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The Relationship Between Temperature and Crime on the Cape Flats of South Africa

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Abstract

This study examined associations between temperature and several categories of crime in two diverse township communities on the Cape Flats of South Africa, namely Nyanga and Manenberg. Analysis of variance (ANOVA) is initially used to identify whether there are significant differences in the mean amount of daily crimes (murder, assault, robbery, and rape) by season. Next, multiple regression analysis is used to determine whether any statistically significant relationships exist between temperature and crime at the daily level while controlling for a number of confounders. Overall, we found evidence that increasing temperature is associated with an increase in the magnitude of assault crimes at both the seasonal and daily level. However, most of the results for murder, robbery and rape were non-significant and/or inconsistent across the two township communities. It is anticipated that through the results of this research we can develop a better understanding of crime on the Cape Flats of South Africa, and in doing so, make a small but meaningful contribution in attempting to alleviate and prevent this scourge.

Keywords: Seasonality, Temperature, Crime, Violence, Cape Flats, South Africa.

1. INTRODUCTION

South Africa has made considerable progress in consolidating democracy and fostering a non-racial society since the demise of apartheid in 1994. There are, however, a number of obstacles that the country still needs to overcome in order for residents of South Africa to truly achieve a better quality of life for all. Chief among them is crime. Post-apartheid

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South Africa remains plagued with the devastatingly high rates of crime, and violent crime in particular. Indeed, the country has one of the highest murder rates in the world with roughly 57 people murdered every day (South African Police Services (SAPS), 2019). This equates to a murder rate of approximately 35 per 100 000 population, substantially higher than the global average of around 6.2 per 100 000 population (UNDOC, 2013). A total of 162,012 assaults were recorded in 2018/19, an increase from 156,243 the year before. On average, 444 people are victims of this type of assault every day (SAPS, 2019). In addition to murder and assault, the rate of sexual assaults and robberies in South Africa also rate among the highest in the world (UNDOC, 2013).

The causes of crime in the country are multifaceted and complex. Societies going through a transitional period are often characterised by high crime rates, especially in countries distinguished by high levels of inequality, as is the case in South Africa (see e.g., Breetzke, 2012; Shaw, 2002). In addition to these transitional challenges, there are a number of additional factors that have been found to contribute towards crime in the country such as inequality (see Demombynes & Özler, 2005), poverty and unemployment (Seedat et al., 2009), alcohol and drug abuse (Maree, 2003) and the availability of firearms (see e.g., Perry & Potgieter, 2013). The frequency of crime has also been shown to increase in settings where there is an unequal distribution of resources coupled with a lack of faith in, and the weakening of, institutional controls such as the policing and judicial systems (see e.g., Pillay, 2008).

Importantly however crime in the country is not evenly distributed with crime most often concentrated in and around major cities such as Durban, Johannesburg, and Cape Town (see e.g., Breetzke, 2012; Schönteich & Louw, 2001). Cape Town in particular now ranks among the most violent and dangerous cities in the world (Conway-Smith, 2019). Even within Cape Town however, crime has been found to be spatially clustered (Breetzke & Edelstein, 2019) with occurrences most often concentrated in poor communities and townships situated on the outskirts of the city, particularly in an area known as the Cape Flats (see e.g., Breetzke & Edelstein, 2019; Standing, 2003). The Cape Flats is an expansive, low-lying, flat area situated approximately 30 kilometres to the southeast of the central business district (CBD) of Cape Town. This region of greater Cape Town has a history profoundly shaped by the legacy of apartheid-era's spatial urban planning policy which prioritized the development and servicing of former whites-only neighbourhoods in the urban core while neglecting the so-called township areas most often located on the urban periphery. As a result residents on the Cape Flats were, and continue to be, burdened by high levels of poverty, unemployment, and most importantly, crime (see e.g., de Swardt et al., 2005; Bowers du Toit, 2014). In fact, crime on the Cape Flats became so dire that in July 2019 the South African National Defence Force (SANDF) were deployed to the area in an operation known as 'Operation Lockdown' in an effort to suppress and prevent the recent spate of violent crime affecting the communities.

Although some research has been done examining the nature and magnitude of crime on the Cape Flats of South Africa, very little is known about how crime in these communities is impacted by climatic conditions. The main aim of this research is to determine if there is an association between temperature and crime in two separate diverse township communities on the Cape Flats, namely Nyanga and Manenberg. Specifically,

we are interested in examining whether the magnitude of crime changes depending on temperature recorded at a number of temporal resolutions and seek to identify whether these trends are consistent across both communities.

This study is important for a number of reasons. First, given the persistent issue of crime in South Africa in general and on the Cape Flats specifically, there is a real need to better understand underlying trends and associations of crime in order to effectively address the problem. Second, over the past century there has been a growing interest to determine how environmental factors such as weather and climate influence different types of crime (see e.g., Anderson, 1989; Baron & Bell 1976; Hipp & Bauer, 2004; Linning et al., 2017; McLean, 2016). The results of this study will add to the existing literature and further our understanding of how temperature is associated with crime in a unique post-apartheid township setting. Third, given the ongoing threat and uncertainty of climate change's impact on communities and the growing empirical evidence indicating significant associations between increasing temperatures and violent crime (see e.g., Gamble & Hess, 2012; Hsiang & Burke, 2013; Mares, 2013), it is important to further our understanding of the potential links between increasing temperatures and crime in the South African context. Last, the results of this study could potentially have positive implications for practice and policy makers tasked with reducing crime in Nyanga and Manenberg. Results could allow these stakeholders to more accurately predict when and under what climatic conditions specific crimes are more likely to occur, with the hope of reducing crime in township communities throughout the Cape Flats.

The rest of the paper proceeds as follows. We first provide a brief overview of the two most common theories used to explain the nature of the relationship between temperature and crime before we outline the geographical focus area for this research. Next, we provide information on the data we employed and the methods used before we describe our analysis and highlight our results. Our discussion concludes.

2. THEORETICAL FRAMEWORK

2.1 The Temperature/Aggression (T/A) theory

The temperature-aggression (T/A) theory (Quetelet, 1842) is commonly used to explain the nature of the relationship between temperature and crime. The theory motivates that uncomfortably hot temperatures increase the discomfort and frustration levels of individuals leading to more aggressive behaviour and, ultimately, more violent crime. T/A theory emphasizes the physiological effects of increasing temperatures on the human body which are likely to lead to increased aggression. Several different versions of the T/A theory have emerged over the years (see e.g., Anderson et al., 1995; Baron & Bell, 1976; Zillman, 1983), which differ mainly in terms of the underlying curve characterising the nature of the relationship between temperature and aggression. For example, some scholars advocate for a linear relationship between temperature and crime (see e.g., Anderson & Anderson, 1998) whilst others motivate for a curvilinear effect (see e.g., Rotton & Cohn, 2000; Stevens et al., 2019). With a few notable exceptions, the general consensus among scholars is that violent crime does increase with an increase in temperature although the degree to which crime increases is much dependent on the

geographical locations under investigation and the associated socioeconomic characteristics (amongst others).

The T/A theory and its variants have been extensively used to account for associations between temperature and crime. Early laboratory evidence (see e.g., Baron, 1972; Baron & Bell, 1976) found an increase in aggressive behaviour with an increase in temperature in the United States (US). Later Rotton and Cohn (2003) examined the effect of temperature on assault and homicide across the whole of the US between 1950 and 1999. Overall they found that years which experienced higher average temperatures exhibited higher assault rates, indicating that temperature is positively associated with assault. More recently, in Cleveland, Ohio, Butke and Sheridan (2010) examined the influence of temperature on aggressive crime at the city-wide level in the US while controlling for seasonality, weekday, and time of day. Results also showed that aggressive crimes peaked in warmer summer months and reached a minimum in winter. Gamble and Hess (2012) also found a positive relationship between temperature and aggravated crime up to a mean daily temperature of 27°C (80°F), after which crime starts to level off and in fact decreases beyond 32°C (90°F); in this instance, providing some support for the curvilinear effect.

Outside of the US several studies have used the T/A theory as the basis to examine the relationship between temperature and crime. In Brazil Ceccato (2005) found considerable evidence for seasonal variation of homicide in Sao Paulo. The researcher found more homicides take place in warm summer months than in colder winter months. In Santiago, Chile, Téllez et al. (2006) found sexual abuse to be seasonal, with the highest incidences occurring in spring (November) and the lowest in winter (June). In China, Hu et al. (2017) found a strong positive relationship between increasing temperatures and violent crime on a monthly level while in Australia, Stevens et al. (2019) found assault to be seasonal with roughly 18% more assaults occurring in summer than winter. At the daily level, their results also showed that assault counts significantly increased with temperature.

Locally, Collings (2008) assessed seasonal variations in child rape in Kwazulu-Natal and found that child rape peaked during the summer months and reached their lowest levels during winter while Breetzke and Cohn (2012) investigated seasonal assault and neighbourhood deprivation in Tshwane and also found evidence of seasonality for violent crime, with cases of assault reaching a maximum during summer and a minimum during winter. More recently Schutte and Breetzke (2018) examined the influence of temperatures on violent and sexual crime incidences in Tshwane and found some support for the T/A theory, with significantly higher rates of violent and sexual crimes occurring on warmer days compared to 'cold' or 'normal' days.

2.2 The Routine Activities (RA) theory

The routine activities (RA) theory of Cohen and Felson (1979) offers a more sociological approach to explaining the association between temperature and crime. RA theory was developed as a more general theory of criminality and postulates that crime patterns shift with changing opportunity patterns which are ultimately driven by people's daily activities (Mares, 2013). The theory focuses on opportunities and risks and is based on the notion that in order to understand criminal behaviour, one must first understand how individuals routinely use their time. According to the RA theory individuals generally follow strict daily, weekly, and even monthly routines, which affects

opportunities for different crime to occur (Brunsdon et al., 2009). While some of these activities are compulsory with a fixed duration (such as school or work), others are more flexible/discretionary (such as socialising on weekends or leisure holidays) and leave individuals with a greater amount of choice as to when or where they will occur. The theory motivates that environmental factors such as temperature can play a role in determining how individuals choose to spend their time. Certain temperature ranges are predicted to promote conditions favourable for crime, while other temperature ranges can lead to decreased risk of crime. For instance, on a cold, rainy winter's day in Cape Town individuals are more likely to stay at home. As more people choose the comfort and safety of their houses, the amount of contact between potential victims and motivated offenders outside on the streets are reduced leading to fewer opportunities for interpersonal violence to occur, therefor decreasing interpersonal crime rates. In contrast, on a warm sunny day people are more likely to engage in social and recreational activities (like going to public parks and malls, restaurants and bars, sporting and entertainment events and family gatherings). Temperatures that promote the increased concentration of people increase the risk associated with interpersonal violent crime in particular. This is largely due to the fact that there is significantly more contact between motivated offenders and potential victims. Climatic and meteorological variables (such as temperature) therefore undoubtedly play a role in how, where and when individuals choose to spend their time. They therefore have some influence over the routine activities of individuals and can in turn be used to account for crime trends.

The RA theory has been used extensively to explain associations between temperature and different crime types in a variety of contexts including the US (see e.g., Cohn & Rotton, 1997; Cohn, 2000; Hipp & Bauer, 2004), Brazil (Ceccato, 2005), the United Kingdom (UK) (McLean, 2006), Canada (Linning et al., 2017), and South Africa (see e.g., Collings, 2008; Cohn & Breetzke, 2017; Schutte & Breetzke, 2018). In the US, Cohn and Rotton (1997) used the RA theory to examine the nature of the relationship between temperature and assaults at three-hour time intervals in Minneapolis and found fewer assaults were reported to the police during working hours (09:00 am – 15:00 pm) than during other hours of the day. The researchers concluded that this was simply because more people are engaged in obligatory activities during that time interval. In accordance with RA theory, their results showed that people are much more likely to be assaulted when the majority of people are engaged in discretionary activities (e.g., relaxing, socialising, attending sporting and entertainment events) during evening hours, weekends and during the warmer summer months. In South Africa Cohn & Breetzke (2017) found that violent crime in Tshwane peaked roughly every 7 and 75 days over a five-year study period. The largest peaks in violent crime were found to occur every 5-7 days. The authors explained this peak by highlighting the fact that during weekends people are more likely to be socialising and interacting with each other, thus increasing the risk of violent crime opportunities, in line with the RA theory.

One drawback to RA theory is in its ability to fit almost any pattern of results. For example, Cohn and Rotton (2000) used the RA theory to explain summer robbery peaks, while Landau and Fridman (1993) used the RA theory to explain winter robbery peaks. In this sense the results are used to fit the theory, rather than the theory used to interpret the results. Such contradictory predictions are due to the theory's flexibility, which makes it

compatible with multiple outcomes. Most of the research that has relied on RA theory has therefore used it to organise findings, not as a source of falsifiable hypotheses (McDowall, Loftin & Plate, 2011). Nonetheless and for the purposes of this study, it is still expected that that the magnitude of crime will increase during warmer seasons and days due to warmer weather facilitating a higher concertation of people leading to increased social interaction which leads to increased opportunities for interpersonal violence to occur.

3. GEOGRAPHICAL FOCUS AREA

The geographical focus area for this research are two township communities located on the Cape Flats of South Africa, namely Nyanga and Manenberg. Nyanga is one of the oldest and largest black African townships on the Cape Flats and covers a small area of approximately 3.09 km^2. According to Statistics South Africa (2011), Nyanga has a population of 57,996 people, of which almost all residents are black African (99%). The township is impoverished with a staggering 45% of residents unemployed and roughly three quarters of households earning less than R3200 (± US$225) per month. Nyanga has gained a reputation as being South Africa's perennial murder capital, with 308 murders reported in the township in 2018/2019 (Institute for Security Studies, 2019). This equates to a murder rate of roughly 179 per 100 000 population. In addition to murder, there were 1040 common assaults, 1646 aggravated robberies and 210 rapes reported in this small township during 2018/2019 (CrimeHub, 2018).

Manenberg covers a slightly larger area (3.35 km^2) than Nyanga and also has a larger number of population (n = 61,615 inhabitants). Similar to Nyanga, Manenberg has high unemployment (36%) with roughly 61% of households earning less than R3200 (± US$225) per month. Unlike Nyanga however the population in Manenberg is predominantly Coloured (85%) and the dominant language is Afrikaans. One of the most defining features of Manenberg is the organised crime and gangsterism prevalent in the township (Pinnock, 2016). Criminal gangs in Manenberg have substantial power over the community and their presence is widely felt (see e.g., Mullagee & Bruce, 2015). Indeed, criminal gang activity has become increasingly institutionalised with residents having little faith in the ability of the police to maintain law and order (Lambrechts, 2012). Generally, crime rates in Manenberg are slightly lower compared to Nyanga however violent crime rates in this township is still considerably higher than national averages. During 2018/2019 there were 61 murders, 562 common assaults, 280 aggravated robberies and 65 rapes reported (CrimeHub, 2018).

4. DATA AND METHODS

4.1 Climate data

Climate data was obtained from the South African Weather Service from 1 January 2007 to 31 December 2014 (eight calendar years). The data included daily temperature observations in degrees Celsius (°C) from the Cape Town International Airport weather station (33.9630° S, 18.6020° E) which is the closest weather station to either township. Descriptive statistics for the temperature for both townships over the study period are provided in Table 1.

Table 1. Mean daily temperature (°C) statistics for Nyanga and Manenberg (2007-2014)

	Mean	Mean	Max	SD
Overall	7.5	17.3	29.9	4.2
Seasonal				
Winter	7.5	13.0	20.1	2.0
Spring	9.4	16.6	24.7	3.0
Summer	13.1	21.8	29.3	2.2
Autumn	10.0	18.1	29.9	3.4

Over the eight-year study period both townships experienced an overall mean daily temperature of 17.3°C. Distinct temperature variations were observed between the different seasons with winter experiencing the coldest mean daily temperature, followed by spring, autumn, and summer.

4.2 Crime data

Crime data for this study was obtained from the SAPS. The data included the x and y location, type of crime, and the date and time at which the offence occurred for both Nyanga and Manenberg from 2007 to 2014. From this dataset we extracted murder (n = 1636), assault (n = 8206), robbery (n 3583), and rape (n = 1189) offences. The selection of these four crime types was driven largely by the fact that we were interested to determine whether these different types of interpersonal violent crime exhibit similar relationships with temperature in the two townships. Descriptive statistics for the crime data are provided in Table 2.1 (Nyanga) and Table 2.2 (Manenberg) below.

A total of 916 and 720 murders were committed in Nyanga and Manenberg respectively over the eight-year study period. Assault accounted for most of the crime in each community with 3511 assaults reported in Nyanga and 4695 assault case reported in Manenberg. Rape was the lowest reported crime committed with only 602 incidences reported in Nyanga and 587 cases reported in Manenberg. There were 2057 and 1526 robberies reported in Nyanga and Manenberg respectively Seasonally, murder was the highest during autumn and the lowest during summer in Nyanga, while in Manenberg murder was the highest during winter and the lowest during autumn. Interestingly, and in contrast to the expectations of both the T/A theory and RA theory, murder in both townships was higher during winter. More predictably, assault peaked during summer and reached a minimum during winter in both townships. Robbery in Nyanga was highest during spring and lowest during summer, while in Manenberg robbery was highest during winter/autumn and reached a minimum during summer. Rape was highest during summer and lowest during winter in Nyanga, while in Manenberg rape peaked during spring and reached a minimum during winter. Of course, it is well-known that crime, and especially sexual crime, is notoriously under-reported in South Africa (see Breetzke 2006), and potentially even more so in township communities which have essentially lost all confidence in the police. While unfortunate, these problems are simply a reality in the country with little possibility of recourse. The data are, however, official and the most spatially replete data available with which to conduct analysis and draw inferences.

Table 2.1 Descriptive statistics of daily counts of murder, assault, robbery, and rape in Nyanga (2007-2014)

	Murder		Assault		Robbery		Rape	
	n	Mean	n	Mean	n	Mean	n	Mean
Overall	916	0.31	3511	1.20	2057	0.70	602	0.21
Season								
Winter	239	0.33	759	1.03	526	0.72	108	0.15
Spring	225	0.31	939	1.29	532	0.73	173	0.24
Summer	259	0.35	801	1.09	504	0.69	141	0.19
Autumn	193	0.27	1012	1.40	495	0.69	180	0.25

Table 2.2 Descriptive statistics of daily counts of murder, assault, robbery, and rape in Manenberg (2007-2014)

	Murder		Assault		Robbery		Rape	
	n	Mean	n	Mean	n	Mean	n	Mean
Overall	720	0.25	4695	1.61	1526	0.52	587	0.20
Season								
Winter	208	0.28	1025	1.39	441	0.60	119	0.16
Spring	179	0.25	1152	1.58	341	0.47	180	0.25
Summer	146	0.20	1098	1.49	440	0.60	116	0.16
Autumn	187	0.26	1420	1.97	304	0.42	172	0.24

4.3 Analysis

Two main analytical methods were used in this study. First, analysis of variance (ANOVA) was used to determine if there are statistically significant differences in the mean daily crime counts observed during different seasons. Second, multivariate regression analysis was carried out in order to examine associations between mean daily temperatures and crime counts, while controlling for several confounding variables. A total of four models were developed, one for each type of crime (murder, assault, robbery, and rape). The dependent variable in all regression models is the daily crime counts. The independent variable (variable of interest) in the regression analyses is the mean daily temperature, averaged over 24 hours. Importantly, we included a number of covariates that may confound the relationship between temperature and crime. These variables have previously previously been shown to exhibit an association between temperature and crime both locally and internationally (see; Breetzke, 2015; Cohn & Rotton, 2003; Felson & Poulsen, 2003; Schutte & Breetzke, 2018) and include the mean daily precipitation, month of the year, day of the week, public holidays, and school holidays. Importantly, seasonality was not accounted for directly but rather indirectly by controlling for month of the year because all months correspond to a specific season. Similarly, public and school holidays were only accounted for at the daily level, mainly because these days occur during the same month every year and it is not necessary to account for them independently. The problem of seasonality was addressed by including dummy variables to

control for months of the year, and hierarchical regression was employed to control for the possibly confounding effects of rainfall. Dummy variable (1,0) coding was also used to assess differences between public and school holidays and other periods. Table 3 below show descriptive statistics for all variables used in the regression models.

Table 3. Descriptive statistics for all variables used in the multivariate regression models in Nyanga and Manenberg

	Nyanga				Manenberg			
	Min	Mean	Max	SD	Min	Mean	Max	SD
Dependent variables								
Murder, count	0	0.31	7	0.62	0	0.25	6	0.60
Assault, count	0	1.20	11	1.36	0	1.61	8	1.41
Robbery, count	0	0.70	5	0.87	0	0.52	5	0.76
Rape, count	0	0.21	7	0.52	0	0.20	5	0.48
Independent variable								
Mean daily temperature, °C	7.5	17.35	29.9	4.17	7.5	17.34	29.9	4.17
Confounding variables								
Total daily precipitation, mm	0.0	1.42	49.2	4.25	0.0	1.41	49.2	4.25
Public holidays, dummy	0	0.02	1	0.13	0	0.02	1	0.13
School holidays, dummy	0	0.16	1	0.37	0	0.16	1	0.37
January – December, dummy	0	0.08	1	0.28	0	0.08	1	0.28
Monday – Sunday, dummy	0	0.14	1	0.35	0	0.14	1	0.35

5. RESULTS

Table 4 shows the results of an ANOVA used to assess whether the differences in mean daily crime by season observed in Table 2.1 and Table 2.2 were significant. In both townships there was no significant difference in murder counts during summer, winter, autumn, or spring, contrary to expectations. In both communities assault was found to be significantly higher during summer compared to winter, as expected. No significant difference was found between seasons for robbery in Nyanga, while in Manenberg there were significantly more robbery reports during winter compared to summer; again, contrary to expectations. In terms of rape, statistically significant differences were found in both townships. In Nyanga there were significantly more rapes reported during summer compared to winter, while in Manenberg rape peaked in spring and reached a minimum during winter/autumn. These results of the ANOVA suggest that some types of crime are influenced by varying seasonal temperatures, however the magnitude and direction of association often varies between crime types and are, at times, opposite to what would typically be expected based on the T/A and RA theories.

Table 4. Results of ANOVA

	Nyanga				Manenberg			
Crime	Mean	df	F	Sig.	Mean	df	F	Sig.
Murder		3	2.35	0.07		3	2.58	0.05
Winter	0.33				0.28			
Spring	0.31				0.25			
Autumn	0.35				0.20			
Summer	0.27				0.26			
Assault		3	11.93	0.00***		3	23.43	0.000***
Winter	1.03				1.39			
Spring	1.29				1.58			
Autumn	1.09				1.49			
Summer	1.40				1.97			
Robbery		3	.45	0.69		3	10.63	0.000***
Winter	0.72				0.60			
Spring	0.73				0.47			
Autumn	0.69				0.60			
Summer	0.69				0.42			
Rape		3	5.91	0.00**		3	7.27	0.000***
Winter	0.15				0.16			
Spring	0.24				0.25			
Autumn	0.19				0.16			
Summer	0.25				0.24			

NOTE: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; Nonsignificant results are excluded for each ease of interpretation

Table 5.1 (Nyanga) and Table 5.2 (Manenberg) below provide the results of the multivariate regression analyses. Overall the models performed poorly with all models exhibiting adjusted-R^2 values of less than 23 percent. In Nyanga the level of prediction ranged between roughly one percent and 22% and in Manenberg between one percent and eight percent. More encouragingly, a positive and statistically significant relationship was found for daily temperature and murder (in Manenberg) and for assault (in both Nyanga and Manenberg). This provides some initial indication that daily temperatures may play a small but contributing role in the commission of these two types of offences in both townships although the low overall performance of the models indicates that this role is most likely tangential. No significant association was found for daily temperature and robbery and rape in either location. Regarding other results, we found a positive and significant relationship with precipitation and robbery in Nyanga and a number of positive relationships between crime and public holidays in both townships. Only two significant relationships were found to occur with crime and school holidays – for murder in Nyanga (positive), and for robbery in Manenberg (negative). No general trend was observed for months of the year for any crime type in both townships although there were a few significant associations; however Saturdays and Sundays were associated with significant increases in murder, assault, robbery (except in Manenberg) and rape in both communities. The poor performance of these models could be indicative of the influence

of the harsh socioeconomic conditions within these communities (historic inequality, poverty, unemployment, poor education, substance abuse, gangs, political unrest etc) and future research should attempt to control for such factors when examining the influence of temperature on crime.

Table 5.1 Results of regression analyses for Nyanga .

	Murder	Assault	Robbery	Rape
Temperature, mean		0.03*		
Precipitation, count			0.01*	
Public holidays		0.84***		0.15*
School holidays	0.08*			
January	-0.14*			
February	-0.14*			
March				
April		-0.27*		
June				
July				
August				
September				
October				
November		0.28*		0.10*
December				0.15*
Monday		0.26*		
Tuesday				
Thursday				
Friday	0.12*	0.41***	0.14*	
Saturday	0.26***	1.54***	0.19*	0.18***
Sunday	0.34***	1.48***	0.13*	0.19***
F statistics	6.78***	40.44***	2.02*	5.94***
Adjusted R2	0.04	0.23	0.01	0.03

NOTE: 'May" and 'Wednesday" were excluded for reference; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 5.2 Results of regression analyses for Manenberg.

	Murder	Assault	Robbery	Rape
Temperature, mean	0.02**	0.05***		
Precipitation, count				
Public holidays	0.19*	0.45*		0.27***
School holidays			-0.09*	
January				0.11*
February				
March		-0.27*		
April				
June				
July	0.25***			

August	0.18**			
September				
October			-0.17*	0.13**
November			-0.19*	0.16***
December			-0.23*	0.13*
Monday	0.10*	0.23*		
Tuesday				
Thursday				
Friday				
Saturday	0.12*	0.66***		0.13***
Sunday	0.14**	0.7***	-0.15*	0.10**
F statistics	3.24***	13.39***	2.91***	3.38***
Adjusted R2	0.02	0.08	0.01	0.02

NOTE: 'May" and 'Wednesday" were excluded for reference; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

6. DISCUSSION

Associations between temperature and murder have often produced inconsistent findings (see e.g., Rotton & Cohn, 2003; Hipp & Bauer, 2004; Ceccato, 2005; Butke & Sheridan, 2010; Gamble & Hess, 2012). Like this previous research, we also failed to find any consistent association between murder and temperature across the two study areas. Positive and significant associations were found for murder in Manenberg at the daily level but not at the seasonal level. No significant association was observed in Nyanga. These findings are against expectations derived from the T/A and RA theories and indicate that temperature does not have a consistent significant influence over murder in the two township communities. It is possible that frustration and aggression brought about by increasing temperatures are not sufficient to increase the risk of extreme violence in the form of murder, at least in Nyanga. It is also likely that the harsh socioeconomic conditions within these communities which are present all year round (i.e., historic inequality, poverty, unemployment, poor education, substance abuse, gangs, political unrest etc.) have a much stronger influence over murder trends, rendering the influence of temperature almost negligible.

In terms of assault, results were more encouraging with positive and statistically significant results obtained for temperature in both communities. Positive associations between temperature and assault have largely been observed in previous literature (see e.g., Rotton & Cohn, 2003; Butke & Sheridan, 2010; Breetzke & Cohn, 2012; Stevens et al., 2019). This study also found considerable evidence for similar associations between temperature and assault. In both Nyanga and Manenberg assault was found to be seasonal, with a peak during summer and a minimum during winter. Moreover, mean daily temperature was also associated with an increase in assault in both communities. This increase in assault with an increase in temperature is supported by the T/A and RA theories which predicted higher levels of interpersonal crime during warmer periods of time. In terms of the T/A theory these results support the notion that warmer weather cause increased frustration and anger which reduces an individuals' tolerance for annoyances that otherwise might be dismissed, which may result in an increase in assaults.

In terms of the RA theory, the results support the notion that warmer weather in these communities may change the routine activities of individuals in such a way that creates favourable opportunities for interpersonal contact and concomitantly, increase the risk of crime.

Similar to murder, the relationship between temperature and property crimes such as robbery have generally been conflicting in previous research (see e.g., Mares, 2013; Rotton & Cohn, 2003; Sorg & Taylor, 2011). Similarly, in this study we found a lack of association between temperature and robbery in both communities. At the daily level there was no association between mean daily temperature and robbery in either community. In Nyanga robbery did not differ significantly by season, however in Manenberg robbery was seasonal, but the peak was observed during winter rather than summer. Explaining this trend is problematic because it is contradictory to the predictions derived from the T/A and RA theories. One possible reason for this finding could be that the longest school holiday occurs during summer. Considering that the population is very poor, one can assume that fewer families go away on leisure school holidays. This will result in many more people (especially children) out on the streets that can act as capable guardians against property crime. This explanation is supported by the fact that robberies also decreased significantly during school holidays in Manenberg. Nonetheless, results of this study suggest that increased temperatures are not associated with increased robberies. The general lack of association between temperature and robbery in these communities could be due to a number of reasons. The high unemployment and poverty in both communities could play a role. Due to a large percentage of the population being unemployed it could be that the routine activities of many individuals differ from other more 'traditional' neighbourhoods where unemployment levels are lower. For example, if a large percentage of a population is unemployed, more people are available to engage in social interactions than in a community where unemployed levels are lower. This increased social interaction could increase guardianship of properties lessening temperature's effect on property crime in general. It could also be that robbery events in both communities are not specifically related to the tenets of frustration and aggression purported by the T/A theory. In locations of extreme poverty, the motivation behind robberies may be to acquire personal property and/or cash which can be used for self-sustenance. In such instances the increased frustration/aggression brought about by warmer temperatures may not play such as significant role. This assertion is supported by Sorg and Taylor (2011) who found temperature's influence to be much stronger felt in communities with a higher socioeconomic status compared to communities with a low socioeconomic status.

The results for rape were also inconsistent between communities. Seasonally the magnitude of rape was found to be higher during summer compared to winter in Nyanga, like expected. In Manenberg however rape peaked during spring and reached minimum during winter and autumn. The regression analysis however failed to find any significant association between rape and temperature at the daily level. This general lack of association could be due to several reasons. First, the high unemployment and poverty could lead to alterations in people's routine activities which could lead to different temporal risk factors for rape. If for example a significant proportion of the population are unemployed this can result in an increase in social interaction and the amount of people

coming into contact with one another on a daily basis. Temperature variations will then not have such a big influence over the number of social interactions that occurs on a daily basis, and as a result rates of rape remain fairly constant regardless of temperature. High unemployment can also lead to more people being able to act as guardians against defence of rape as more people are able to witness the crime taking place, causing a perpetrator to think twice before committing a rape. Second, rape statistics are notoriously underreported in South Africa. Given the political history on the Cape Flats, the animosity between police and the general public in these communities is exacerbated. This non-cooperation tendency between the public and the police certainly results in extreme underreporting or even non-reporting of rapes. The lack of reporting could be responsible (or at least partly responsible) for the lack of association between rape and temperature, as the data obtained on rape is likely much less in magnitude than what actually occurred. Additionally, rapes are often not reported immediately after or even close to the time period when it actually occurred. It may take hours, days or even weeks for victims to actually summit the courage to report the crime, which could have had an impact on the results. Finally, it could also be that the central tenents of the TA theory does not necessarily apply to sexual crimes because these crimes are not necessarily motivated by anger and frustration brought about by heat.

This study is not without limitation. The first and most notable limitation relates to the accuracy and precision of reported crime statistics obtained from the SAPS (see e.g., Breetzke, 2006). While most official crime data globally should be treated with a degree of caution, in South Africa this issue is exacerbated given the recent political history of the country (Edelstein & Arnott, 2019). As previously mentioned however the data available to us is the only official and spatially replete source of crime data available in the country. Second, we did not account for underlying socio-demographic and socio-economic factors that may play a role in the facilitation of these four crime types. Indeed, it could be that the increase in crime during certain time periods may not be related to temperature itself but could simply be a criminogenic manifestation of the broader built, social, economic, political, and cultural environment. In this study we did not control for the so-called underlying environmental backcloth. This concern is valid; however, much like previous research of this nature the focus of our study was to examine the relationship between temperature specifically and crime. Some evidence was found that this meteorological parameter does indeed have a role to play in crime occurring in these communities. Future research could attempt to integrate additional socio-demographic factors into more advanced statistical techniques and determine their interaction with crime and temperature. Third, we failed to account for the time-lag effects often associated with data collected over time. Time-lagged effects are changes in overall crime levels that occur naturally over time due to a variety of different factors. The most effective way to address time-lagged effects on time series data is to employ a time-series method, such as ARIMA (autoregressive integrated moving average). ARIMA models are used in time-series data where non-stationarity are assumed (i.e. the dependent variable are not constant over time). Time series models are however more effective when examining trends over much longer time periods. Considering that the time period of this study is only eight years, it was decided to make use of multivariate regression instead of time series decomposition. Moreover, past research has successfully used regression models

to examine the impact of temperature on crime over similar time periods (see e.g., Hu et al., 2017; Stevens et al., 2019). A final limitation of this research is that we did not incorporate any spatial component in our analysis. It could be, for example, that when temperatures rises, so too does crime, but not uniformly and only within certain neighbourhoods of Nyanga and Manenberg. It has recently been shown that within township communities crime also clusters in specific areas or 'hotspots' (see e.g., Edelstein & Arnott, 2019; Edelstein et al., 2020). Future research could aim to tease out the nature of the relationship between temperature fluctuations and changing spatial crime patterns within Nyanga and Manenberg.

7. CONCLUSION

The main aim of this research was to determine if different categories of crime were associated with temperature and to contrast these findings between two township communties on the Cape Flats of South Africa. Overall the results suggest that temperature is associated with certain types of crime (i.e. assault) but not with most others (i.e. murder, robbery and rape). Results also showed that associations were largely similar between communities for the same crime types. In achieving the results of this research, we believe that we have made a number of unique contributions. First, this study contributes to the existing literature examining associations betweeen temperature and crime by being one of the first to investigate and compare temperature associations with crime on the Cape Flats. The study provides empirical evidence for associations between specific crime types, most notably assault, and temperature on the Cape Flats. This evidence can and should be used to more effectively address and police crime in these communities. Second, this study provides arguments for, and against, the use of the T/A and RA theories in a South African context. Our results show that certain proponents of the T/A theory does not equally apply to all types of interpersonal violent crime. The results indicate that hypotheses derived from the T/A theory are the most accurate for assault and somewhat for rape, but not necessarily for murder or robbery. This study also demonstrates that the RA theory can be a valueable tool in interpreting and understanding crime results in the South African context, but should not neccesarily be used as a source of falsifiable hypotheses, mainly because the RA theory is often compatible with multiple outcomes. Third, this research provides increasing support for evidence-based policing. This type of policing argues that in order for police to more effectively reduce crime, they must make use of the most up to date and accurate crime data and feed the knowledge obtained from the analysis of this data into their tactical, operational and strategic processes. The SAPS should acknowledge that accurate crime data is critically important and necessary in order to address the crime situation on the Cape Flats more effectively. Indeed, constant monitoring and analysing of crime data should be a priority for the SAPS. In doing so, an organisational culture can be fostered in which empirical knowledge sharing is encouraged which could lead to a concominant reduction in crime, particularly in high risk communities that need it the most.

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