EXAMINING THE RELATIONSHIP BETWEEN WEATHER AND HOMICIDE

By

Chae M. Mamayek

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Criminal Justice – Master of Science

2013

ABSTRACT

EXAMINING THE RELATIONSHIP BETWEEN WEATHER AND HOMICIDE

By

Chae M. Mamayek

Despite broad interest in the relationship between weather and crime, few studies have been crime-specific and evaluated the relationship between weather and homicide. The present study draws from existing literature and examines the relationship between weather and homicide. A unique and rich data set of homicides known to the police in Newark, New Jersey is employed in answering the following research questions: (1) Is weather an important situational covariate in the occurrence of homicide, (2) given that a homicide occurs, is weather an important situational covariate of homicide once it is disaggregated by location (i.e. outdoor and indoor), and (3) is there a relationship between the number of homicide incidents and temperature? Results suggest that overall weather is not an important situational covariate as to whether or not a homicide occurs, where it occurs, or the number of incidents that occur. The theoretical, methodological, and policy implications are discussed.

To my mother, for always helping to steer the ship.

ACKNOWLEDGEMENTS

I would like to thank all of my committee members, Dr. Jesenia Pizarro, Dr. Christopher Melde, Dr. April Zeoli, and Dr. Julie Winkler for their continued guidance, support and patience throughout this process. I am exceedingly thankful to my thesis chair, Dr. Jesenia Pizarro for not only her hard work and professional knowledge of homicide time and time again, but also for always helping me to keep things in perspective. I thank Dr. Melde for making himself available and providing countless impromptu methodology lessons. I would also like to thank Dr. April Zeoli for offering her insight and asking hard questions. My sincere thanks additionally goes to Dr. Julie Winkler, for contributing her knowledge of climatology and significantly helping to improve my understanding of weather. Without the support of my committee, this thesis would have never been possible.

I would also like to say thank you to my consultant from the Center for Statistical Training and Consulting (CSTAT), Monthien Satimanon, for answering my methodology and analysis related questions. In the midst of completing his own dissertation, Montheien found time to assist me on short-notice, and for that I am very grateful.

Lastly, I would like to thank my family (Lorrie, Corky, Bailee, Francis) and Craig for listening to my frustrations and always being supportive. I know I cried-wolf many times telling you that, “My thesis will be done this week.” This time however… I am done!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Propositions relating weather and violent crime were studied through astrology 5000 years ago and continue to be a prevalent theme in Western science, philosophy, and perception (Cheatwood, 1988). The effect of weather on human behavior is studied within a wide range of disciplines and has been found to influence outcomes in virtually every area of study. The emotions of children (Ciucci et al., n.d.); hospital admissions for cardiac events (Bakal, Ezekowitz, Westerhout, Boersma, & Armstrong, 2012); the amount of time individuals spend outdoors doing activities (Dunn, Shaw, & Trousdale, 2012); consumer behavior (Niemira, 1997), and various crimes have all been empirically tied to weather. There is also a large body of literature examining the relationship between heat and aggression as expressed through violent crime (Anderson, Bushman, & Groom, 1997; Cohn & Rotton, 2005; Rotton & Cohn, 2004), with some scholars attributing increases in violence during summer months violence to hot weather (Cohn, 1990). Today, this theme continues to be perpetuated in popular media, often focusing on the relationship between heat and homicide, with headlines exclaiming, “In New York, Number of Killings Rises with Heat,” noting within the article that, “In the summer months, the bad guys tend to be deadliest” (Lehren & Baker, 2009).

While the association between weather and behavior appears intuitive, the present research seeks to further the understanding of the relationship between weather and homicide through theoretical perspectives based largely on temperature and aggression, routine activities and lifestyle theories. Using homicide data from Newark, New Jersey and weather data from the National Climate Data Center, the present research seeks to ask the specific questions: Is weather an important situational covariate in the occurrence of homicide, (b) given that a homicide occurs, is weather an important situational covariate of homicide when it is disaggregated by location (i.e. outdoor, indoor) and (c) is there a relationship between temperature and the number of homicide incidents? Extant research has focused largely on violent crime and aggression's relationship with weather, with far fewer studies focusing specifically on homicide, and very few disaggregating homicide by location. As a result, the current study adds to the literature exploring the effect weather has on general human behavior. Furthermore, the current study may develop understanding of the relationship between meteorology and criminology through considering associations between crime and various elements of weather (i.e. temperature, wind speed, precipitation). From a practical perspective, findings could also influence police distribution of resources and allow for more efficient forecasting of expected calls for police service. For example, if findings suggest that, consistent with popular belief, homicides are more likely to occur as the temperature rises, police and other emergency personnel can increase staff during periods of increased temperature so that homicide calls can be responded to more efficiently.

The next section provides a review of the literature followed by the theoretical framework sophomorically guiding previous research and the current study. This section will be followed by a discussion of the current study's purpose, data sources, methodologies, and results. The thesis will end with concluding remarks discussing policy implications for crime prevention and forecasting, shortcomings of the study, and suggestions future research.

CHAPTER 1: REVIEW OF LITERATURE

Researchers have often worked toward understanding the causes or circumstances that lead towards crime, or more distinctly, violence. One of the various covariates that have been explored is weather. To date multiple studies have explored the relationship between weather and various types of crime as weather and temporal variables can provide insight as to the circumstances that contributed to the occurrence of the criminal event. It is not surprising that hypotheses concerning these variables are common, considering it is highly intuitive that human behavior varies according to circumstances such as the weather outside or the time-of-day. What researchers seek to more clearly grasp, however, is how crime is related to weather and temporal variables, which will be explored in the following subsections.

Weather and Violent Crime

Weather conditions such as temperature, humidity, wind speed, and precipitation are often noticeable and continuously changing environmental factors. Weather is defined as the specific conditions, such as temperature, precipitation, and wind that occur within the atmosphere at a specific time and place, while climate is an aggregation of weather over a period of time (Tennebaum & Fink, 1994). Within crime literature the importance of avoiding treating the terms *weather* and *climate* as synonymous is expressed (LeBeau, 1988). The differentiation between the two concepts is essential when conducting research to ensure correct inferences are reached.

Criminologists tend to accept that weather is highly correlated with short-run changes in crime rates, typically with heat positively associated with crime, and unpleasant weather associated with a decrease in crime (Jacob, Lefgren, & Moretti, 2007). Often, weather is described as "unpleasant" as opposed to "pleasant," "worse" as opposed to "better," or as "extreme." These terms are quite vague, and unfortunately, this is in part due to the inherent nature of variation in human preference. Individuals may have different thresholds as to exactly what point temperature becomes too hot, too humid, too cold, or too windy. These thresholds may be also influenced by the activities individuals plan to undertake, and/or the way they are dressed. For example, hot temperatures considered ideal for a day at the beach might be considered uncomfortable or unpleasant for someone working outdoors in construction.

Jacob and colleagues (2007) noted that the relationship between weather and violent crime is consistent, regardless of factors such as the victim-offender relationship, severity of the crime, weapon use, and age of the offender. Peng, Xueming, Hongyong, and Dengsheng (2011) support this notion, as they found few robberies occur during "extreme weather." A study in Newark (Feldman & Jarmon, 1979), however, found temperature variables to be associated with total crime and assault, but found no relationship with homicide; contradicting the assumption by Jacob and colleagues (2007) that effects of weather are consistent across all types of violent crime.

Factors such as temperature, sunlight, precipitation, humidity, and wind can also create weather conditions that may influence an individual's comfort outdoors, causing them to vary their activities accordingly (Zacharias, Stathopoulos, & Wu, 2001). For instance, temperatures that are uncomfortably high or low can decrease the number of people within a public space and decrease the time individuals spend in public settings (Zacharias et al., 2001). Cheatwood (1995) found the strongest weather-related predictor of homicide to be the number of consecutive days the discomfort point[1] remains over 79. Other studies have found that a one-degree Fahrenheit increase is correlated with a 3.68 per 100,000 population increase in serious and lethal assault (homicide) (Anderson et al., 1997); with another study finding a 1.21 per 100,000 population increase in assaults associated with the same temperature increase (Rotton & Cohn, 2003). Similar findings support a positive relationship between temperature and homicide (Ceccato, 2005) and assault (Michael & Zumpe, 1983; Rotton & Frey, 1985). More specifically, these studies suggest a positive correlation between rape and temperature (Cohn, 1993; Michael and Zumpe, 1983; Rotton, 1993); a positive correlation between domestic violence and temperature (Cohn, 1993; Michael & Zumpe, 1986; Rotton & Frey 1985), and no correlation between temperature and robbery (Cohn & Rotton, 2000; Peng et al., 2011). Rotton and Cohn (2003) found the U.S. area-averaged annual temperatures from 1950-1999 to be correlated with assault but not homicide, and state-centered crime rates from 1960-1998 to have a positive association between annual temperature and assault, robbery, and rape, but not homicide. Applying data from 8,460 U.S. police units during 1990-1992, Hipp, Bauer, Curran, & Bollen (2004) found that cities with greater variation in temperature have greater oscillations in violent crime, with a one-degree increase in temperature associated with a 4.9% increase in violence.

Although high temperature is the most commonly discussed weather-related factor in association with homicide, and violent crime in general, it has been proposed that low temperature may also have an effect as researchers have specifically suggested cold temperatures inhibit human behavior (McFarland, 1983; Rotton, 1993). Contributing further, Cheatwood

---

[1] The discomfort point (DP), is a specific point on the temperature/humidity index (THI), a scale combined to measure how one feels when the effects of temperature and humidity are combined (Cheatwood, 1995; Schlatter, 1987). Generally, humans feel comfortable with a THI less than 70, and feel uncomfortable as the THI reaches 79 and above (Cheatwood, 1995)

(1995) proposed that there is a Cold Floor Effect on homicide in which extremely low temperatures decrease human aggression, to the point where homicides will not occur, perhaps because it is simply too cold to do much of anything, let alone kill (McFarland, 1983); although, findings typically do not support the Cold Floor Effect on homicide (Cheatwood, 1995; Loftin & Cheatwood, 1996).

While many studies have supported a positive linear relationship between temperature and violent crime (Anderson et al., 1997; Bushman et al., 2005), there is also evidence indicating temperature and assault have an inverted U-shaped relationship, where as temperature continuously increases, assaults also increase up until a specific point, at which point assaults then begin to decrease (Cohn & Rotton, 1997; Cohn & Rotton, 2005; Rotton and Cohn, 2000). This relationship has also been observed in New Zealand (Horrocks & Menclova, 2011). When replicating Cohn and Rotton (1997), Rotton and Cohn (2000) found a curvilinear relationship to be present during warm hours of the day (9:00 am-8:59 pm) and the spring season, but from 9:00 pm-8:59 am and during all other seasons the relationship appeared linear.

In addition to temperature, academics have studied the relationship between crime and amount of sunshine. Research has produced mixed results when evaluating the correlation between this variable and violent crime. No statistically significant relationship has been found between sunshine and violent crime in general (Field, 1992); robbery (Peng et al., 2011); or assault (Rotton & Frey, 1985). Domestic violence has had mixed findings, with some research suggesting no relationship (Rotton & Frey, 1985), while other studies support a negative relationship (Cohn, 1993). Cohn (1993) also found rape to have a negative relationship with the presence of sunlight, while Ceccato (2005) found weak-to-modest support for a relationship between cloud coverage and homicide. Overall, findings suggesting a negative relationship with sunlight and crime imply these crimes occur more commonly when it is dark (Cohn, 1993); therefore, the causal factor may be temporal instead of weather related.

The relationship between crime and precipitation has also been examined in the literature. Jacob and colleagues (2007) found a negative correlative relationship when studying the effects of precipitation on violent crime. Specifically, findings suggest a one-inch increase in average weekly precipitation is associated with a ten percent decrease in violent crime (Jacob et al., 2007). Horrocks and Menclova (2011) also found evidence supporting a negative relationship between violent crime and precipitation; although, Field (1992) found no relationship between violent crime and rainfall, and Horrocks & Menclova (2011) note the relationship between weather and precipitation is ambiguous.

Humidity and wind speed have also been explored in the literature. Peng et al. (2011) found that humidity was highly correlated with the other independent variables in the study (temperature, sun light, and wind speed) and thus eliminated as a regression variable. Ceccato (2005) found weak-to-modest support relating humidity to homicide, while Rotton & Frey (1985) found domestic violence and assaults to have no correlation with humidity. Furthermore, variables such as wind speed and fog have been thought to influence crime levels. Cohn (1993), and Rotton and Frey (1985) found a slight negative correlation between domestic violence and wind speed, although, Rotton & Frey (1985) found no significant correlation between wind and assaults. Horrocks and Menclova (2011) were unable to establish a relationship between the Nor'wester winds of New Zealand and violent crime; however, they are hopeful that future studies with improved measures of wind conditions may find a significant positive relationship. In a recent international study that focused on China, Peng et al. (2011) found that 93.1% of robberies occurred when the wind speed was less than 4 m/s (about 9 mph), although regression results did not show the relationship to be significant. Finally, studies examining fog have produced mixed findings. Fog and domestic violence were found to be negatively correlated (Cohn, 1993), while Rotton & Frey (1985) found no correlation for domestic violence and assaults.

Temporal variables

Temporal variables are measured as units of time. For instance, temporal variables include season, holidays, day of week, and time of day. Previous research suggests that a combination of weather and temporal variables may influence violent crime (LeBeau & Corcoran, 1990; Rotton & Cohn, 2000). Contradicting early propositions made by Quetelet (1842) that summer is the season in which the greatest numbers of crimes against persons were committed; research appears to be rather ambiguous regarding seasonal criminality. Cecato (2005) found that in Sao Paulo, Brazil "summer alone" did not contain the greatest number of homicides, suggesting increased homicide in the hot months of the year (not only the summer), more closely attributing the effect to people's increased free time rather than the temperature. Cheatwood's (1988) findings similarly suggest an absence of seasonality in relation to homicide. Research, however, also has found evidence supporting seasonality and homicide (Tennebaum & Fink, 1994); rape (Michael & Zumpe, 1983), assault (Michael & Zumpe, 1983; Rotton & Cohn, 2000; Rotton & Frey, 1985), and domestic violence (Michael and Zumpe, 1986; Rotton & Frey, 1985). Feldman and Jarmon (1979) found total crimes and assaults dropped between December and January, with assaults dropping dramatically after January 1.

A significant negative correlation between robbery and temporal variables such as holidays and days schools were closed has also been discussed in the literature (Peng et al., 2011). Cohn (1993) found the days in which schools were closed to be negatively correlated with domestic violence and more modestly, yet still significantly, negatively correlated with rape. Ceccato (2005) similarly found that homicides in São Paulo, Brazil take place while people have time off from work (i.e. vacations, evenings, and weekends). Cohn and Rotton (2003) found violent crime to be positively correlated with all major holidays (New Years, President's Day, Memorial Day, Independence Day, Labor Day, Veteran's Day, Thanksgiving, Christmas), with the exception of a negative relationship between disorderly conduct and Christmas. Research also appears to support the positive relationship between major holidays and domestic violence (Cohn, 1993; Rotton & Frey, 1985), although the relationship with assault was not supported (Rotton & Frey, 1985).

Although some studies have found no significant relationship between crime and day of the week, even when comparing workdays to weekends (Cheatwood, 1995; Peng et al., 2011), some studies have found evidence suggesting a significant relationship. For example, research suggests there is a correlation between day of the week and robbery (Cohn and Rotton, 2000), domestic violence (Cohn, 1993; Rotton & Frey, 1985; Shepherd, 1990), and assault (Rotton & Frey, 1985). More specifically, research has found homicides to be positively correlated with weekends, with rates highest on Saturdays (Kposowa & Breault, 1998). Total crimes, however, were found to be lowest on Saturdays (Feldman & Jarmon, 1979). Finally, literature relating crime and temporal variables has found a correlation between domestic violence and the first day of the month (Cohn, 1993), and increase in total crimes on days welfare checks are received, but not on days social security checks are received (Feldman & Jarmon, 1979).

Similar to season, holiday, and day of the week, time of day is also commonly associated with crime. Some studies suggest that a large majority (75%) of robbery incidents occur between 6:00 PM and 6:00 AM, with incidents peaking around midnight (Felson & Poulsen, 2003; Peng et al., 2011). Cohn & Rotton (2000) also found time of day to be a strong predictor of robbery. In terms of homicide, the peak hours are suggested to be from 8:00 p.m. to 2:00a.m. (Kposowa & Breault, 1998). A correlation between time of day and domestic violence has also been found (Cohn, 1993). Research suggests that the correlation between crime and time of day may also be influenced by the lack of sunlight allowing for greater anonymity provided by the dark (Cohn, 1993; Rotton & Kelly, 1985).

CHAPTER 2: THEORETICAL FRAMEWORK

Drawing largely from the temperature-aggression, routine activities (Cohen and Felson, 1979) and lifestyle (Hindelang, Gottfredson, & Garofalo, 1978) theories, researchers have sought to understand how environmental changes may influence human behavior and activities. More specifically, the previously discussed relationships between crime and weather and temporal variables have been explained through the lens of these psychological and criminological theories. For example, psychologists have used temperature-aggression theories to explain aggressive crime, whereas criminologist have applied routine activities and life styles theories as a social approach to explaining this relationship.

Psychological Explanations

When examining the relationship between crime and weather, the theoretical foundation is routinely based on the relationship between crime and heat. Originally proposed by Quetelet (1842), the *Temperature/Aggression (T/A)* theory of crime proposes that increased temperatures lead to greater discomfort, which in turn leads to aggression. Since the T/A theory's inception, several models have been created to further expand upon the relationship between aggressive crime and temperature. While they all suggest a psychological casual mechanism, each model offers a unique perspective as to the nature of the temperature-aggression relationship. To date, three additional models have been explored by researchers – General Affect (GA); Negative Affect Escape (NAE); and the General Affective Aggression Model (GAAM).

Closely aligning with T/A theory, the *GA* model proposed by Anderson and Anderson (1998) suggests that temperature has a generally linear relationship with affective aggression. Affective aggression is defined as aggression with the distinct purpose of harming another individual

(Anderson & Anderson, 1998). Under the GA model, a linear relationship exists where as temperature increases, aggression also increases (Anderson & Anderson, 1998).

Diverging from the GA model, The *NAE* proposes that the relationship between heat and aggression is an inverted U-shaped curve in which aggression increases with discomfort, until discomfort reaches a point where the desire to escape supersedes motivation toward aggression (Anderson, 1989; Baron & Bell, 1976; Bell & Baron, 1976; Bell, 1992). Conversely, the *GAAM* suggests both high and low temperatures can become negative stimuli, which in turn can result in increased aggression, expressed through violence (Anderson et al., 2000). These models are illustrated in Figure 1.

Criminological Explanations

Routine activities theory (RAT) and lifestyle theories elucidate the situational characteristics that facilitate the occurrence of crime (Cohen & Felson, 1979). Routine activities are defined as, "the recurrent and prevalent vocational and leisure activities individuals undertake in a regular day-to-day basis" (p. 593). Originally proposed by Cohen and Felson in 1979, RAT focuses on specific conditions that provide the opportunity for an individual to commit a crime (Cohen & Felson, 1979). This theory posits that in order for a crime to occur there must be a convergence in space and time of three necessary elements: a *motivated offender* who is both inclined toward and capable of carrying out a crime, an object or person considered a *suitable target,* and a lack of an object or person acting as a *capable guardian* to prevent a crime (Cohen & Felson, 1979). Cohen and Felson (1979) further illustrate that an individual's routine daily activities influence their risk of victimization to the extent that they lead to the convergence of these three elements.

Directly relating RAT to weather, Horrocks and Menclova (2011) note "better" weather conditions may attribute to the likelihood that people interact, which could lead to an increased possibility of capable guardians, and increased probability of being caught. Better weather leading to interaction also makes it more probable that an individual encounters a motivated offender, whereas worse temperatures make it more probable that individuals stick more closely to their routine occupational and residential settings (Rotten & Cohn, 2000). Weather deemed as "worse" may also decrease the number of capable guardians, and could therefore, increases the probability of crime when people do come into contact (Horrocks & Menclova, 2011). For example, during poor weather conditions such as rain, snow, or extreme heat, individuals may seek shelter from the outdoor environment and remain indoors. When choosing to stay indoors, possibly in their homes, individuals are more likely to encounter other residents. In instances of domestic violence, contact could become fatal, especially in the privacy of a home where there are few watchful eyes.

Using a micro approach, Hindelang, Gottfredson, & Garofalo (1978) developed lifestyle theory which further explains how the aggregation of routine daily activities make up a *lifestyle* that is closely intertwined with human behavior, and eventually may influence the probability of personal victimization. Figure 2 illustrates how demographic characteristics influence an individual's cultural role expectations and structural constraints (Hindelang et al., 1978). For instance, age influences role expectations because behavior that is considered acceptable for a child may be considered inappropriate for an adult (Hindelang et al., 1978). Marital status is another example of a demographic characteristic that can influence role expectations because married individuals are typically expected to spend more time within their household whereas unmarried individuals are expected to spend more time outside of the home in social situations (Hindelang et al., 1978). The model also demonstrates that a person's role expectations within society influence, and are influenced by, structural constraints (Hindelang et al., 1978). All individuals face some sort of structural constraint that influences their activities. For instance, economic constraints greatly influence a person's residence, choice to partake in leisure activities, type of leisure activities, type of accessible educational experiences, and use of various types of transportation (Hindelang et al., 1978).

Adapting Figure 2, weather is proposed as a structural constraint influencing lifestyle, which in turn influences the convergence in time and space of the suitable victim, motivated offender, and lack of capable guardian. For instance, extreme temperature or levels and type of precipitation may influence transportation decisions, leisure decisions, and even disrupt otherwise daily routine activities such as going to work. Together, role expectations and structural constraints cause individuals as well as groups to adapt, influencing their lifestyle (Hindelang et al., 1978). For instance, Hindelang et al. (1978) noted that age and sex are demographics commonly associated with specific role expectations established by cultural norms. For instance, men may be expected to act tough and adults expected to provide comfort and safety for youth. When faced with poor weather, men may be culturally expected to brave the storm, or work to improve conditions (such as plowing streets to remove snow). Adults may also feel a heightened sense of responsibility to adapt and continue their daily activities (going to work, shopping for groceries) during poor weather in order to provide for their families. These adaptations result in variations in lifestyles. Different lifestyles in turn, mean a variation in routine activities that influence associations and exposure (possibly altering the probability of the convergence of a suitable target, motivated offender, and lack of capable guardian), affecting the likelihood of personal victimization. Specifically, structural constraints such as poor weather conditions could result in various lifestyle changes causing individuals to remain indoors or outdoors, influencing the likelihood and place of victimization based on the routine activities theory.

Studies have recently noted that that psychological based temperature/aggression theories are not necessarily mutually exclusive from routine activities and lifestyle theories and that it is possible they are concurrently at work (Cecato, 2005; Hipp et al., 2004). For example, an individual's routine activities such as work or leisure may draw them outdoors, where they are subject to various forms of weather that could potentially increase aggression. To provide an example, a construction worker may work outdoors under extreme heat conditions with little opportunity to seek shade or shelter contributing to the potential for increased aggression caused by the heat. If the worker, know an aggressive motivated offender, is also at a relatively secluded construction site, there may be potential victims (other workers) with relatively few capable guardians, which could contribute to conditions fit for violence crime. Rotten and Cohn (2000) found evidence supporting NAE and RA for assaults, but caution against generalizing between temperature and other types of violent crime because previous research found inconsistent results regarding the relationship between temperature and various sex crimes (Rotton, 1993).

CHAPTER 3: PURPOSE OF STUDY

As violent crime, more specifically homicide, continues to be a prevalent problem in many cities, it is imperative for scholarly work to address the gaps in knowledge surrounding the events and occurrence that result in this crime. An examination of how weather and temporal variables contribute to the occurrence of homicide can add to this knowledge base since despite the large number of academic studies focusing on the relationship between crime and weather-related variables, there is little consensus regarding the strength and direction of these relationships. Additionally, only a limited number of studies have examined the relationship between violent crime and weather, with even fewer studies exclusively looking at incidents of homicide. As such, the purpose of this study is to explore the relationship between weather, temporal variables, and homicide by answering three research questions: (1) Does weather have an effect on whether or not a homicide occurs (2) given that a homicide occurs, does weather have an effect on homicide location (outdoor, indoor), and (3) does plotting and analysis of temperature and homicide frequency lend support toward any of the proposed temperature-aggression models?

Research suggests that when studying homicide it is best to look at the total situation as an accumulation of situational, temporal, event, victim, and offender covariates (Block and Block, 1992; Pizarro, 2008). Referring to Figure 2, the present research proposes that weather variables have the ability to act as structural constraints, causing an individual to make adaptations that could influence their lifestyle or routine activities, and thus, the occurrence of homicide. For instance, extreme temperatures may cause individuals to alter their leisure activities by avoiding the outdoors and selecting to stay home or go to public places that have adequate heating or air-conditioning. Large amounts of precipitation, particularly snow could also have an effect on individual's routines, producing a "snow-day" effect in which individuals remain indoors and do not attend work. Furthermore, the theoretical assumption that pleasant weather draws people outdoors, and inclement weather draws people indoors is consistent with previous research (Cohn, 1990; Horrocks & Menclova, 2011; Rotton & Cohn, 2000). Once the assumption is drawn that weather influences an individual's location, theoretically it follows that weather may influence the location of a homicide (indoor or outdoor). Based on the theoretical assumptions of the heat and aggression psychological models, routine activities, lifestyle theory, and previous research, *it is hypothesized that weather elements will be correlated with whether or not a homicide occurs, where it occurs and the frequency of incidents*. It is also hypothesized that *during poor conditions, weather will act as a structural constraint influencing routine activities, and ultimately having a relationship with homicide.*

CHAPTER 4: METHODOLOGY

Research Site

Located in the northeastern coast (New Jersey), Newark has geographically a mid-latitude continental climate with four seasons (winter, spring, summer, and fall). New Jersey's location causes the state to be influenced by "wet, dry, hot, and cold airstreams," resulting in weather that is highly variable (ONJSC, 2013, para 1). Its long-term average precipitation is estimated at 45-47 inches annually (NCDC, 2007; NCDC, 2013a). The temperatures in the city have reached a record maximum of 108 degrees Fahrenheit and a minimum of -14 degrees Fahrenheit (NWS, 2013). Table 1 provides insight into the temperature, precipitation, and snowfall associated with each season. When comparing the seasons from 1981 to 2010, Newark winters (December-February) were generally the coldest with an average temperature of 34.2 degrees Fahrenheit and summers (June-August) were the hottest with an average temperature of 75.2 degrees Fahrenheit (NWS, 2013).

Structurally, in 2010, the city of Newark had a population of 277,140, with about 86% of the resident population comprised of African Americans, Hispanics or those of Latino ethnic origin (U.S. Census Bureau, 2013). Between 2007 and 2011, 26.1% of Newark's population was considered below the poverty level, which is much higher than the state average at 9.4%, and even the national average at 14.3% (U.S. Census Bureau, 2013). Additionally, Newark (2007-2011) fell below state and national averages for demographic factors such as percent of people over 25 years obtaining at least a Bachelor's degree and homeownership rate (U.S. Census Bureau, 2013).

In addition to demographic factors, understanding the routine activities and lifestyles undertaken by citizens within the city of Newark could allow for a better understanding of how these activities transition into or contribute to deadly incidents. During the period from 1997-2007, the Newark-Union monthly unemployment rate averaged about 4.7%, reaching the minimum of 3.2% and a maximum of 6.6% (U.S. Bureau of Labor Statistics, 2013). From 2007-2011, Newark residents over 16 years of age spent an average of about 31 minutes per day traveling to work, thus outside or in a public space (U.S. Census Bureau, 2013). Time traveling to work, “includes time spent waiting for public transportation, picking up passengers in carpools, and time spent in other activities related to getting to work" (U.S. Census Bureau, 2013). Additionally, with an average household income of $35,696, one can assume most leisure activities are not associated with high costs (U.S. Census Bureau, 2013).

Typically, Newark is above the national murder rate average and ranked among large cities as one of the highest in percentage change in murders from 1998–1999 to 2005–2006 (O’Flaherty & Sethi, 2010). The increasing subculture of gang violence, prosperity of drug markets and availability of firearms within the city contributed to making Newark one of the most violence cities in New Jersey and the country (Pizarro, Zgoba, & Jennings, 2011). From 1997-2007, a total of 817 homicide incidents occurred in the city, with the majority of homicides occurring outside (75.2%), on a public street (57.8%), and face-to-face (58.5%) between a victim and an offender who knew each other (73%).

Data

The present study employs the Newark homicide dataset (Pizarro et al., 2011 for details). The data was coded from homicide investigation files obtained from the Newark Police Department (NPD). Secondary data from the National Climate Data Center (NCDC) are also employed. Newark Liberty International Airport is a National Weather Service (NWS) first order weather station in which observations are drawn for the city as part of the Automated

Surface Observing System (ASOS)[2]. The first order weather station undergoes quality control following the end of each month (NOAA, 2013). NCDC Quality Controlled Local Climatological Data (QCLCD) was obtained from 2005-2007 and NCDC Unedited Local Climatological Data (ULCD) was obtained from 1997-2004.

In creating the current study database, QCLCD data, which includes enhanced quality control when compared to the ULCD data, was only available for January 2005 and later. Daily weather (i.e. temperature, wind speed, precipitation, precipitation type, significant weather) was collected from 1997 to 2007 for everyday within the 11-year span totaling 4017 days. Weather data was also collected from detailing Newark's daily and hourly weather (i.e. temperature, relative humidity, wind speed, significant weather, precipitation, precipitation type,) for all 817 incidents that occurred from 1997 to 2007 homicide.[3]

Measures

Dependent variables. The analyses places emphasis on three dependent variables (see Table 2 for variable coding schema): (1) homicide occurrence, (2) homicide location, and (3) number of homicide incidents (controlling for opportunity). Homicide occurrence (whether or not a homicide occurred on a specific day) and location (whether a homicide occurred indoor or outdoor) are coded dichotomously and are mutually exclusive. The number of homicide incidents is a discrete variable, providing a count of the number of incidents at each DOI

---

[2] ASOS is a collaborative effort between the National Weather Service (NWS), the Federal Aviation Administration (FAA), and the Department of Defense (DOD) toward collecting surface weather observations (NWS Office of Meterology, 1999).

[3] ASOS observations are collected hourly (nine minutes before the hour) and then more frequently collected during period of significant weather types such as rain and snow. For the purpose of this study, only hourly observations were used. For each incident, the closest hourly observation was selected, through rounding to the nearest half hour. The mean time difference between the ASOS hourly observation and time of incident was 15.44 minutes.

temperature. As seen in Figure 3, a majority of Newark's homicides occurred within the range of 35-80°F. This is not surprising, in that on a given day, the temperature within Newark has a high probability of falling into this range. To provide an example, the most common daily average temperature in Newark from 1997-2007 was 76°F. A total of 105 days within the time frame had 76°F as the daily average temperature, where as only one day within the sample had a daily average temperature of 11°F. Therefore, the opportunity to kill at 76°F is much more common than the opportunity to kill at 11°F. To control for this increased opportunity to commit a homicide at temperatures that occur more frequently in Newark, the count variable (number of homicide incidents at each DOI temperature) was divided by the total number of days from 1997-2007 with that daily average temperature.

Descriptive statistics for the dependent variables can be found in Table 3. There were a total of 4017 days from 1997-2007. Of the 4017 days, a homicide occurred on 743 (18.5%) of the days. As previously mentioned, there were 65 days in which more than one homicide occurred. From 1997-2007 817 homicide incidents occurred, with 615 (75.3%) of homicides occurring outside and 202 (24.7%) of homicides occurring inside.

<u>Independent variables</u>. Two sets of independent variables are employed – weather and temporal variables (see Table 2 for variable coding schema). The first set of variables includes *weather characteristics*. These variables include: (a) temperature (°F), (b) humidity (percentage), (c) wind speed (mph), (d) significant weather (e) precipitation (f) precipitation type and (g) daily snow/ice on the ground. Temperature, humidity, and wind speed are continuous variables, while precipitation[4], snow and/or ice on the ground and significant weather[5] are coded

[4] Precipitation includes: snow, snow grains, small hail & or snow pellets, ice pellets, ice crystals, freezing rain, thunderstorms, hail, rain, drizzle, and rain shower.

dichotomously for whether or not they are present. Precipitation type is also coded dichotomously as either liquid or freezing (see notes from Table 2 for definitions). Theoretically, these variables are included in order to model "poor" weather, which is indicated by the presence of uncomfortable temperatures, high winds, high humidity, significant weather and/or snow/ice on the ground.

Secondly, to gain further understanding, a set of *temporal variables* will be used, including (see Table 2 for variable coding schema): (a) season, (b) season 2 (c) holiday[6] (d) weekend, and (e) evening. Coding schemas for season, weekend, and evening were drawn from Pizarro (2008). While the first season variable is coded as winter, spring, summer and fall, the variable "season 2" was included in order to examine if there may be an effect if months were coded into either warm or cool seasons. Overall, previous research gives reason to believe activities and changes in lifestyle associated with temporal variables could influence the convergence of a motivated offender, suitable target, and lack of a capable guardian. Indeed, they may influence the amount of time individuals spend taking part in leisure activities and have an effect on their daily routine (Felson, 1987). For example, the holidays and weekends are a time in which individuals are likely to be active interacting with one another, whether they are purchasing gifts,

---

[5] Significant weather includes the presence of any weather phenomena listed under "significant weather types" within the Quality Controlled Local Climatological Data Codebook (NCDC, 2013c); examples include fog, haze, and rain.

[6] Originally, the present study drew from previous research and coded "holiday" as the day of major holiday (New Year's Day, Memorial Day, Independence Day, Labor Day, Thanksgiving, and Christmas) and the day after, recorded dichotomously (Cheatwood, 1995; Lester, 1979). Preliminary analysis however, suggested that "holiday" was more significant if defined not only as inclusive of New Year's Day, Memorial Day, Independence Day, Labor Day, Thanksgiving, and Christmas (as proposed by Cheatwood, 1995); but also, Halloween, Valentine's Day, Super Bowl Sunday, St. Patrick's day, and Cinco de Mayo**.** Additionally, preliminary analysis provided evidence to support coding "holiday" as the day of, day before, and day after each holiday. Therefore, holiday was recoded dichotomously to fit this definition.

traveling, or at a party. The activities and changes in lifestyle associated with holidays and weekends make the convergence of a motivated offender, suitable target, and lack of a capable guardian more probable by contributing to more people congregating in indoor or outdoor locations.

Table 4 displays Newark daily weather characteristics from 1997-2007, significant weather occurred on 52.6% of days. On days in which precipitation occurred (33.2%) the precipitation was liquid (rather than freezing) about 90% percent of the time. There was only snow or ice on the ground on 3.4% of days. Regarding temporal variables, within the 11 years of data, 42.9% of the days were considered weekends, 9.0% were holidays, and the seasons were equally distributed at 25%.

Homicide incident weather and temporal characteristics for the Date of Incident (DOI) and Time of Incident (TOI) are also provided in Table 4. Of the homicides that occurred (N=817) from 1997-2007, significant weather was present on the same day as 51.4% of homicides. It rained the day-of 32.6% of homicides, with 91.4% of the precipitation being liquid. At the time an incident occurred, there was significant weather present 20.8% of the time, with precipitation present only 11.5% of the time, in which 84% of the precipitation was liquid and 16% was freezing. There was snow and/or ice on the day-of 4% of homicides. Taking temporal variables into account, 52.3% of homicides occurred on the weekend and 7.1% occurred on a holiday, and a majority of homicides occurred during the evenings (69.2%). When compared to spring (23.6%) and fall (23.5%), more homicides occurred more frequently in the winter (26.6%) and summer (26.3%).

Analysis

The analytic strategy employed throughout this study was largely explorative, and thus, encompassed many bivariate and multivariate examinations. Analysis required the use of three data sets. The first data set, which is referred to as the "daily" data set, contains daily weather and temporal information for the 4017 days from 1997-2007. Weather variables from this data set are referred to with the prefix "daily." The daily data was used to examine if weather had an effect on whether or not a homicide occurred. For bivariate analyses, days were coded dichotomously as either having had an incident occur on the day, or having had no incident occur on the day. Therefore, days in which more than one homicide occurred (65 days) were not weighted differently than days where there was only one homicide.

A second incident-level data set was used to examine the relationship between weather and homicide through disaggregating homicide by location. For clarity, this data set is referred to as "incident" and weather variables from this data set are identified with the prefix day-of-incident (DOI) or time-of incident (TOI). T and chi-squared tests were employed in the analysis of this dataset.

The third data set used, combined measures from the incident (i.e. number of homicide incidents, DOI temperature) and daily (i.e. number of days at each temperature) data sets to employ Multiple Linear Regression (OLS), testing the relationship between the number of homicide incidents and the DOI temperature. OLS multivariate regression estimates a best-fitting regression line for the dependent variable (number of homicide incidents controlling for opportunity) and the continuous independent variables (DOI temperature and DOI temperature-squared). Drawing from theoretical models, five regressions are employed.

The first model, tests for a linear relationship. The second, third, fourth, and fifth models are drawn from previous findings suggesting an inverted-U, U-shaped and/or butterfly-shaped curve (NAE), and therefore include a temperature-squared variable because of the potential for non-linear relationships between temperature and homicide incidents. The second model is inclusive of all of the data, and is testing for an inverted-U or U-shaped curve. The third and fourth models test for inverted-U shaped relationships. These models however, only include data that is less than 55°F (Model 3) and data that is greater than 55°F (Model 4). These temperature ranges were selected through sensitively testing. Model five analyzes a more central temperature range between 40-80°F (examining the relationship in between the two inverted-U's), tentatively expecting a U-shaped curve in which the minimum is representative of the trough of the overall distribution between homicide incidents and temperature (inclusive of all temperatures).

A variation inflation factor (VIF) score greater than 10 was considered to signify a potential issue with multicollinearity. In order to remove collinearity between the DOI temperature and DOI temperature-squared, mean centering was employed throughout the models. Multicollinearity tests suggest that all VIF scores are less than two. Mean centering also allows estimates to be obtained which are more easily interpreted and results that more closely estimate the data, given that a DOI temperature of zero (°F) was not observed and therefore should not be the approximated intercept.

CHAPTER 5: FINDINGS

Bivariate Findings

In Table 5 various temperature, and wind specific bivariate tests are presented. These tests were conducted to compare alternate measures and to guide future analysis. Initially, the mean DOI temperature (55.85°F) was compared to the TOI temperature, with findings suggesting there is no statistically significant difference. The average daily temperature (55.85°F) was then compared to the non-incident daily temperature, the incident daily temperature, the DOI temperature, and the TOI temperature; all of which were found to have no differences statistically.

The average daily wind speed (9.89 mph) was then compared to the daily non-incident wind speed, the daily incident wind speed, and the TOI wind speed. Results indicate that the TOI wind speed (M=8.61, SD=4.97) was significantly lower than the average daily wind speed (M=9.89, SD=3.68), t (816) =-7.35, p<.001; the other wind related variables, however, were insignificant when compared to average daily wind speed. Table 5 also provides results suggesting that neither daily temperature nor daily wind speed have an effect on whether or not a homicide incident occurs.

Additional weather and temporal descriptive and bivariate analyses specific to the occurrence of homicide can be found in Table 6. Similar to temperature and wind speed, daily significant weather, precipitation, type of precipitation and snow/ice on the ground also do not have an impact on whether or not a homicide occurs. The temporal variables season (winter/spring/summer/fall and cool/warm) and holiday also do not appear to have a significant effect on the occurrence of homicide. In fact, the only variable found to be statically significant in its relationship to whether or not a homicide occurs was day of week, with results indicating homicides are more likely to occur on weekends X^2 (1, N=4017)=28.00, p<.001. The Phi measure of association, however, is only .084, indicating a weak relationship in which only 8.4% of the variation in homicide occurrence is explained by the day of week being a weekend (Friday, Saturday, and Sunday).

Homicide Location (Indoor or Outdoor)

Table 5 and Table 7 display bivariate analysis findings for homicide location and weather variables. Table 5 compares homicide location with TOI temperature, TOI wind speed, and TOI humidity. Findings suggest that although TOI temperature an TOI wind speed do not have an effect on whether or not a homicide occurs indoors or outdoors, TOI humidity (%) when a homicide occurs outside (M=64.88, SD=20.80) is significantly higher than TOI humidity when a homicide occurs inside (M=60.66, SD=23.28), $t(815)=2.43$, p<.05.

Table 7 includes additional descriptive statistics and bivariate findings comparing homicide location with TOI and DOI significant weather, precipitation, precipitation type and DOI snow/ice on the ground; with results suggesting there is no significant relationship between these weather variables and location. Of the temporal variables (see Table 7): season (winter/spring/ summer/fall and warm/cool), holiday, weekend and evening, only evening (6pm-5am) was found to be significantly related to homicide location, X^2 (1, N=798)=4.73, p<.05. The Phi measure of association is weak; however, suggesting only 7.7% of the variation in homicide location can be explained by the time of day (evening or daytime).

Multivariate Analyses

Mean temperature on the day of the incident and the number of homicide incidents, prior to controlling for opportunity, were plotted in Figure 3. Examining the shape of the plotted data, it appeared as if the relationship between the number of homicide incidents and DOI temperature might reflect two theoretical models of temperature-aggression: the Inverted-U shape, and the NAE model. Figure 4 however, provides the number of homicides and DOI temperature plot, controlling for increased crime-opportunity resulting from more common temperatures. Once controlling for opportunity, it appears the data no longer resembles the inverted-U, NAE, or any discussed model of temperature-aggression. Regression results considering the relationship between number of homicide incidents and temperature, relative to specific models of temperature-aggression when controlling for opportunity can be found in Table 8 and 9[7]. Model 1 tests for a linear relationship, in which as temperature increases the number of homicide incidents also increases, and produces no statically significant findings. This indicates there is no evidence to suggest a linear relationship between temperature and the number of homicide incidents.

Model 2 then tests for a curvilinear relationship (i.e. Inverted-U shape, and U-shape cures) between temperature and homicide incidents. The Inverted-U shape curve theoretically is a positive correlation between temperate and the number of incidents, until a specific temperature, where the correlation then becomes negative; and a U-shape in which both extreme hot and cold temperatures create discomfort, leading to increased aggression through homicide. Model 2 again produces no significant findings. Together, Model 3, Model 4, and Model 5 were employed based on the NAE model of heat-aggression. Neither Model 3, 4, or 5 had significant

---

7 Models were run with and without outliers included. Model 2 Findings were initially significant with outliers included (although very low effect sizes and R^2 was present). Once 3 outliers were removed, the variables no longer reached significance. Results without the outliers included were therefore presented. Models were also run employing the natural log of the outcome given Kurtosis in the data (Kurtosis=2.81), but substantive findings remained unchanged.

findings. Jointly these models provide no support for the NAE model. Overall, there were no findings that supported a model of T/A, based on Figure 4, these results were expected.

CHAPTER 6: DISCUSSION

The present inquiry concentrated on answering three primary research questions: (1) Are weather covariates significant in determining whether or not a homicide occurs, (2) Given that a homicide occurs, are weather variables significant once homicide is disaggregated by location, and (3) is there a relationship between the number of homicide incidents and temperature? Bivariate findings generally suggest that temperature, humidity, wind speed, significant weather, precipitation, precipitation type, and snow and/or ice on the ground have no impact on whether or not a homicide occurs. In instances where a homicide occurs, the only weather-related variable found to be a significant indicator of homicide location (indoor or outdoor) was humidity (%), in which homicides were more likely to occur outdoors as humidity levels increased. Generally, findings provide little-to-no support that weather is related to whether or not a homicide occurs or where it occurs.

Drawing from temperature-aggression, routine activities (Cohen and Felson, 1979) and lifestyle (Hindelang et al., 1978) theories, the effect environmental changes, specifically weather, has on homicide was examined. According to the proposition that weather may affect human behavior, lifestyles, and routine activities, Hindelang et al.'s (1978) model was adapted in Figure 2 was to include "weather" was a structural constraint ultimately influencing personal victimization. The study findings, however, provide very weak justification for this adaptation. More specifically, findings do not support that the weather variables tested have a relationship with homicide or should be considered structural constraints influencing victimization as suggested in Figure 2.

The final research question, "Does temperature have an effect on the number of homicide incidents," was included to more closely examine various temperature-aggression models, using number of homicides as a proxy for aggression. Regression results indicate that there is not a significant relationship between temperature and number of homicide incidents, regardless of the shape of the curve. Specifically, based on the selected operationalization of the variables, there is no support drawn for the GA, GAAM, U-shaped, Inverted-U shaped, or NAE model of temperature-aggression.

Findings within this study have various methodological implications. As previous research has recognized, different types of homicides are characterized by unique situational covariates (Block and Block, 1992; Pizarro, 2008). Based on these research findings, however, weather-related variables generally should not be considered significant situational covariates that have unique effects among disaggregated homicide types. Although weather does not appear to have a significant impact on the occurrence of homicide, consistent with previous research the present study does support that temporal variables (notably season, weekend, and evening) are significant covariates when studying homicide and should continue to be employed in research. Specifically, whether or not it was a weekend was significantly related to whether or not a homicide occurred and a relationship was found between homicide location (indoor and outdoor) and whether or not the crime occurred in the evening. Furthermore, there were no findings to suggest significant differences exist between DOI and TOI weather related data. Consequently, future criminological temperature-specific studies could select one or the other, or use the two interchangeably.

Albeit weather variables were not found to have a relationship with whether or not a homicide occurs, where it occurs, or the number of incidents, findings still carry important policy implications. For instance, despite instances where violence is attributed to "the heat of the summer," individuals should be aware of findings in which no relationship exists. As beneficial as it may have been for law enforcement and first responders to be able to forecast homicides based on precipitation or any other weather variable, there may be a benefit in knowing weather variables may have little, if any ability to forecast homicide.

The present study is not without limitations. Primarily, incident-level findings are based only on data that is known to law enforcement. Additionally, theoretical underpinnings for analysis of homicide location rely on the assumption that indoor environments provide shelter from extreme weather conditions. There are some circumstances, however, in which this assumption may not hold true. Namely, in conditions of extreme temperature, it is quite possible that some of the indoor environments within the study do not have air conditioning or heating. This is a significant drawback since research has found differences in the relationship between temperature and assault when comparing climate-controlled settings to settings that lacked climate control (Rotton & Cohn, 2004). The present study does not have data to determine whether or not indoor homicides occurred in climate-controlled environments, and questions whether this control variable would have affected study results. This limitation is mitigated by the theoretical assumption that regardless of climate-control technology, indoor environments can still be considered shelter from other sources of discomfort such as significant weather such as precipitation. The ability to select only specific weather-related variables of interest also establishes a limitation. While this study tested many weather variables, others were not included (such as fog, barometric pressure, and degree of sunlight). Therefore, generalizations regarding "weather" only speak to the specific variables tested, and does not encompass variables that were not included within the study. This limitation is due to the complexity inherent when studying weather, an concept which is the statistical aggregating of countless elements. Finally, the daily data bivariate analysis only includes information on whether or not a homicide occurred on a specific day. The 65 Days in which more than one homicide occurred are not weighted differently than days in which only one homicide occurred, resulting in 74 incidents that are not included in daily analysis. There is a potential that results may have differed if the number of daily incidents was included in the daily analysis.

CHAPTER 7: CONCLUSION

Although conventional wisdom has for some time supported propositions that weather, most notably temperature, is strongly correlated with violent crime, the present study found no support that weather variables are related to whether or not a homicide occurs. Very weak support was found suggesting that humidity may influence where a homicide occurs (outside or inside), other weather-related variables were found to have no effect on homicide location. Based on the selected method for operationalization of data, there is also no evidence to support a relationship between temperature and the number of homicide incidents. Generally, findings are unable to suggest that a relationship between weather elements and homicide exists within Newark.

Future studies can contribute to these findings in many ways. Firstly, studies should be conducted in an effort to support or oppose specific models of temperature-aggression, which can aid in understanding of human behaviors, routine activities, and lifestyles. Greater understanding of the relationship between temperature and aggression could allow for more detailed theoretical assumptions with respect to temperature's role in routine activities and lifestyles theories. Researchers should also further explore how weather variables affect homicide occurrence and location in various temperature ranges. The ranges chosen to examine the NAE model were done so through sensitivity testing, but other ranges may be theoretically justified and necessary to assess for other researchers. Similar studies should also be conducted in diverse climates and areas with differing levels of violence to examine whether Newark is unique in these findings. The high homicide rate and therefore violent nature of the city may overpower and any effect weather may have on homicide. It is possible however, that cities where homicide is less of a day-to-day occurrence, are more highly influenced by weather elements. Consequently, future research should involve replication of this study, in order to enhance study generalizability.

APPENDIX

Figure 1. Models of Temperature-Aggression

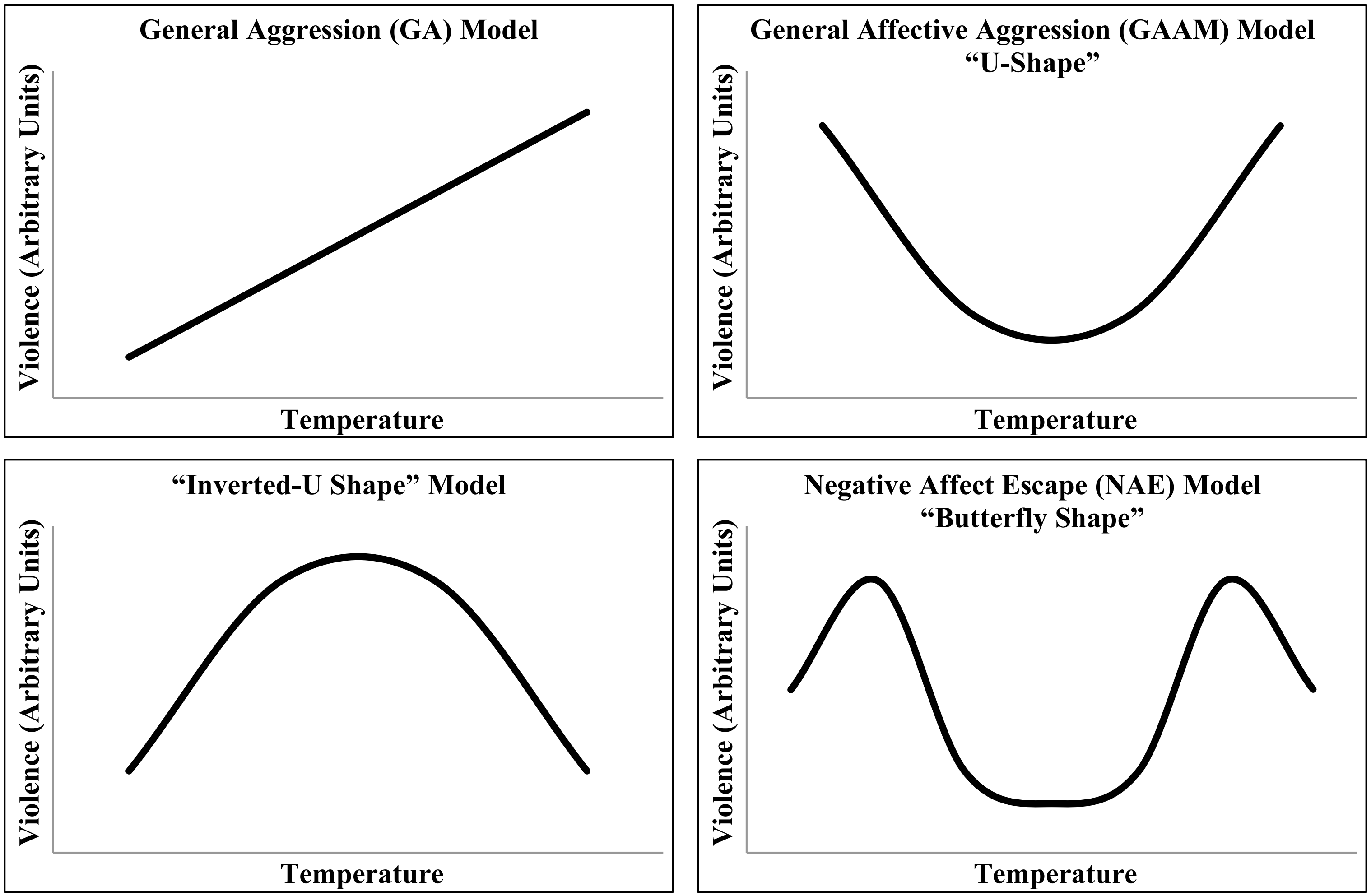
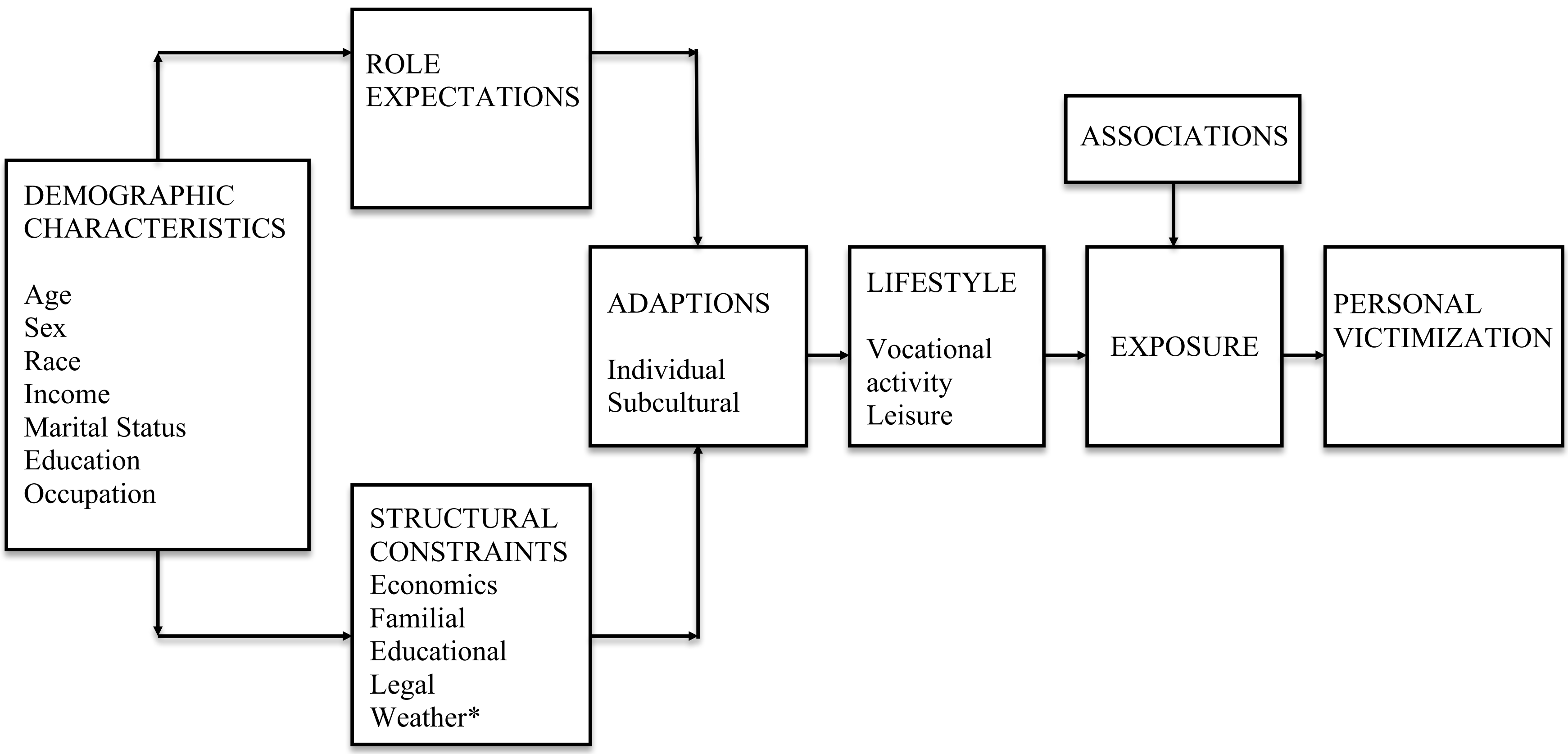


Figure 2. Weather as a Structural Constraint in Hindelang et al.'s (1978) Lifestyle Model



From Hindelang et al. (1978), p. 243

Figure 3. Temperature and Aggression Modeled through Newark Incidents of Homicide from 1997 to 2007

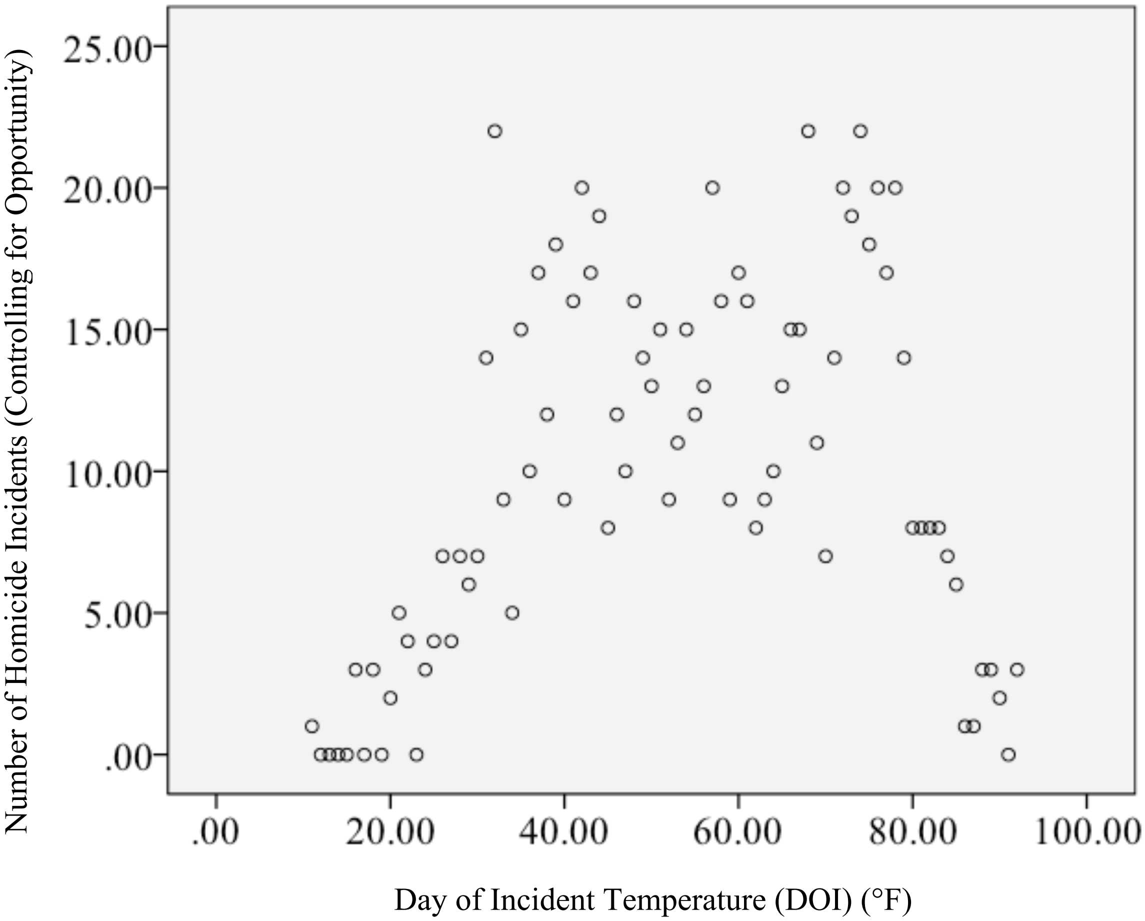


Figure 4. Temperature and Aggression (Controlling for Opportunity) Modeled through Newark Incidents of Homicide from 1997 to 2007

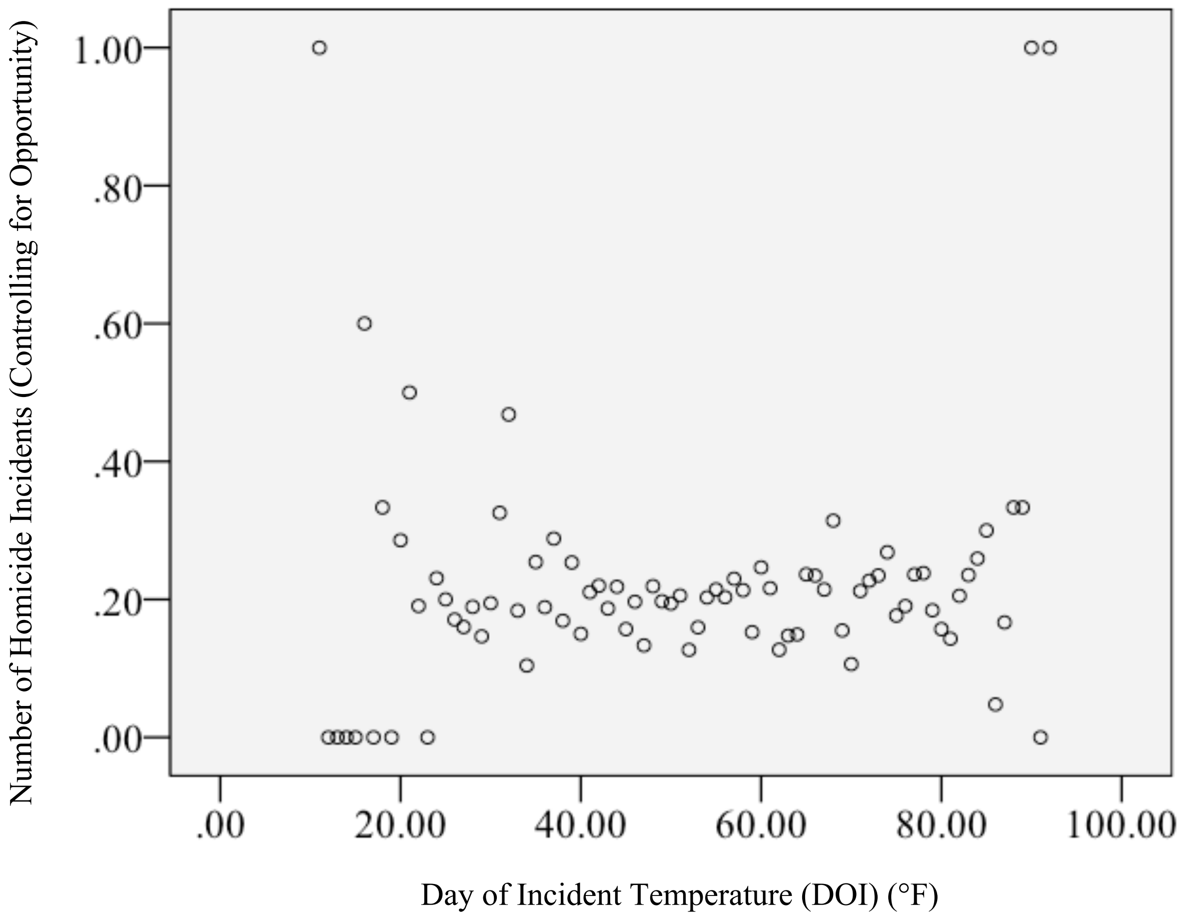


Table 1. Newark Season Averages from 1981-2010

	Month			
	December-February (Winter)	March- May (Spring)	June- August (Summer)	September-November (Fall)
Temp Average Max (°F)	41.5	61.6	83.9	65.5
Temp Average Min (°F)	27.0	43.5	66.5	48.9
Temp mean (°F)	34.2	52.6	75.2	57.2
Precipitation daily average (in)	10.23	12.47	12.48	11.07
Snowfall total (in)	22.7	5.5	0.0	0.4

Table 2. Variable Coding Schema	
Dependent Variables	
Occurrence	Did a homicide incident occur on this day? 1=Yes, 0=No
Location	Where did the homicide occur (indoors or outdoors)? 0=Outdoors, 1=Indoors
Number of Incidents (controlling for opportunity)	A count of the number of homicide incidents at each average day of incident (DOI) temperature divided by the number of days with the daily average temperature equal to the DOI temperature.
Independent Variables	
<u>*Weather variables*</u>	
Temperature	Degrees Fahrenheit
Humidity	Percentage, a ratio of moisture in the air relative to the amount present at full saturation
Wind Speed	Miles per hour
Significant Weather	Was there significant weather? 0=N0; 1=Yes[1]
Precipitation	Was there precipitation?[2] 0=N0; 1=Yes
Precipitation Type	Which type of precipitation occured?[3] 1=Liquid; 2=Freezing
Daily Snow/Ice on ground	Was there snow or ice on the ground?[4] 0=N0; 1=Yes
<u>*Temporal Variables*</u>	
Season	Which season did the day fall? 1=Winter; 2=Summer; 3=Spring; 4=Fall
Season 2	Did the day fall within a cool or warm season? 0=Cool (October-March); 1=Warm (April-September)
Holiday	Was the day a holiday[5] 0=N0; 1= Yes
Weekend	Was the day of week a weekend? 0= No (Monday to Thursday); 1=Yes (Friday to Sunday)
Evening	Did the incident occur during the evening or daytime hours? 0=No (6 a.m. to 5 p.m.); 1=Yes (6 p.m. to 5 a.m.)

Note: The variables can be specific to the daily data set (N=4017) in which they will be referred to as "daily"; or the incident data set (N=817) in which they will be referred to as either day-of-incident (DOI) or time-of-incident (TOI).
1: Significant weather includes the presence of any weather phenomena listed under "significant weather types" within the Quality Controlled Local Climatological Data Codebook (NCDC, 2013c).
2. TOI precipitation is determined by viewing both the hourly observation before and after the incident. An occurrence of precipitation in either of these observations is considered precipitation at the TIO.

Table 2 (cont'd)

3: Freezing (1) includes: snow, snow grains, small hail & or snow pellets, ice pellets, ice crystals, and freezing rain. Liquid (0) includes thunderstorms, hail, rain, drizzle, and rain shower. In instance where more than one significant weather type occurs, the primary weather type (listed first) is considered the incident precipitation type.
4: Trace amounts of snow or ice on the ground are coded as 0. Measurements are taken daily at 7 a.m. Eastern Standard Time (EST).
5: In instances where the U.S. Federal Holiday fell on a Saturday, the preceding Friday was also coded at 1. Similarly, for U.S. Federal Holidays that fell on a Sunday, the proceeding Monday was coded as 1. This was done because these days are legal holidays for employees who work Monday to Friday workweeks (see 5 U.S.C. 6103(b) and Executive Order 11582).

Table 3. Homicide Descriptive Characteristics

Variable	N (%)
Occurrence (N=4017)	
No	3274 (81.5%)
Yes	743 (18.5%)
Location (N=817)	
Outside	615 (75.3%)
Inside	202 (24.7%)
	N (%)

Table 4. Weather and Temporal characteristics of Newark

Variable		Daily (N=4017)	DOI (N=817)	TOI (N=817)
Weather				
Temperature (°F)		55.78 (17.23)	55.85 (17.51)	55.10 (17.28)
Humidity (%)		---	---	63.84 (21.50)
Wind Speed (mph)		9.89 (3.68)	---	8.61 (4.97)
Significant Weather	No	1901 (47.3%)	394 (48.3%)	629 (77.0%)
	Yes	2111 (52.6%)	420 (51.4%)	170 (20.8)
Precipitation	No	2679 (66.7%)	550 (67.3%)	723 (88.5%)
	Yes	1332 (33.2%)	266 (32.6%)	94 (11.5%)
Precipitation Type[1]	Liquid	1194 (29.7%)	244 (29.9%)	79 (9.7%)
	Freezing	138 (3.4%)	23 (2.80%)	15 (1.8%)
Snow/ice on the ground	No	2941 (73.2%)	752 (92.0%)	---
	Yes	135 (3.4%)	33 (4.0%)	
Temporal				
Season 1	Winter	992 (24.7%)	217 (26.6%)	
	Spring	1012 (25.2%)	193 (23.6%)	---
	Summer	1012 (25.2%)	215 (26.3%)	
	Fall	1001 (24.9%)	192 (23.5%)	
Season 2	Cool	2004 (49.9%)	413 (50.6%)	---
	Warm	2013 (50.1%)	404 (49.4%)	
Holiday	No	3656 (91.0%)	759 (92.9%)	---
	Yes	361 (9.0%)	58 (7.1%)	
Weekend	No	2295 (57.1%)	387 (47.4%)	---
	Yes	1722 (42.9%)	427 (52.3%)	
Evening	No	---	---	233 (28.5%)
	Yes			565 (69.2%)

Note: N (%), Unless temperature, humidity, or wind speed in which mean (standard deviation) are provided; TOI= Time of Incident; DOI= Day of Incident

[1]Only accounts for days or incidents in which precipitation was present, therefore the N is given in the Precipitation-Yes category directly above.

Table 5. Bivariate Tests Including Temperature, Humidity and Wind Speed

Dependent Variable	*Independent Variable*	Mean Temperature (°F)	Std. Deviation	Df	*t*	Sig.
DOI Temp		**55.85**				
	TOI Temp	55.10	17.28	797	-1.23	
Daily Temperature		**55.78**				
	Non-Incident Daily Temp	55.77	17.23	3264	-0.05	
	Incident Daily Temp	55.85	17.23	742	0.11	
	DOI Temp	55.85	17.51	816	0.12	
	TOI Temp	55.10	17.23	797	-1.11	
Daily Wind Speed		9.89				
	Non-Incident Wind Speed	9.87	3.67	3273	-0.38	
	Incident Wind Speed	10.01	3.65	742	0.37	
	TOI Wind Speed	8.61	4.97	816	-7.35	***
Did a Homicide Incident Occur? (0=No; 1=Yes)						
	Daily Temp Average	No=55.77 Yes=55.85	No=17.23 Yes=17.23	4006	-0.12	
	Daily Wind Speed Average (mph)	No=9.87 Yes=10.01	No=3.69 Yes=3.65	4015	-0.98	
Where was the Homicide Location? (0=Outside; 1=Inside)						
	TOI Temperature	Outside=55.54 Inside=53.70	Outside=17.08 Inside=17.86	796	1.29	
	TOI Humidity (%)	Outside=64.88 Inside=60.66	Outside=20.80 Inside=23.28	815	2.43	**
	TOI Wind Speed	Outside=8.63 Inside=8.54	Outside=4.92 Inside=5.14	815	.23	

Note: A separate t-test was performed between each dependent variable and the independent variables directly underneath
*p ≤.05, **p≤01, ***p≤.001

Table 6. Weather and Temporal Variable Descriptive Statistics When a Homicide Incident Does Not Occur and Occurs and Chi-Squared Tests of Significance				
Dependent Variable				
Did a homicide incident occur? (N=4017)		No	Yes	
		81.5%	18.5%	
Independent Variables				
Weather Variables				
Was there any daily significant weather (N=4012)				
X^2=.109	No	38.7%	8.7%	
	Yes	42.8%	9.8%	
Was there any daily precipitation? (N=4011)				
X^2=.659	No	54.7%	12.1%	
	Yes	26.8%	6.4%	
Which type of daily precipitation occurred? (N=1332)				
X^2=1.588	Liquid	72.0%	17.6%	
	Freezing	8.8%	1.6%	
Was there snow and/or ice on the ground? (N=3076)				
X^2=1.694	No	77.9%	17.7%	
	Yes	3.4%	1.0%	
Temporal Variables				
In which season was this day? (N=4017)				
X^2=2.059	Winter	19.8%	4.9%	
	Spring	20.8%	4.4%	
	Summer	20.6%	4.6%	
	Fall	20.3%	4.6%	
Did the incident occur in a cool or warm season? (N=4017)				
X^2=0.073	Cool	40.6%	9.3%	
	Warm	40.9%	9.2%	
Was this day a holiday? (N=4017)				
X^2=.100	No	74.2%	16.8%	
	Yes	7.3%	1.7%	
Was this day a weekend? (N=4017)				***
X^2=28.004	No	48.2%	9.0%	
	Yes	33.3%	9.5%	

*p ≤.05, **p≤01, ***p≤.001

Table 7. Weather and Temporal Variable Descriptive Statistics for Homicide Location and Chi-Squared Tests of Significance

<u>Dependent Variable</u>				
Where was the homicide location? (N=817)		Outdoor	Indoor	
		75.3%	24.7%	
<u>Independent Variables</u>				<u>Significance</u>
Weather Variables				
At the TOI was there any significant weather? (N=799)				
X^2=.383	No	59.3%	19.4%	
	Yes	16.5%	4.8%	
On the DOI was there any significant weather? (N=814)				
X^2=.131	No	36.1%	12.3%	
	Yes	39.1%	12.5%	
At the TOI was there any precipitation? (N=817)				
X^2=.679	No	66.2%	22.3%	
	Yes	9.1%	2.4%	
On the DOI was there any precipitation (N=816)				
X^2=.297	No	51.0%	16.3%	
	Yes	24.1%	8.5%	
On the TOI which type of precipitation occurred? (N=94)				
X^2=.310	Liquid	67.0%	17.0%	
	Freezing	11.7%	4.3%	
On the DOI which type of precipitation occurred? (N=268)				
X^2=2.672	Liquid	68.7%	22.4%	
	Freezing	5.2%	3.4%	
On the DOI was there any snow or ice on the ground? (N=785)				
X^2=.551	No	72.2%	23.6%	
	Yes	2.9%	1.3%	
Temporal Variables				
In which season did the incident occur? (N=817)				
X^2=6.696	Winter	19.8%	6.7%	
	Spring	16.3%	7.3%	
	Summer	20.7%	5.6%	
	Fall	18.5%	5.0%	
Did the incident occur in a cool or warm season? (N=817)				
X^2=.219	Cool	37.7%	12.9%	
	Warm	37.6%	11.9%	
Did the incident occur on a holiday? (N=817)				
X^2=2.844	No	69.3%	23.6%	
	Yes	6.0%	1.1%	

Table 7 (cont'd)

Did the incident occur on a weekend (Fri, Sat, Sun)? (N=817)				
X^2=.641	No	36.4%	11.1%	
	Yes	38.9%	13.6%	
Did the incident occur during the evening (6pm-5am)? (N=798)				*
X^2=4.730	No	20.7%	8.5%	
	Yes	55.3%	15.5%	

*p ≤.05, **p≤01, ***p≤.001

Table 8. Linear Regression of Number of Homicide Incidents

	Model 1 "Linear" (N=78)				Model 2 Non-linear: "Inverted-U or U-Shape" (N=84)			
Variable	β	*S.E*	*t*		β	*S.E*	*t*	
DOI Temperature	0.00	0.00	0.76		0.00	0.00	1.22	
DOI $Temp^2$	-	-	-		0.00	0.00	-1.09	
Constant	0.20	0.01	16.56	***	0.28	0.08	3.57	***
R^2	0.01				0.02			

*$p \leq .05$, **$p \leq 01$, ***$p \leq .001$

Table 9. Linear Regression of Number of Homicide Incidents Continued

	Model 3 "NAE" Temperature<55°F (N=43)			Model 4 "NAE" Temperature >55°F (N=35)			Model 5 "NAE" Temperature 40-80°F (N=39)		
Variable	β	*S.E*	*t*	β	*S.E*	*t*	β	*S.E*	*t*
DOI Temperature	0.02	0.01	2.97	0.01	0.02	0.54	0.00	0.00	0.70
DOI $Temp^2$	0.00	0.00	-1.85	0.00	0.00	-0.54	0.00	0.01	-0.61
Constant	0.50	0.17	14.47**	0.59	0.71	0.83	0.04	0.22	0.20
R^2	0.09			0.01			0.05		

*$p \leq .05$, **$p \leq 01$, ***$p \leq .001$

REFERENCES

REFERENCES

Anderson, C. A. (1989). Temperature and aggression: Ubiquitous effects of heat on occurrence of human violence. *Psychological Bulletin, 106*(1), 74-96.

Anderson, C. A., & Anderson, K. B. (1998). Temperature and aggression: paradox, controversy, and a (fairly) clear picture. In R. Geen & E. Donnerstein (Eds.), Human aggression: Theories, research and implications for social policy (pp. 49–72). San Diego: Academic.

Anderson, C.A., Anderson, K.B., Door, N., DeNeve, K.M., & Flanagan, M. (2000). Temperature and aggression. In M. Zanna (Ed.), Advances in experimental social psychology (Vol. 32, pp. 63-133). New York. Academic Press.

Anderson, C. A., Bushman, B. J., & Groom, R. W. (1997). Hot years and serious and deadly assault: Empirical tests of the heat hypothesis. *Journal of Personality and Social Psychology, 73*(6), 1213-1223.

Bakal, J.A., Ezekowitz, J.A., Westerhout, C.M., Boersma, E., & Armstrong, P.W. (2012). Association of global weather changes with acute coronary syndromes: gaining insights from clinical trials data. *International Journal of Biometeorology*. Retrieved: http://www.springerlink.com.proxy1.cl.msu.edu/content/764m672643643032/fulltext.pdf

Baron, R. A., & Bell, P. A. (1976). Aggression and heat: The influence of ambient temperature, negative affect, and a cooling drink on physical aggression. *Journal of Personality and Social Psychology, 33*(3), 245-255.

Bell, P. A. (1992). In defense of the negative affect escape model of heat and aggression. *Psychological Bulleti*n, 111, 342–346.

Bell, P. A., & Baron, R. A. (1976). Aggression and heat: The mediating role of negative affect. *Journal of Applied Social Psychology, 6*(1), 18-30.

Block, C. R., & Block, R. (1992). Homicide syndrome and vulnerability: Violence in Chicago community areas over 25 years. *Studies on Crime and Crime Prevention, 1*, 61-87.

Bushman, B. J., Wang, M. C., & Anderson, C. A. (2005). Is the curve relating temperature to aggression linear or curvilinear? assaults and temperature in Minneapolis reexamined. *Journal of Personality and Social Psychology, 89*(1), 62-66.

Ceccato, V. (2005). Homicide in São Paulo, Brazil: Assessing spatial-temporal and weather variations. *Journal of Environmental Psychology, 25*(3), 307-321.

Cheatwood, D. (1988). Is there a season for homicide? *Criminology, 26*(2), 287-306.

Cheatwood, D. (1995). The effects of weather on homicide. *Journal of Quantitative Criminology, 11*(1), 51-70.

Ciucci, E., Calussi, P., Menesini, E., Mattei, A., Petralli, M., & Orlandini, S. (n.d.). Weather daily variation in winter and its effect on behavior and affective states in day-care children. *International Journal of Biometeorology, 55*(3), 327-337.

Cohen, L. E., & Felson, M. (1979). Social change and crime rate trends: A routine activity approach. *American Sociological Review, 44(4),* 588-608.

Cohn, E. G. (1990). Weather and crime. *British Journal of Criminology, 30*(1), 51-64.

Cohn, E. G. (1993). The prediction of police calls for service: The influence of weather and temporal variables on rape and domestic violence. *Journal of Environmental Psychology, 13*(1), 71-83.

Cohn, E. G., & Rotton, J. (1997). Assault as a function of time and temperature: A moderator-variable time-series analysis. *Journal of Personality and Social Psychology, 72*(6), 1322-1334.

Cohn, E. G., & Rotton, J. (2000). Weather, seasonal trends and property crimes in Minneapolis, 1987–1988. A moderator-variable time-series analysis of routine activities. *Journal of Environmental Psychology, 20*(3), 257-272.

Cohn, E. G., & Rotton, J. (2003). Even criminals take a holiday: Instrumental and expressive crimes on major and minor holidays. *Journal of Criminal Justice, 31*(4), 351-360.

Cohn, E. G., & Rotton, J. (2005). The curve is still out there: A reply to Bushman, Wang, and Anderson's (2005) 'is the curve relating temperature to aggression linear or curvilinear?' *Journal of Personality and Social Psychology, 89*(1), 67-70.

Dunn, R. A., Shaw, W. D., & Trousdale, M. A. (2012). The effect of weather on walking behavior in older adults. *Journal of Aging and Physical Activity, 20*(1), 80-92.

Feldman, H. S., & Jarmon, R. G. (1979). Factors influencing criminal behavior in Newark (NJ) a local study in forensic psychiatry. *Journal of Forensic Sciences,* 24(1), 234-239.

Felson, M. (1987). Routine activities and crime prevention in the developing metropolis. *Criminology, 25*, 911-931.

Felson, M., & Poulsen, E. (2003). Simple indicators of crime by time of day. *International Journal of Forecasting, 19*(4), 595-601.

Field, S. (1992). The effect of temperature on crime. *British Journal of Criminology, 32*(3), 340-351.

Hindelang, M., Gottfredson, M. & Garofalo, J. (1978). *Victims of personal crime: An empirical foundation for a theory of personal victimization*. Cambridge, Mass.: Ballinger.

Hipp, J. R., Bauer, D. J., Curran, P. J., & Bollen, K. A. (2004). Crimes of opportunity or crimes of emotion? testing two explanations of seasonal change in crime. *Social Forces, 82*(4), 1333-1372.

Horrocks, J., and Menclova, A.K. (2011). The effects of weather on crime, New Zealand Economic Papers, 45:3, 231-254.

Jacob, B., Lefgren, L., & Moretti, E. (2007). The dynamics of criminal behavior: Evidence from weather shocks. *Journal of Human Resources, 42*(3), 489-527.

Kposowa, A. J., & Breault, K. D. (1998). Temporal factors and homicide in the United States. *Journal of Interpersonal Violence, 13*, 590-604.

LeBeau, J.L. (1988). Comment: Weather and crime: Trying to make social sense of a physical process. *Justice Quarterly*, 5(2), 301-309.

LeBeau, J. L., & Corcoran, W. T. (1990). Changes in calls for police service with changes in routine activities and the arrival and passage of weather fronts. *Journal of Quantitative Criminology, 6*(3), 269-291.

Lehren, A.W. and Baker, A. (2009, June 18). In New York, Number of Killings Rises With Heat. *The New York Times.* Retrieved from: http://www.nytimes.com/2009/06/19/nyregion/19murder.html?pagewanted=all&_r=0

Lester, D. (1979). Temporal variation in suicide and homicide. *American Journal of Epidemiology,* 109: 517- 520.

Loftin, C. & Cheatwood, D. (1996). Cold Floor Effects on Homicide. Journal of Quantitative Criminology, 12:4 (December), 439-444.

McFarland, S. G. (1983). Is capital punishment a short-term deterrent to homicide? A study of the effects of four recent American executions. *The Journal of Criminal Law and Criminology, 74(3),* 1014-1032.

Michael, R. P., & Zumpe, D. (1983). Sexual violence in the United States and the role of season. *The American Journal of Psychiatry, 140*(7), 883-886.

Michael, R. P., & Zumpe, D. (1986). An annual rhythm in the battering of women. *The American Journal of Psychiatry, 143*(5), 637-640.

National Climate Data Center (NCDC). (2007). Climatological data annual summary: New Jersey 2007, 112 (13). Retrieved April 28, 2013, from http://www1.ncdc.noaa.gov/pub/orders/IPS-4637E9C5-21BB-4EB7-8CB8-68F547D3065C.pdf.

National Climate Data Center (NCDC). (2013a). 1981-2010 Normals Data Access. Retrieved April 28, 2013, from http://www.ncdc.noaa.gov/land-based-station-data/climate-normals/1981-2010-normals-data.

National Climate Data Center (NCDC). (2013b). Quality Controlled Datasets. Retrieved February 5, 2013 from http://www.ncdc.noaa.gov/crn/qcdatasets.html

National Climate Data Center (NCDC). (2013c). Quality Controlled Local Climatological Data. Retrieved February 5, 2013 from http://cdo.ncdc.noaa.gov/qclcd/qclcddocumentation.pdf.

National Oceanic and Atmospheric Administration (NOAA). (2013). NCDC Frequently Asked Questions. Retrieved March 5, 2013 from http://www.ncdc.noaa.gov/faqs/climfaq25.html.

National Weather Service (NWS). (2013). Climatological Report (Seasonal). Retrieved February 4, 2013 from http://forecast.weather.gov/product.php?site=NWS&issuedby=EWR&product=CLS&format=CI&version=1&glossary=1.

National Weather Service (NWS) Office of Meteorology. (1999). Automated Surface Observing System (AS0S). Retrieved July 12, 2013, from http://www.nws.noaa.gov/ost/asostech.html.

Niemira, M. P. (1997). How does weather affect consumer behavior? Let me count the ways. *Chain Store Age, 73*(2), 19-19.

O'Flaherty, B. and Sethi, R. (2010) Peaceable Kingdoms and War Zones Preemption, Ballistics, and Murder in Newark. In R. Di Tella, S. Edwards, and E. Schargrodsky (Eds.), *The Economics of Crime: Lessons for and from Latin America* (pp. 305-353). Retrieved January 7, 2013 from http://www.nber.org/chapters/c11847.pdf

Office of the New Jersey State Climatologist (ONJSC). (2013). The climate of New Jersey. Retrieved April 28, 2013 from http://climate.rutgers.edu/stateclim/?section=uscp&target=NJCoverview.

Peng, C., Xueming, S., Hongyong, Y., & Dengsheng, L. (2011). Assessing temporal and weather influences on property crime in Beijing, China. *Crime, Law and Social Change, 55*(1), 1-13.

Pizarro, J. M. (2008). Reassessing the situational covariates of homicides: Is there a need to disaggregate? *Homicide Studies,* 12(4), 323-349.

Pizarro, J. M., Zgoba, K. M., & Jennings, W. G. (2011). Assessing the interaction between offender and victim criminal lifestyles & homicide type. *Journal of Criminal Justice, 39*(5), 367-377.

Quetelet, A. (1842). A treatise on man and the development of his faculties. Edinburgh: W. and R. Chambers. Retrieved: http://hdl.handle.net/2027/uc2.ark:/13960/t78s51j9z.

Rotton, J. (1993). Atmospheric and temporal correlates of sex crimes. endogenous factors do not explain seasonal differences in rape. *Environment & Behavior, 25*(4), 625-642.

Rotton, J., & Cohn, E. G. (2000). Violence is a curvilinear function of temperature in Dallas: A replication. *Journal of Personality and Social Psychology, 78*(6), 1074-1081.

Rotton, J., & Cohn, E. G. (2003). Global warming and U.S. crime rates: An application of routine activity theory. *Environment and Behavior, 35*(6), 802-825.

Rotton, J. & Cohn, E.G. (2004). Outdoor Temperature, Climate Control, and Criminal Assault: The Spatial and Temporal Ecology of Violence. *Environment and Behavior, 36(2), 276-306.*

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), 1207-1220.

Rotton, J. & Kelly, I. W. (1985). Much ado about the full moon: a meta-analysis of lunar-lunacy research. *Psychological Bulletin,* 97, 286-306.

Schlatter, T. W. (1987). Temperature-Humidity index. In Oliver, J. E., and Bainbridge, R. (eds.), *The Encyclopedia of Climatology,* van No strand, Reinhold, New York.

Shepherd, J. (1990). Violent crime in Bristol: an accident and emergency room perspective. *British Journal of Criminology,* 30, 289-305.

Tennenbaum, A. N., & Fink, E. L. (1994). Temporal regularities in homicide: Cycles, seasons, and autoregression. *Journal of Quantitative Criminology, 10*(4), 317-342.

U.S. Bureau of Labor Statistics. (2013). Local Area Unemployment Statistics: Newark-Union, NJ-PA Metropolitan Division. Retrieved July 28, 2013 from http://data.bls.gov/pdq/SurveyOutputServlet.

U.S. Census Bureau. (2013). State & County QuickFacts (Newark, NJ; and U.S.). Retrieved January 4, 2013, from http://quickfacts.census.gov/qfd/states/00000.html and http://quickfacts.census.gov/qfd/states/34/3451000.html

Zacharias, J., Stathopoulos, T., & Wu, H. (2001). Microclimate and downtown open space activity. *Environment & Behavior, 33*(2), 296-315.