

ALCOHOL OUTLET DENSITY AND VIOLENCE: A GEOSPATIAL ANALYSIS

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Abstract — Aims: To examine the relationship between alcohol outlet density and violent crime controlling for neighbourhood sociostructural characteristics and the effects of spatially autocorrelated error. **Design:** The sample for this ecologic study comprised 188 census tracts from the City of Austin, Texas and 263 tracts from the City of San Antonio, Texas. Data pertaining to neighbourhood social structure, alcohol density and violent crime were collected from archival sources, and analysed using bivariate, multivariate and geospatial analyses. **Results:** Using ordinary least squares analysis, the neighbourhood sociostructural covariates explained close to 59% of the variability in violent crime rates in Austin and close to 39% in San Antonio. Adding alcohol outlet density in the target and adjacent census tracts improved the explanatory power of both models. Alcohol outlet density in the target census tract remained a significant predictor of violent crime rates in both cities when the effects of autocorrelated error were controlled for. In Austin, the effects of alcohol outlet density in the adjacent census tracts also remained significant. The final model explains 71% of the variance in violent crime in Austin and 56% in San Antonio. **Conclusions:** The findings show a clear association between alcohol outlet density and violence, and suggest that the issues of alcohol availability and access are fundamental to the prevention of alcohol-related problems within communities.

INTRODUCTION

With the dramatic increase in violent crime that occurred in the USA during the past four decades and the apparent inability of traditional criminal justice approaches to deal with this, the problem has increasingly come to be considered as one that is amenable to epidemiological understanding and public health interventions (Koop and Lundberg, 1992; Farrington and Loeber, 2000). At the same time, criminological research has broadened its perspective from a primary focus on punishment of individuals by rediscovering the scholarship of sociologists from the 1940s and 1950s on the ways in which the physical and structural characteristics of local environments encourage and facilitate violent crime (Skogar, 1990; Brantingham and Brantingham, 1993). This dual movement away from considering violence as entirely the result of individual characteristics has led to an increased emphasis on how aspects of the built environment influence its occurrence (Bottoms and Wiles, 1997).

One aspect of the built environment that has received increased attention in recent years has been the location and concentration of alcohol outlets, especially in urban neighbourhoods (Lipton *et al.*, 2003). Much of the early research in this area was limited by statistical weaknesses and a reliance on aggregated datasets pertaining to large units of analysis such as states and counties (Gruenewald, 1993; Stockwell and Gruenewald, 2001). The statistical weaknesses arose from the failure of ordinary least squares analyses to account for spatial autocorrelations that can bias statistical estimates of effects and lead to either Type I (in the case of positive spatial autocorrelation) or Type II (in the case of negative spatial autocorrelation) errors (Gruenewald *et al.*, 2000). Generalized least squares regression models that estimate and correct for residual spatial autocorrelation

between geographic units can be used to guard against such failures of unit independence (Griffith, 1988) and have been employed in some recent studies (Gruenewald *et al.*, 2000; Gorman *et al.*, 2001; Lipton and Gruenewald, 2002). In addition, it is now recognized that the relationship between alcohol availability and violence is best studied at a relatively small level of analysis, and most recent studies use cities or sub-divisions of these (e.g. census tract) as the geographic unit of analysis (Stockwell and Gruenewald, 2001; Lipton *et al.*, 2003).

The present study is intended to build on previous research, and specifically to address the following three issues. First, does the observed relationship between alcohol outlet density and violent crime exist within cities that are both larger than, and in a different part of the US, from those that have previously been studied? The foci of our study are the cities of Austin and San Antonio in the State of Texas, which had populations of 656 562 and 1 144 646, respectively, in 2000. Previous city-level studies have focused on places with populations (at the time that the studies were conducted) under 600 000, such as Camden, Cleveland and Newark (Roncek and Maier, 1991; Speer *et al.*, 1998; Gorman *et al.*, 2001). Only Scribner *et al.* (1999) and Costanza *et al.* (2001) have assessed the relationship between alcohol outlet density and violent crime in cities in the southern US. Second, what are the implications of using generalized least-squares analysis in assessing the relationship between alcohol outlet density and violent crime? Gruenewald and colleagues (1996, 2000) have described in detail the potential problems that emanate from the use of ordinary least square analysis in geospatial studies of the effects of alcohol availability. However, Scribner *et al.* (1999) have argued that the extent of the problems emanating from spatial autocorrelation have yet to be empirically demonstrated in this field of research. Our study will add to the small body of research that has addressed this issue. Third, is the relationship between alcohol availability and violence contingent upon specific neighbourhood context? For example, might the effect of alcohol outlet density be limited to relatively small geographic areas in some cities but be more

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diffuse in others, depending on systemic features such as sociodemographic composition and transportation networks (Stockwell and Gruenewald, 2001; Gorman *et al.*, 2004). In the present study we assess this primarily through an examination of the effects of alcohol outlet density and other covariates across geographic units.

MATERIALS AND METHODS

Study sites

The sample for this study comprised 188 census tracts from the City of Austin and 263 tracts from the City of San Antonio. Austin is the capital of the State of Texas and has a population of 656 562 according to the 2000 US Census. San Antonio is the third largest city in Texas and the eighth largest in the US, with a 2000 population of 1 144 646. Census tracts have been used as the unit of analysis in previous studies in this area of research (Lipton *et al.*, 2003), and are considered by some to be the most appropriate administrative boundary to use in assessing such neighbourhood effects (Krivo and Peterson, 1996). The boundaries for the tracts used in the study were those established for the 2000 US Census.

Data

Three datasets were employed in the study: one pertaining to alcohol availability, one to violent crime, and one to neighbourhood sociostructural characteristics. For the alcohol availability variables a list of active alcohol outlets in Austin and San Antonio was obtained from the website of the Texas Alcoholic Beverage Commission, 2000. Each record in the dataset included the name, geographic location and type of permit or license of the outlet. There were 1486 alcohol outlets in the City of Austin in 2000, and 2690 in the City of San Antonio. Each alcohol outlet record was geocoded by street address. Geocoding rates were very high in each of the cities — 100% for Austin and 99.5% for San Antonio.

Like most of its counterparts in other states, the Texas Alcoholic Beverage Commission employs a permit classification system that allows outlets to be distinguished by types of beverages sold and type of consumption allowed (specifically, off-premise versus on-premise). Indeed, the State of Texas employs a rather complex system of primary (e.g. 'mixed beverage') and secondary (e.g. 'food and beverage') licences; an outlet must have the former in order to obtain the latter. In addition, outlets can have more than one primary licence — for example, both a mixed beverage permit and a beer/wine retailer permit. Moreover, in some cases one of these permits may be for on-sale and the other for off-sale. In line with previous studies, analyses were conducted separately for on-sale only outlets, off-sale only outlets and combined on-/off-sale outlets, as well as for total outlet densities. Of the 1486 outlets in Austin, 486 (32.7%) were on-sale, 612 (41.2%) were off-sale, and 388 (26.1%) were combined on-/off-sale. In San Antonio, 610 (22.7%) of the total 2690 outlets were on-sale, 1113 (41.4%) were off-sale, and 967 (35.9%) were combined on-/off-sale. In the analysis, census tract densities were entered as outlets per 100 persons.

The violent crime data available for each city differed in respect to type of crime reported. Data pertaining to reports of

violent crime (murder, rape, robbery and 'aggregated assault' i.e. crimes involving an unlawful attack by one person on another for the purpose of inflicting severe bodily harm, usually through the use of a weapon) for the City of Austin were extracted from the website of the city police department. The Austin police department posts data pertaining to the occurrence of violent crime on a monthly basis. The data contained on the website are aggregated up to the census tract level, and are based on first reports of offences (that is, before investigation and final classification of crimes). Such call for assistance data have been used in previous studies of the relationship between alcohol availability and violent crime, and have strengths as well as limitations relative to official crime records (such as the state-level Uniform Crime Reports). Specifically, such data are subject to less refinement than are official records and are therefore considered to capture events that better reflect the 'criminogenic' nature of geographic locations (Sherman *et al.*, 1989; Nelson *et al.*, 2001). However, given that official data have been used in most previous studies, a comparison of the total reports of violent crime contained on the police department website for the year 2000 with the official total contained in the 2000 Uniform Crime Reports (Texas Department of Public Safety, 2001) was conducted. Interestingly, this showed that the former had 295 (9.6%) fewer crimes than the latter (2779 versus 3074). Most of this discrepancy was accounted for by differences in the aggregated assault category, in which there were 283 fewer cases in the website reports than the official Uniform Crime Reports (1683 vs 1400; 16.8%). There were just 24 fewer robberies contained in the website reports than in the Uniform Crime Reports (328 vs 352; 6.8%), while the former contained slightly more robberies than the latter (1018 vs 1006; 1.2%). The number of murders (33) contained in the website reports and Uniform Crime Reports were identical. Given the size of the discrepancy between the two data sources in the aggregated assault category, this was excluded from the analyses.

For San Antonio, violent crime arrest data for 2002 were obtained directly from the city police department. There were a total of 10 465 violent crimes for the year, of which 99 (0.9%) were murders, 527 (5.0%) rapes, 2221 (21.2%) robberies, and 7618 (72.8%) assaults. In the analysis, the census tract violent crime rate for both Austin and San Antonio was calculated as crimes per 100 persons.

Finally, data pertaining to 12 neighbourhood characteristics were extracted from Summary File 1 and Summary File 3 of the 2000 US Census (US Census Bureau, 2003). These variables, that were grouped under three broad headings, were chosen as they had been used in previous ecologic studies of alcohol availability and violent crime (Gorman *et al.*, 2001; Lipton and Gruenewald, 2002), as well as studies of violent crime in urban neighbourhoods (Peterson *et al.*, 2000). Of the 12 neighbourhood sociostructural variables, six were measures of concentrated disadvantage [percent families below poverty line, per cent families receiving public assistance, per cent unemployed individuals (16+) in civilian workforce, per cent female-headed households with children, per cent black, and per cent Latino], three were measures of residential instability (per cent residents over the age 5 years who have lived in the same house for 5 or more years, per cent homes that are owner-occupied, and per cent vacancy rate),

and three were sociodemographic measures of the resident population (adult : child ratio : ratio of adults (18 or older) to children under age 18, population density: number of persons per square mile, and percent population that is male and 15–24 years).

Data analyses

First, basic descriptive analyses (means and standard deviations) were calculated and all variables were then transformed to their natural logarithm to adjust for skew. Next, bivariate and multivariate regression analyses were conducted to examine the relationship between the neighbourhood sociostructural characteristics, alcohol outlet densities and violent crime. Multivariate regression analysis with stepwise selection (using $P = 0.05$ for retention) was used to produce the most parsimonious sociostructural models for each city. As the stepwise procedure can lead to biased estimates for observational data, special care should be taken to select a candidate pool of explanatory variables. Elimination of key covariates can seriously damage the explanatory power, while inclusion of too many independent variables often results in smaller statistical power. The candidate covariates in this study cover 16 factors pertaining to neighbourhood sociostructural characteristics and alcohol availability. Before performing the regression analysis, the distribution of variables was checked to make sure they were not omitted in the selection process due to a narrow range of values. Residual plots after the regression analysis were also checked for nonrandom pattern which indicates that some important independent variable was not incorporated in the model.

As noted above, analyses of small area data are subject to a variety of biases due to unobserved correlations between geographic units (i.e. spatial autocorrelations) and spill-over of the effects of some measures (e.g. densities of alcohol outlets) on outcomes observed in adjacent areas (e.g. violent crime rates). In order to detect and correct for spatial autocorrelated errors in the current analysis as well as to assess the potential dynamic effects between geographic units, three specialized spatial analyses were conducted. The first extended the bivariate and ordinary least squares regression analysis by including tests for spatial autocorrelations—specifically the raw Moran coefficient in the bivariate analysis and Moran's I in the multivariate analysis. The second

analysis further addressed the issue of potential unit dependence by taking into account the correlated error between adjacent census tracts (Gruenewald *et al.*, 2000). Here one is testing whether the effects observed in the ordinary least squares (OLS) model can be replicated under more rigorous analytic conditions using generalized least squares (GLS) analysis (Griffith, 1988). Specifically, for each model the spatial autocorrelation coefficient, ρ , is presented along with a test of its significance. The value of ρ ranges from -1.00 to $+1.00$; Type I errors in analysis occur when the value of ρ is less than 0, and Type II errors when it is greater than 0. Finally, the third form of spatial analysis presented examined the effects of independent variables measured in adjacent census tracts on rates of violence in 'target' census tracts—so-called 'spatial effects' or 'spatial lags' (Gruenewald *et al.*, 2000). Specialized geostatistical software developed by Gruenewald and colleagues was used in the spatial analyses. Details of the software and the computations used in the analyses are contained elsewhere (Gruenewald *et al.*, 1996; 2000; Ponicki and Gruenewald, 1998).

RESULTS

Means and standard deviations (before and after log transformation) for alcohol outlet density (number of alcohol outlets per 100 population), violent crime rate (number of violent crimes per 100 population) and the neighbourhood sociostructural variables that remained following the multivariate regression analysis with backward selection are shown in Table 1 for Austin and Table 2 for San Antonio. Of the five sociostructural variables that remained in the regression model in Austin, three were measures of concentrated disadvantage (percent families below poverty level, percent black, and percent Latino), one was a measure of residential instability (percent vacant housing), and one a sociodemographic measure (population density assessed in terms of population per square mile). In San Antonio, six sociostructural variables remained in the regression model. Two were measures of concentrated disadvantage (per cent female-headed households with children and percent Latino), two were measures of residential instability (percent homes

Table 1 Correlations between neighbourhood sociostructural characteristics, alcohol outlet densities and violent crime rates in Austin, Texas

	Poverty (%)	African American (%)	Latino (%)	Vacant housing (%)	Population density	Total outlet density	Violent crime
Poverty (%)	1.00						
African American (%)	0.55**	1.00					
Latino (%)	0.67**	0.69**	1.00				
Vacant housing (%)	0.20*	-0.03	0.01	1.00			
Population density	0.49**	0.16	0.33**	-0.23**	1.00		
Total outlet density	0.40**	0.10	0.24**	0.06	0.30**	1.00	
Violent crime	0.76**	0.58**	0.67**	0.13	0.42**	0.47**	1.00
Mean (SD) before log transformation	10.25 (9.46)	10.88 (14.02)	29.24 (20.92)	4.01 (2.47)	4223.24 (3420.35)	0.22 (0.64)	0.43 (0.53)
Mean (SD) after log transformation	1.75 (1.32)	1.69 (1.25)	3.08 (0.82)	1.22 (0.61)	7.94 (1.10)	-2.70 (1.67)	-1.77 (1.69)
Raw Moran coefficients	0.52**	0.70**	0.78**	0.16**	0.56**	0.40**	0.63**

*Correlation is significant at the $p = 0.05$ level (two-tailed). **Correlation is significant at the $p = 0.01$ level (two-tailed)

Table 2. Correlations between neighbourhood sociostructural characteristics, alcohol outlet densities and violent crime rates in San Antonio, Texas

	Female-headed households (%)	Latino (%)	Owner-occupied housing (%)	Vacant housing (%)	Population density	Men 15-24 years	Total outlet density	Violent crime
Female-headed households (%)	1.00							
Latino (%)	0.49**	1.00						
Owner-occupied housing (%)	-0.56**	-0.14*	1.00					
Vacant housing (%)	0.32**	0.12*	-0.59**	1.00				
Population density	0.36**	0.51**	-0.23**	0.06	1.00			
Males 15-24 years	0.43**	0.51**	-0.42**	0.22**	0.25**	1.00		
Total outlet density	0.24**	0.25**	-0.40**	0.51**	-0.01	0.10	1.00	
Violent crime	0.61**	0.54**	-0.48**	0.48**	0.27**	0.31**	0.54**	1.00
Mean (SD) before Log transformation	13.36 (6.27)	54.90 (27.17)	56.55 (21.53)	6.64 (5.04)	3922.64 (2427.47)	7.77 (4.20)	0.30 (0.94)	1.01 (1.86)
Mean (SD) after Log transformation	2.48 (0.51)	3.85 (0.59)	3.87 (0.76)	1.73 (0.56)	7.90 (1.14)	1.98 (0.35)	-1.92 (1.15)	-0.69 (1.36)
Raw Moran coefficient	0.36**	0.63**	0.18**	0.33**	0.43**	0.15**	0.23**	0.41**

*Correlation is significant at the $p = 0.05$ level (two-tailed). **Correlation is significant at the $p = 0.01$ level (two-tailed).

Table 3. Regression models for Austin: ordinary least squares (OLS) analysis for neighbourhood sociostructural characteristics (Model 1), OLS with alcohol outlet densities (Model 2), OLS with first-order lagged effects (Model 3), generalized least squares analysis with autocorrelated errors (Model 4)

Variable	Model 1	Model 2	Model 3	Model 4
Poverty (%)	0.325** (0.112)	0.272* (0.106)	0.219* (0.106)	0.256* (0.104)
African American (%)	0.148 (0.076)	0.226* (0.097)	0.212* (0.096)	0.192 (0.113)
Latino (%)	0.955*** (0.164)	0.561** (0.174)	0.572*** (0.171)	0.383 (0.216)
Vacant housing (%)	0.377* (0.179)	0.347* (0.169)	0.329* (0.166)	0.242 (0.162)
Adult : child ratio	0.281* (0.128)	0.036 (0.063)	-0.015 (.134)	0.018 (0.138)
Population density	0.374*** (0.020)	0.367*** (0.095)	0.313*** (0.096)	0.135 (0.113)
Total outlet density		0.242*** (0.056)	0.166** (0.062)	0.187*** (0.056)
First order lag of outlet density			0.250*** (0.010)	0.333** (0.121)
ρ				0.566*** (0.097)
R^2	0.593	0.641	0.656	0.711
Moran's I on residuals	0.180*** (0.045)	0.146*** (0.045)	0.162*** (0.045)	

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$.

that are owner-occupied and per cent vacant housing), and two were measures of resident population sociodemographics (population density and per cent population that is men and 15-24 years).

Of the four alcohol outlet density measures, only total density remained in the models that resulted from the stepwise elimination analysis. In both cities this variable was highly correlated with the other three outlet density variables. In Austin, the correlation between total outlet density and on-sale density was 0.78, that between total outlet density and off-sale density 0.94, and that between total outlet density and on/off-sale density 0.87 (all $P < 0.01$). The comparable correlations for San Antonio were 0.58, 0.79 and 0.86 (all $P < 0.01$).

Bivariate associations among variables are also presented in Tables 1 and 2 for Austin and San Antonio, respectively. In the former city, violent crime rate was positively associated with alcohol outlet density and all of the neighbourhood sociostructural variables except vacant housing. Total alcohol outlet density was positively correlated with three of the five sociostructural variables. In San Antonio, the violent crime rate was positively associated with five of the six neighbourhood variables, and negatively associated with the other.

Total alcohol outlet density was not significantly associated with either of the sociodemographic variables, but was negatively associated with one of the measures of residential instability and positively correlated with the remaining three neighbourhood sociostructural variables.

The Raw Moran coefficient measures presented at the bottom of Tables 1 and 2 assess the extent to which the observations in one geographic unit resemble those in geographic units. Both the Austin and San Antonio analyses show that for each variable included in the model there was significant positive spatial autocorrelation. This means that data pertaining to each variable (e.g. alcohol outlet density) collected from any single census tract tended to resemble the data pertaining to that variable collected from adjacent census tracts. Such a pattern of spatial autocorrelation suggests that OLS analysis of these data would exhibit considerable Type I errors.

Table 3 presents the results of the multivariate and spatial analyses for the City of Austin. Model 1 considers only the neighbourhood sociostructural covariates in the ordinary least square analysis. Six covariates remained after stepwise selection procedure and they explained close to 59% of the

Table 4. Regression models for San Antonio: ordinary least squares (OLS) analysis for neighbourhood sociostructural characteristics (Model 1) OLS with alcohol outlet densities (Model 2), OLS with first-order lagged effects (Model 3) generalized least squares analysis with autocorrelated errors (Model 4)

Variable	Model 1	Model 2	Model 3	Model 4
Female-headed households (%)	0.301 (0.187)	0.470** (0.170)	.322 (0.172)	0.341 (0.181)
Latino (%)	1.166*** (0.137)	.896*** (0.153)	0.689*** (0.154)	0.712*** (0.203)
Owner-occupied housing (%)	-0.544*** (0.110)	-0.462*** (0.110)	-0.315** (0.111)	-0.279* (0.110)
Vacant housing (%)	0.636*** (0.126)	0.233 (0.144)	0.185 (0.143)	0.219 (0.140)
Population density	0.150* (0.065)	0.129 (0.066)	0.100 (0.065)	-0.078 (0.076)
Men 15-24 years (%)	-1.481*** (0.245)	-1.142*** (0.242)	-0.989*** (0.236)	-1.028*** (0.217)
Total outlet density		0.383*** (0.058)	0.305*** (0.060)	0.305*** (0.056)
First order lag of per cent female-headed households			0.740** (0.237)	1.033*** (0.279)
First order lag of outlet density			0.359** (0.113)	0.229 (0.135)
ρ				0.532*** (0.076)
R ²	0.388	0.432	0.476	0.563
Moran's I on residuals	0.212*** (0.034)	0.186*** (0.034)	0.196*** (0.034)	

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$

variability in violent crime rates in the city. Adding alcohol outlet densities (total, on-sale, off-sale, and combined on-/off-sale) to the neighbourhood sociostructural covariates and going through stepwise selection again, Model 2 eliminated the significance of adult : child ratio and diminished the effect of per cent Latino by 41%. All of the coefficients in the model were positively associated with violent crime. This model explained 64% of the variability in violence rates. Model 3 keeps all the covariates in Model 2 and adds the first order spatial lag for each of them. None of the lags for the sociostructural variables was statistically significant, so only the result for the spatial lag for total alcohol outlet density (which was significant) is presented. The introduction of this variable reduces the effect of alcohol outlet density in the target census tract by 31%. It also reduces the magnitude of four of the five neighbourhood sociostructural coefficients, but the effects are smaller than that found for outlet density in the target tract (e.g. a 19% reduction for per cent living in poverty and a 15% reduction for population density).

The Moran coefficient presented at the bottom of Table 3 shows the extent to which spatial autocorrelation remained in the models after accounting for the variance explained by the independent measures. This was statistically significant in all three models based on the OLS analysis (Models 1 to 3). Model 4 keeps all the variables in Model 3 and adds spatial autocorrelation as an explanatory variable. The GLS analysis presented in Model 4 shows that there were statistically significant effects related to spatial autocorrelations in the model. Adding this control for autocorrelated error to the regression serves to eliminate the significance of all but one (per cent poverty) of the neighbourhood sociostructural variables. The coefficient for alcohol outlet density in the target census tract is increased by 13% in Model 4 and that of the first order lag of outlet density by 33%. This final model explains 71% of the variance in violent crime rates in Austin.

The results of the multivariate and spatial analyses for San Antonio are shown in Table 4. Model 1 (the model of neighbourhood sociostructural variables based on OLS analysis) explained close to 39% of the variability in violent crime rates in the city. Total alcohol outlet density was added in Model 2. This eliminated the significance of per cent vacant housing and population density while the coefficient for per cent

female-headed households was now significant. This variable and per cent Latino were both positively related to violent crime, while per cent owner-occupier housing and per cent men aged 15-24 years were both negatively related to violence rates in Model 2. This model explained an additional 4% of the variance in violent crime. The first order spatial lags for covariates were added in Model 3. The lag for total alcohol outlet density and per cent female-headed household were both statistically significant. The addition of these variables to the model eliminated the effect of per cent female-headed households in the target census tract. Model 3 explained 48% of the variability in violent crime rates.

As with Austin, the Moran coefficients for Models 1, 2 and 3 in San Antonio (presented at the bottom of Table 4) showed that a significant level of spatial autocorrelation remained in the OLS models after accounting for the variance explained by the independent measures. Controlling for this autocorrelated error in Model 4 eliminates the significance of the lag effect of total alcohol outlet density. The final model, comprised of three sociostructural variables in the target census tract, one in the neighbouring tracts and total outlet density in the target tract, explained 56% of the variance in violent crime rates in San Antonio.

DISCUSSION

This study assessed the effects of alcohol outlet density and sociostructural variables on violent crime rates within census tracts in two cities in the southwestern US using multivariate regression and spatial analyses. In line with previous research focused on the immediate neighbourhood context (Gorman *et al.*, 2001; Lipton and Gruenewald, 2002), the results showed a clear association between alcohol outlet density and violence, after controlling for neighbourhood sociostructural features as well as the effects of spatially autocorrelated error. These findings, together with those from other spatial analyses of alcohol-related problems such as motor vehicle and pedestrian accidents (Gruenewald *et al.*, 1996; LaScala *et al.*, 2001), suggest that the issues of alcohol availability and access are fundamental to the prevention of alcohol-related problems (Stockwell and Gruenewald, 2001).

As noted above, the spatial analysis presented enabled identification and correction for spatially-autocorrelated errors along with assessment of the potential dynamics effects between geographic units. The assessment of these first order lagged effects using OLS analysis indicated that alcohol outlet density in adjacent areas influenced rates of violence in target areas in both Austin and San Antonio. In San Antonio, however, the effect was eliminated once the autocorrelated error was taken into account. This was in line with our previous analysis in Camden, New Jersey, which also found the effects of alcohol outlet densities on violent crime rates to be spatially limited (Gorman *et al.*, 2001). Such differences suggest that the spatial effects of alcohol availability on violence may vary from location to location, thereby indicating the importance of understanding this relationship within a specific community context (Gorman *et al.*, 2004; Stockwell and Gruenewald, 2001).

The spatial analyses also demonstrate the importance of controlling for autocorrelated error in small area analyses of the association between alcohol availability and violence. Scribner *et al.* (1999) recently observed that the extent of the potential problems emanating from spatial autocorrelation had yet to be determined in this field of research. And, indeed, in our previous study in Camden, spatial autocorrelation was not found to be a significant source of bias (Gorman *et al.*, 2001). However, in the present study considerable Type I error was present in the models estimated using OLS analysis. Specifically, in San Antonio, the first order lag of alcohol outlet density was no longer significant once the effects of autocorrelated error were taken into account. In Austin, a number of sociostructural variables appeared significant in the OLS model but were not found to be in the more rigorous GLS analysis. Thus, the model for Austin was quite different from that found in our earlier analysis of Camden, New Jersey or in other ecologic studies of crime in large urban centres such as Chicago, Illinois and Columbus, Ohio (Sampson *et al.*, 1997; Peterson *et al.*, 2000). One possible reason for this is that aggregated assault was excluded from the Austin analysis, whereas it was included in previous studies. In addition, it may be that the underlying social mechanisms related to crime in older urban centres in the northeast and mid-west US are different from those in a southwestern city such as Austin (Ousey, 2000). Again, this points to the importance of understanding the alcohol-violence relationship within a specific neighbourhood context.

The latter points to one of the main limitations of the present study, namely that it only took into account fairly limited aspects of neighbourhood ecology. The study focuses on the socioeconomic and sociodemographic composition of census tracts along with alcohol outlet density, but fails to account for other aspects of neighbourhood life that influence the occurrence of acts of violence. These include other potential crime 'attractor' locations such as convenience stores and major street intersections (Block and Block, 1995; Nelson and Bromley, 2001), signs of physical and social disorder (Skogan, 1990), as well as cultural aspects of neighbourhood life such as social integration and cohesion (Sampson *et al.*, 1997). A second limitation of the study is that it is unable to address the question of exactly what it is about alcohol outlets that is important in explaining violent crime. For example, is it the density of outlets *per se* that matters or is it that attractor

bars tend to be found in areas of high outlet density (Block and Block, 1995)? More detailed micro-spatial and temporal analysis of the type undertaken in recent British studies (Nelson *et al.*, 2001; Bromley and Nelson, 2002) will be needed to answer such questions.

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REFERENCES

- Block, R. L. and Block, C. R. (1995) Space, place and crime: hot spot areas and hot places of liquor-related crime. In *Crime and Place* (Crime Prevention Studies, Vol. 4), Eck, J. E. and Weisburd, D., eds, pp. 145–183. Criminal Justice Press, Monsey, NY.
- Bottoms, A. E. and Wiles, P. (1997) Environmental criminology. In *The Oxford Handbook of Criminology*, Maguire, M., Morgan, R. and Reiner, R., eds, pp. 305–359. Oxford University Press, Oxford.
- Brantingham, P. L. and Brantingham, P. J. (1993) Nodes, paths and edges: considerations on the complexity of crime and the physical environment. *Journal of Environmental Psychology* 13, 3–28.
- Bromley, D. F. B. and Nelson, A. L. (2002) Alcohol-related crime and disorder across urban space and time: evidence from a British city. *Geoforum* 33, 239–254.
- Costanza, S. E., Bankston, W. B. and Shihadeh, E. (2001) Alcohol availability and violent crime rates: a spatial analysis. *Journal of Crime and Justice* 24, 71–83.
- Farrington, D. P. and Loeber, R. (2000) Epidemiology of juvenile violence. *Juvenile Violence* 9, 733–748.
- Gorman, D. M., Speer, P. W., Gruenewald, P. G. and Labouvie, E. W. (2001) Spatial dynamics of alcohol availability, neighborhood structure and violent crime. *Journal of Studies on Alcohol* 62, 628–636.
- Gorman, D. M., Gruenewald, P. J., Hanlon, P. J., Mezic, I., Waller, L., Castillo-Chavez, C., Bradley, E. and Mezic, J. (2004) Implications of systems dynamic models and control theory for environmental approaches to the prevention of alcohol- and drug-related problems. *Substance Use and Misuse*.
- Griffith, D. A. (1988) *Advanced Spatial Statistics*. Kluwer, Dordrecht, The Netherlands.
- Gruenewald, P. J. (1993) Alcohol problems and the control of availability: theoretical and empirical issues. In *Economics and the Prevention of Alcohol-Related Problems*, NIAAA Research Monograph No. 25, Hilton, M. E. and Bloss, G., eds, pp. 59–90. National Institute on Alcohol Abuse and Alcoholism, Rockville, MD.
- Gruenewald, P. J., Millar, A. B., Treno, A. J., Yang, Z., Ponicki, W. R. and Roeper, P. (1996) The geography of availability and driving after drinking. *Addiction* 91, 967–983.
- Gruenewald, P. J., Millar, A. B., Ponicki, W. R. and Brinkley, G. (2000) Physical and economic access to alcohol: the application of geostatistical methods to small area analysis in community settings. In *The Epidemiology of Alcohol Problems in Small Geographic Areas*, Wilson, R. A. and Dufour, M. C., eds, pp. 163–212. National Institute on Alcohol Abuse and Alcoholism, Bethesda, MD.
- Koop, C. and Lundberg, G. D. (1992) Violence in America: a public health emergency. *Journal of the American Medical Association* 267, 3075–3076.
- Krivo, L. J. and Peterson, R. D. (1996) Extremely disadvantaged neighborhoods and urban crimes. *Social Forces* 75, 619–650.
- LaScala, E. A., Johnson, F. W. and Gruenewald, P. J. (2001) Neighborhood characteristics of alcohol-related pedestrian injury collision: a geospatial analysis. *Prevention Science* 2, 123–134.
- Lipton, R. and Gruenewald, P. J. (2002) The spatial dynamics of violence and alcohol outlets. *Journal of Studies on Alcohol* 63, 187–195.
- Lipton, R., Gorman, D. M., Wieczorek, W. F. and Gruenewald, P. (2003) The application of spatial analysis to the public health understanding of alcohol and alcohol-related problems. In *Geographic Information Systems and Health Applications*, Khan, O. A., ed. pp. 57–79. Idea Group Publishing, Hershey, PA.

- Nelson, A. L., Bromley, R. D. F. and Thomas, C. J. (2001) Identifying micro and temporal patterns of violent crime and disorder in the British city center. *Applied Geography* 21, 249-274
- Ousey, G. C. (2000) Explaining regional and urban variation in crime: a review of research. In *Criminal Justice 2000 — Volume 1: The Nature of Crime: Continuity and Change*, LaFree, G., ed, pp. 261-308. National Institute of Justice, Washington, DC.
- Peterson, R. D., Krivo, L. J. and Harris, M. A. (2000) Disadvantage and neighborhood violent crime: do local institutions matter? *Journal of Research on Crime and Delinquency* 37, 31-63.
- Ponicki, W. R. and Gruenewald, P. J. (1998) *S²: The Spatial Statistical System Users' Guide, V4.0*. Prevention Research Center, Pacific Institute for Research and Evaluation, Berkeley, CA.
- Roncek, D. W. and Maier, P. A. (1991) Bars, blocks, and crimes revisited: linking the theory of routine activities to the empiricism of 'hot spots'. *Criminology* 29, 725-753.
- Sampson, R. J., Raudenbush, R. W. and Earls, F. (1997) Neighborhoods and violent crime: a multilevel study of collective efficacy. *Science* 277, 918-924.
- Scribner, R. A., Cohen, D. A., Kaplan, S. and Allen, S. H. (1999) Alcohol availability and homicide in New Orleans: conceptual considerations for small area analysis of the effect of alcohol outlet density. *Journal of Studies on Alcohol* 60, 310-316.
- Sherman, L. W., Gartin, P. R. and Buerger, M. R. (1989) Hot spots of predatory crime: routine activities and the criminology of place. *Criminology* 27, 27-55.
- Speer, P. W., Gorman, D. M., Labouvie, E. W. and Ontkush, M. J. (1998) Violent crime and alcohol availability: relationships in an urban community. *Journal of Public Health Policy* 19, 303-318.
- Stockwell, T. and Gruenewald, P. (2001) Controls on the physical availability of alcohol. In *International Handbook of Alcohol Dependence and Problems*, Heather, N., Peters, T. J. and Stockwell, T., eds, pp. 699-719. Wiley & Sons, New York.
- Texas Department of Public Safety (2001) *Crime in Texas 2000: The Texas Crime Report*. Texas Department of Public Safety, Austin, TX.
- US Census Bureau (2003) *2000 United States Decennial Census (Summary File 1 and Summary File 3)*. US Department of Commerce, Washington, DC.