Observational cohort study. *British Medical Journal*, 350.

Pratt, G., Vadali, M., Kvale, D., & Ellickson, K. (2015). Traffic, air pollution, minority and socio-economic status: addressing inequities in exposure and risk. *International Journal of Environmental Research and Public Health,* 12(5), 5355-5372.

Pugh, T. A., MacKenzie, A. R., Whyatt, J. D., & Hewitt, C. N. (2012). Effectiveness of green infrastructure for improvement of air quality in urban street canyons. *Environmental Science & Technology*, *46*(14), 7692-7699.

Pulido, L. (2016). Flint, environmental racism, and racial capitalism. *Capitalism Nature Socialism, 27*(3), 1-16.

Pulido, L. (2015). Geographies of race and ethnicity 1: White supremacy vs white privilege in environmental racism research. *Progress in Human Geography*, *39*(6), 809-817.

Pulido, L. (2017). Geographies of race and ethnicity II: Environmental racism, racial capitalism and state-sanctioned violence. *Progress in Human Geography*, *41*(4), 524-533.

Qato, D. M., Daviglus, M. L., Wilder, J., Lee, T., Qato, D., & Lambert, B. (2014). Pharmacy deserts are prevalent in Chicago's predominantly minority communities, raising medication access concerns. *Health Affairs*, *33*(11), 1958-1965.

Rabin, Y. (1973). Highways as a barrier to equal access. *The Annals of the American Academy of Political and Social Science*, *407*(1), 63-77.

Ramirez, J. M., Andreu, J. M., & Fujihara, T. (2001). Cultural and sex differences in aggression: A comparison between Japanese and Spanish students using two different inventories. *Aggressive Behavior*, *27*(4), 313-322.

Rammal, H., Bouayed, J., Younos, C., and Soulimani, R. (2008). Evidence that oxidative stress is linked to anxiety-related behaviour in mice. *Brain, Behavior, and Immunity, 22*(8), 1156–1159.

Raudenbush, S. W. (1995). *Posterior modal estimation for hierarchical generalized linear models with application to dichotomous and count data* [Unpublished manuscript]. Michigan State University, College of Education.

Reyes, J. W. (2007). Environmental policy as social policy? The impact of childhood lead exposure on crime. *BE Journal of Economic Analysis & Policy, 7*(1), 300–341.

Riis-Vestergaard, M.I., van Ast, V., Cornelisse, S., Joels, M. and J. Haushofer (2018). The effect of hydrocortisone administration on intertemporal choice. *Psychoneuroendocrinology*, 88, 173-182.

Rosenlund, M., Forastiere, F., Porta, D., De Sario, M., Badaloni, C., & Perucci, C. (2009). Traffic-related air pollution in relation to respiratory symptoms, allergic sensitisation and lung function in schoolchildren. *Environmental Exposure*, *64*(7), 573-577.

Rotton, J. (1983). Affective and cognitive consequences of malodorous pollution. *Basic and Applied Social Psychology*, *4*(2), 171-191.

Rotton, J., & Frey, J. (1985). Air pollution, weather, and violent crimes: concomitant time-series analysis of archival data. *Journal of Personality and Social Psychology*, *49*(5), 1207-1215.

Rotton, J., Frey, J., Barry, T., Milligan, M., & Fitzpatrick, M. (1979). The air pollution experience and physical aggression 1. *Journal of Applied Social Psychology*, *9*(5), 397-412.

Rotton, J., Yoshikawa, J., Francis, J., & Hoyler, R. (1978). *Urban atmosphere: Evaluative effects of malodorous air pollution.* Southeastern Psychological Association.

Sæbø, A., Popek, R., Nawrot, B., Hanslin, H. M., Gawronska, H., & Gawronski, S. W. (2012). Plant species differences in particulate matter accumulation on leaf surfaces. *Science of the Total Environment*, *427*, 347-354.

Sager, L. (2016). Estimating the effect of air pollution on road safety using atmospheric temperature inversions. *Journal of Environmental Economics and Management, 98,* 1-16.

Sampson, R. J. (1983). Structural density and criminal victimization. *Criminology,* 21(2), 276–293.

Sampson, R. J., Raudenbush, S. W., & Earls, F. (1997). Neighborhoods and violent crime: A multilevel study of collective efficacy. *Science*, *277*(5328), 918-924.

Scalia, A. & Supreme Court of The United States. (2000). *U.S. Reports: Alexander, Director, Alabama Department of Public Safety, et al. v. Sandoval, Individually and on Behalf of All Others Similarly Situated, et al., 532 U.S. 275.* Library of Congress. https://www.loc.gov/item/usrep532275/.

Schinasi, L. H., & Hamra, G. B. (2017). A time series analysis of associations between daily temperature and crime events in Philadelphia, Pennsylvania. *Journal of Urban Health*, *94*(6), 892-900.

Schively, C. (2007). Understanding the NIMBY and LULU phenomena: Reassessing our knowledge base and informing future research. *Journal of Planning Literature, 21*(3), 255-266.

Sherman, B. P. (2014). *Racial bias and interstate highway planning: a mixed methods approach.* College Undergraduate Research Electronic Journal. https://repository.upenn.edu/curej/176/

Simister, J., & Cooper, C. (2005). Thermal stress in the USA: Effects on violence and on employee behaviour. *Stress and Health*, *21*(1), 3-15.

Siegel, J. Z. and Crockett, M. J. (2013). How serotonin shapes moral judgment and behavior. *Annals of the New York Academy of Sciences,* 1299(1), 42–51.

Silva, G. A. (2006). Neuroscience nanotechnology: progress, opportunities and challenges. *Nature Reviews Neuroscience*, *7*(1), 65-74

Snell, T. L. (2011). *Capital punishment, 2010—Statistical tables*. Bureau of Justice Statistics. https://www.bjs.gov/content/pub/pdf/cp10st.pdf

Soulage, C., Perrin, D., Cottet-Emard, J.-M., Pequignot, J., Dalmaz, Y., and Pequignot, J.-M. (2004). Central and peripheral changes in catecholamine biosynthesis and turnover in rats after a short period of ozone exposure. *Neurochemistry International,*
45(7), 979–986.

Statista. (2019, July 22). *Number of motor vehicles registered in the United States from 1990 to 2016.* https://www.statista.com/statistics/183505/number-of-vehicles-in-the-united-states-since-1990/

Stephanopoulos, N. O. (2015). Political powerlessness. *New York University Law Review*, *90*(5), 1590-1599.

Stretesky, P. B. (2003). The distribution of air lead levels across US counties: Implications for the production of racial inequality. *Sociological Spectrum, 23(1),* 91-118.

Stretesky, P. B., & Lynch, M. J. (2004). The relationship between lead and crime. *Journal of Health and Social Behavior, 45(2)*, 214-229.

Stromberg, J. (2016, May 11). Highways gutted American cities. So why did they build them? *Vox*. https://www.vox.com/2015/5/14/8605917/highways-interstate-cities-history

Strosnider, H., Kennedy, C., Monti, M., & Yip, F. (2017). Rural and urban differences in air quality, 2008–2012, and community drinking water quality, 2010–2015—United States. *Surveillance Summaries*, *66*(13), 1-4.

Tiihonen, J., Halonen, P., Tiihonen, L., Kautiainen, H., Storvik, M., & Callaway, J. (2017). The association of ambient temperature and violent crime. *Scientific Reports, 7*(1), 1-4.

Thornhill, R., & Palmer, C. T. (2000). *A natural history of rape: biological bases of sexual coercion*. MIT Press.

Tomazinis, A. R. (1967). *An introduction to urban transportation planning, emerging techniques and theories*. University of Pennsylvania, Institute for Environmental Studies.

Tomlinson, K. D. (2016). An examination of deterrence theory: Where do we stand. *Federal Probation, 80*(3), 33-37.

Torpey, E. (2017). *Jobs for people who love being outdoors*. Bureau of Labor Statistics. https://www.bls.gov/careeroutlook/2017/article/outdoor-careers.htm

Truman, J., Langton, L., & Planty, M. (2013). *Criminal victimization, 2012*. Bureau of Justice Statistics. https://www.bjs.gov/content/pub/pdf/cv12.pdf

Uboh, F., Akpanabiatu, M., Ekaidem, I., Ebong, P., and Umoh, I. (2007). Effect of inhalation exposure to gasoline on sex hormones profile in Wistar albino rats. *International Journal of Romanian Society of Endocrinology*, 3(1), 23–30.

United Church of Christ. (1987). *Toxic wastes and race in the United States: A national report on the racial and socio-economic characteristics of communities with hazardous waste sites.* United Church of Crist Commission for Racial Justice. https://www.nrc.gov/docs/ML1310/ML13109A339.pdf

Uniform Crime Reports. (2013). *Arrests by sex, 2012* [Data set]. Federal Bureau of Investigation. https://ucr.fbi.gov/crime-in-the-u.s/2012/crime-in-the-u.s.-2012/tables/42tabledatadecoverviewpdf/table_42_arrests_by_sex_2012.xls

Uniform Crime Reports. (2016a). *Arrests by age, 2015* [Data set]. Federal Bureau of Investigation. https://ucr.fbi.gov/crime-in-the-u.s/2015/crime-in-the-u.s.-2015/tables/table-38

Uniform Crime Reports. (2016b). *Crime in the United States*. https://ucr.fbi.gov/crime-in-the-u.s/2015/crime-in-the-u.s.-2015/offenses-known-to-law-enforcement/violent-crime/violentcrimemain_final

Union of Concerned Scientists. (2019, June). *Inequitable exposure to air pollution from vehicles in Massachusetts*. https://www.ucsusa.org/sites/default/files/attach/2019/06/Inequitable-Exposure-to-Vehicle-Pollution-MA.pdf

United Nations Office on Drugs and Crime. (2011). *Global study on homicide 2011: trends, contexts, data*. https://www.unodc.org/documents/congress/background-information/Crime_Statistics/Global_Study_on_Homicide_2011.pdf

United States Census Bureau. (2015a). *Age groups and sex: 2015* [Data set]. https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_15_1YR_S0101&prodType=table

United States Census Bureau. (2015b). *Gini index of income inequality* [Data set]. https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_15_5YR_B19083&prodType=table

United States Census Bureau. (2012). *Means of transportation to work for the U.S.: 1960-1990* [Data set]. https://www2.census.gov/programs-surveys/commuting/tables/time-series/journey/mode6790.txt

United States Census Bureau. (2016a, December 8). *Measuring America: our changing landscape.* https://www.census.gov/library/visualizations/2016/comm/acs-rural-urban.html

United States Census Bureau. (2016b, December). *New census data show differences between urban and rural populations*. https://www.census.gov/newsroom/press-releases/2016/cb16-210.html

United States Census Bureau. (2015c). *Occupation by sex for the civilian employed population 16 years and over* [Data set]. https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_15_1YR_S2401&prodTy

United States Census Bureau. (2015d). *Quickfacts: Flint City, Michigan* [Data set]. https://www.census.gov/quickfacts/table/INC110214/2629000

United States Census Bureau. (2019). *U.S. and world population clock.* Retrieved September 10, 2019, from United States Census Bureau: https://www.census.gov/popclock/

United States Department of Transportation. (2016). *2015 status of the nation's highways, bridges, and transit: conditions & performance* [Data set]. https://www.bafuture.org/sites/default/files/key-topics/attachments/2015cpr-ilovepdf-compressed.compressed.pdf

United States Department of Transportation. (2017a, May 31). *National household travel survey daily travel quick facts*. Retrieved January 10, 2019, from United States Department of Transportation: https://www.bts.gov/statistical-products/surveys/national-household-travel-survey-daily-travel-quick-facts

United States Department of Transportation. (2017b). *Highway traffic noise barriers at a glance*. https://www.fhwa.dot.gov/environment/noise/noise_barriers/design_construction/keepdown.cfm

United States Department of Transportation. (2012, August 16). *Transportation for a new generation*, *strategic plan for 2012-2016*. https://www.transportation.gov/dot-strategic-plan

United States Equal Employment Opportunity Commission. (2000). *Title VII of the civil rights act of 1964*. https://www.eeoc.gov/laws/statutes/titlevii.cfm

United States General Accounting Office. (1983, June 1). *Siting of hazardous waste landfills and their correlation with racial and economic status of surrounding communities*. http://archive.gao.gov/d48t13/121648.pdf

University of Cambridge. (2011, September 15). *Serotonin levels affect the brain's response to anger*. https://www.cam.ac.uk/research/news/serotonin-levels-affect-the-brain's-response-to-anger

Van Berlo, D., Albrecht, C., Knaapen, A. M., Cassee, F. R., Gerlofs-Nijland, M. E., Kooter, I. M., Palomero-Gallagher, N., Bidmon, H.-J., van Schooten, F.-J., Krutmann, J., et al. (2010). Comparative evaluation of the effects of short-term inhalation exposure to diesel engine exhaust on rat lung and brain. *Archives of Toxicology, 84*(7), 553–562.

van Honk, J., Harmon-Jones, E., Morgan, B. E., & Schutter, D. J. L. G. (2010). Socially explosive minds: The triple imbalance hypothesis of reactive aggression. *Journal of Personality, 78*(1), 67–94.

Vanka, S., Handy, S., & Kockelman, K. M. (2005). State-local coordination in managing land use and transportation along state highways. *Journal of Urban Planning and Development*, *131*(1), 10-18.

Vardoulakis, S., Fisher, B. E., Pericleous, K., & Gonzalez-Flesca, N. (2003). Modelling air quality in street canyons: A review. *Atmospheric Environment*, *37*(2), 155-182.

Volpi-Abadie, J., Kaye, A. M., & Kaye, A. D. (2013). Serotonin syndrome. *The Ochsner Journal, 13*(4), 533–540.

Walker, R. E., Keane, C. R., & Burke, J. G. (2010). Disparities and access to healthy food in the United States: A review of food deserts literature. *Health & Place*, *16*(5), 876-884.

Wang, T. (2018). *U.S. waste management and remediation services gross output from 2007 to 2018 (in million U.S. dollars)*. Statista. https://www.statista.com/statistics/262831/us-waste-management-and-remediation-services-gross-output/

Wang, Y., Zhang, R., & Saravanan, R. (2014). Asian pollution climatically modulates mid-latitude cyclones following hierarchical modelling and observational analysis. *Nature Communications*, *5*(1), 1-7.

Wallach, C. (1986). The effects of air quality on the serotonin irritation syndrome. *International Bio-Environmental Foundation, 6*(2), 1-2.

Weather Underground. (2019). Cleveland Hopkins International Airport, Ohio. *Weather Underground* [Data set]. https://www.wunderground.com/history/daily/us/oh/cleveland/KCLE/date/2015-1-1

Wegmann, M., Fehrenbach, A., Heimann, S., Fehrenbach, H., Renz, H., Garn, H., & Herz, U. (2005). NO2-induced airway inflammation is associated with progressive airflow limitation and development of emphysema-like lesions in C57BL/6 mice. *Experimental and Toxicologic Pathology*, *56*(6), 341-350.

Woolf, S. H., Aron, L., Dubay, L., Simon, S. M., Zimmerman, E., & Luk, K. X. (2015). *How are income and wealth linked to health and longevity*. Urban Institute. https://www.urban.org/sites/default/files/publication/49116/2000178-How-are-Income-and-Wealth-Linked-to-Health-and-Longevity.pdf

World Bank. (2019). *GDP (current US$)* [Data set]. https://data.worldbank.org/indicator/ny.gdp.mktp.cd?end=2012&most_recent_year_desc=true&start=2012

World Health Organization. (2018, May 2). *Ambient (outdoor) air quality and health*. http://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

World Health Organization. (2013, October 17). *IARC: outdoor air pollution a leading environmental cause of cancer deaths*. https://www.iarc.fr/wp-content/uploads/2018/07/pr221_E.pdf

Wright, B. H. (1997*). New Orleans neighborhoods* under siege, in *Just transportation: dismantling race and class barriers to mobility* (R. D. Bullard and G. S. Johnson, Ed.) New Society Publishers.

Yang, A. C., Tsai, S. J., Huang, N. E., & Peng, C. K. (2011). Association of Internet search trends with suicide death in Taipei City, Taiwan, 2004–2009. *Journal of Affective Disorders*, *132*(1), 179-184.

Yang, T. (2001). The form and substance of environmental justice: The challenge of title vi of the civil rights act of 1964 for environmental regulation. *Boston College Environmental Affairs Law Review. 29*(2), 143-150.

YouGov. (2016, April 14). *Climate change.* https://d25d2506sfb94s.cloudfront.net/cumulus_uploads/document/o5vu6aqdxz/tabs_OP_Earth_Day_20160418.pdf

Younan, D., Tuvblad, C., Franklin, M., Lurmann, F., Li, L., Wu, J., ... & Chen, J. C. (2018). Longitudinal analysis of particulate air pollutants and adolescent delinquent behavior in Southern California. *Journal of Abnormal Child Psychology*, 46(6), 1283-1293.

Zavorsky, G. S., Tesler, J., Rucker, J., Fedorko, L., Duffin, J., & Fisher, J. A. (2014). Rates of carbon monoxide elimination in males and females. *Physiological Reports*, *2*(12), 1-7.

Zinzow, H. h., & Jeffirs, S. M. (2018). Driving aggression and anxiety: Intersections, assessment, and interventions. *Journal of Clinical Psychology*, *74*(1), 43-82.

Zivin, G. J., & Neidell, M. (2012). The impact of pollution on worker productivity. *American Economic Review, 102*(7), 3652-73.

VITA

ERIK CRUZ

2011-2014	B.A., Sociology Florida International University Miami, Florida
2014-2015	M.S., Criminal Justice Florida International University Miami, Florida
2016 -2020	Doctoral Candidate Florida International University Miami, Florida
2016-2020	Graduate Assistant Florida International University Miami, Florida
2018	Doctoral Summit Scholarship Academy of Criminal Justice Sciences Greenbelt, MD
2019	Dissertation Year Fellowship Award Florida International University Miami, Florida

PUBLICATIONS AND PRESENTATIONS

Back, S., Sung, Y., & Cruz, E. (2017). Capable guardianship and crisis of identity theft in the United States: Expanding cyber-routine activities theory. *International Journal of Crisis & Safety*, 2, 16-24.

Cruz, E., D'Alessio, S. J., & Stolzenberg, L. (2018). *The Impact of Terrorism on Desired Immigration Policy*. Paper presented at the annual meeting of the American Society of Criminology, Atlanta, GA.

Cruz, E. (2019). *Is the Heat to Blame? The Effect of Maximum Daily Temperature on Outdoor Violence*. Poster presented at Graduate Student Appreciation Week (GSAW), Scholarly Forum, Florida International University, Miami, FL.

Lee, J., Cruz, E., & Torres, C. (2019). *Crime Archetypes in the Media. Dataset presented at the American Society of Criminology.* Paper presented at the annual meeting of the American Society of Criminology, San Francisco, CA.

Cruz, E. (2019). *The Effect of Maximum Daily Temperature on Outdoor Violence.* Paper presented at the annual meeting of the American Society of Criminology, San Francisco, CA.

Cruz, E., D'Alessio, S. J., & Stolzenberg, L. (2019). Decisions made in terror: Testing the relationship between terrorism and immigration. *Migration Studies, mnz014.*

Cruz, E., D'Alessio, S. J., & Stolzenberg, L. (2020). The labor market and terrorism. *Studies in Conflict & Terrorism*, 43(3), 224–238.