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Spatial Relationships between Alcohol-Related Road Crashes and Retail Alcohol Availability

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Abstract

Background—This study examines spatial relationships between alcohol outlet density and the incidence of alcohol-related crashes. The few prior studies conducted in this area used relatively large spatial units; here we use highly resolved units from Melbourne, Australia (Statistical Area level 1 [SA1] units: mean land area = 0.5 km^2; SD = 2.2 km^2), in order to assess different micro-scale spatial relationships for on- and off-premise outlets.

Methods—Bayesian conditional autoregressive Poisson models were used to assess cross-sectional relationships of three-year counts of alcohol-related crashes (2010 to 2012) attended by Ambulance Victoria paramedics to densities of bars, restaurants, and off-premise outlets controlling for other land use, demographic and roadway characteristics.

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Conflict of Interest: No conflict declared.

Contributors: CM conceptualized the study and was primarily responsible for the data analysis and manuscript preparation. WRP and PJG assisted in conceptualizing the study and contributed to the analyses. DJW assisted writing the manuscript, and KS provided advice in managing the Ambulance Victoria records and data analyses. All authors helped to interpret findings, review drafts of the manuscript and approved the final manuscript.

Results—Alcohol-related crashes were not related to bar density within local SA1 units, but were positively related to bar density in adjacent SA1 units. Alcohol-related crashes were negatively related to off-premise outlet density in local SA1 units.

Conclusions—Examined in one metropolitan area using small spatial units, bar density is related to greater crash risk in surrounding areas. Observed negative relationships for off-premise outlets may be because the origins and destinations of alcohol-affected journeys are in distal locations relative to outlets.

Keywords

Keywords: alcohol; outlet; density; motor vehicle; crash; spatial

1. Introduction

Approximately 20% of all fatal crashes worldwide are alcohol-related, amounting to over 250,000 deaths annually (WHO, 2011). Research over the last several decades has identified interventions that successfully reduce this global health burden, such as raising the minimum legal drinking age and conducting random roadside breath tests (Anderson et al., 2009). It is possible that reducing the physical availability of alcohol will have similar public health benefits. There is now substantial evidence that geographic areas with fewer alcohol outlets have lower incidence of other alcohol-related problems (e.g., assault, child abuse, crime; Campbell et al., 2009; Popova et al., 2009); however, there is comparatively little available evidence for road crashes. The current paper addresses this gap, investigating the geographic association between alcohol-related road crashes and the availability of alcohol through retail outlets within highly resolved spatial units.

The earliest studies to relate outlets to crashes used data aggregated within the very large spatial units of states (Colon, 1982; Colón and Cutter, 1983) and counties (Giacopassi and Winn, 1995; Jewell and Brown, 1995; Kelleher et al., 1996). Most found positive relationships, although some findings were negative or null. Recognising that larger spatial units increase the likelihood that results will be affected by aggregation bias (which attenuates parameter estimates towards null), recent studies have generally used smaller units, such as cities (McCarthy, 2003; Scribner et al., 1994), ZIP codes (Ponicki et al., 2013; Treno et al., 2007), or other custom units (Gruenewald and Johnson, 2010; Gruenewald et al., 1996), and have categorised outlets according to licence type. These studies consistently find on-premise outlets (e.g., bars, restaurants) to be positively related to crashes, but findings for off-premise outlets (e.g., liquor stores) are mixed.

To date, no published studies have examined these geographic relationships using spatial units smaller than California ZIP codes (mean = 158.7 km^2; SD = 295.0 km^2; Ponicki et al., 2013; Treno et al., 2007). This is problematic because on-premise and off-premise alcohol sales are likely to produce alcohol-related crashes in different locations, and studies using larger spatial units may not be able to disentangle the two. That is, an alcohol-impaired driver who departs from an on-premise outlet may crash somewhere between the outlet (origin) and another location (destination); whereas an alcohol-impaired driver who purchases alcohol at an off-premise outlet may crash somewhere between the place it is consumed (origin) and a third location (destination). The larger the spatial unit, the more likely it is that outlets, origins, destinations and crashes will be co-located within spatial units, washing out the distinct spatial signatures for on- and off-premise outlets while at the same time increasing the likelihood that effects will not be detectable due to aggregation bias.

For this study, we aggregated crash data and alcohol outlet data within Statistical Area level 1 (SA1) units from the city of Melbourne, Australia. These units have an average resident population of 415.3 (SD = 208.8) and cover a land area of 0.5 km^2 (SD = 2.2 km^2). In such small spatial units, we expected that greater density of on-premise outlets would be positively associated with alcohol-related crash rates in local and adjacent (i.e., spatially lagged) areas, but that there would be no detectable association for off-premise outlets.

2. Materials and Methods

2.1. Sample

The spatial sample for this study was all SA1 units from the 2011 Australian Census with an internal centroid within the Australian Bureau of Statistics Major Cities region of Melbourne (n = 9,214). We aggregated cross-sectional data from five sources within SA1 units: (i) alcohol-related road crashes from Ambulance Victoria (the sole emergency medical service provider in Melbourne) for 2010 to 2012, (ii) road crashes in which at least one person was injured from Victoria Police for 2010 to 2012, (iii) alcohol outlets from the Victorian Commission on Gambling and Liquor Regulation for 2011, (iv) 2011 roadway network and land use characteristics from VicMap, the state mapping authority, and (v) demographic characteristics from the 2011 Census.

2.2.Measures

The dependent measure was counts of alcohol-related crashes attended by Ambulance Victoria paramedics within each SA1 unit (Cox et al., 2013). We accessed reports for each patient within each case (a “casepatient”), then identified individual road crashes as all cases with one or more casepatients for which the paramedics assigned a case nature of motor vehicle collision, motorcycle collision, or bicycle collision. Cases were considered alcohol-related where paramedics indicated or queried that at least one casepatient had been drinking. We were not able to distinguish drivers from passengers. These data were provided to us geocoded to the SA1 unit.

The main independent measure of interest was the density of alcohol outlets within each SA1 (outlet counts denominated by SA1 land area). Outlets were categorized according to licence type as *bars* (general licences), *restaurants* (restaurant and café licences), and *off-premise outlets* (packaged licences). Outlet densities were calculated for adjacent SA1 areas by aggregating all SA1 units that share a boundary with the local SA1 unit. The mean distance between the centroid points of local and adjacent SA1 units was 0.63 km (SD = 0.54 km).

Other independent measures were the total length of roadways within each SA1 and the proportion by length that were highways or freeways (class code 0 or 1) and arterials or subarterials (class code 2 or 3), as well as the total count of intersections and the proportion that were “T” intersections (i.e., with three exits). Roadways representing SA1 boundaries were randomly assigned to one of the SA1 units they bordered. Population demographic characteristics were the median age of the resident SA1 population, the proportion that were male, and the proportion that spoke English at home. Socio-economic status was described using national deciles of the Index of Relative Social Advantage and Disadvantage (IRSAD), a composite measure published by the Australian Bureau of Statistics for which higher values indicate greater advantage. Commercial land use in local and adjacent SA1 units was the proportion of land area zoned for retail (zones B1Z, B2Z, B3Z, B4Z, B5Z) or capital city (CCZ1, CCZ2) use.

2.3.Statistical Analyses

We assessed relationships between alcohol-related road crashes and alcohol outlet density in a Bayesian conditional autoregressive (CAR) Poisson model. Separating model errors into spatially unstructured noise and a spatially structured CAR random effect accounted for any loss of independence due to spatial autocorrelation (Waller and Gotway, 2004). We set non-informative prior distributions, and allowed the model to burn-in for 150,000 iterations before sampling 50,000 iterations to obtain posterior estimates. Spatial data management was performed using ArcGIS v.10.3 (ESRI, 2011), and the Bayesian spatial Poisson model was fitted using WinBUGS v1.4.3 (Lunn et al., 2000).

The expectancy for the Poisson model was a count of all Victoria Police injury crashes (n = 30,232) within each SA1. These data are publically available from VicRoads CrashStats, including latitude and longitude coordinates which we geocoded to SA1 units. 1,453 SA1 units (15.8%) had no police-reported injury crashes; one additional crash was shared evenly between these units in order to avoid denominating the model by zero. By this approach, all injury crashes serve as an estimate of background crash risks due to road conditions, prevailing weather, traffic volume, driver behavior or other factors. This local variation is effectively constrained within a constant term, and parameter estimates for other independent variables describe the rate of alcohol-related crashes relative to this expected rate. We attempted a sensitivity analysis using all Ambulance Victoria injury crashes as the expectancy, but the very low number (n = 3,572) produced a count of zero in the majority (75.3%) of SA1 units. An additional sensitivity analysis used the subset of Victoria Police injury crashes that occurred at night (6pm to 6am everyday) and on weekends (4pm to 6pm Fridays; 6am to 8am and 2pm to 6pm Saturdays; 6am to 10am and 4pm to 6pm Sundays), to account for traffic and background crash rates related to recreation around bars, restaurants and off-premise outlets rather than commuting.

3. Results

There were 1,614 alcohol-related road crashes attended by Ambulance Victoria paramedics over the three years of the study. The characteristics of the 9,214 SA1 units are described in Table 1.

Table 2 presents the results of the Bayesian spatial Poisson model. Compared to the rate of Victoria Police injury crashes, increased bar density of 10 outlets/km^2 within local SA1 units was unrelated to the rate of alcohol-related crashes (IRR = 1.00; 95% CI: 0.92, 1.07). In contrast, an increase of 10 bars/km^2 in adjacent SA1 units was associated with a well-supported increased rate of alcohol-related crashes (IRR = 1.39; 95% CI: 1.10, 1.75). Relationships for restaurants were not supported, but 10 additional off-premise outlets/km^2 in local SA1 units (IRR = 0.84; 95% CI: 0.70, 1.00) was associated with a decreased rate of alcohol-related crashes. Results of the sensitivity analysis were substantively similar to the estimates presented in Table 2.

4. Discussion

In very highly resolved spatial units, we found no evidence that greater bar density was associated with greater rates of alcohol-related crashes within local areas, however there was a well-supported positive relationship in adjacent spatial areas. In contrast, greater off-premise outlet density was associated with fewer alcohol-related crashes in local areas.

These findings were consistent with most previous studies (Giacopassi and Winn, 1995; Gruenewald and Johnson, 2010; Gruenewald et al., 1996; Jewell and Brown, 1995; Kelleher et al., 1996; Lunn et al., 2000; McCarthy, 2003; Ponicki et al., 2013; Scribner et al., 1994; Treno et al., 2007) and our expectations given the geographic locations of origins and destinations of alcohol-affected journeys relative to on- and off-premise outlets. Alcohol-affected drivers are at increased risk of crashing after leaving an on-premise outlet (observable here within adjacent SA1 units). Importantly, this increased risk is likely to be dispersed over a wide geographic area, and observed effect sizes within these highly resolved units were very small. Calculated from the parameter estimates, a 10% increase in bar density was associated with 0.3% increased crash risk in adjacent SA1 units. By contrast, drivers who consume alcohol purchased in off-premise outlets will be affected while driving between distal origins and destinations. The negative relationship for off-premise outlets does not suggest that these outlets in some way protect against alcohol-related crashes, rather it may support our contention that alcohol-related crashes occur elsewhere on the roadway network.

Four main limitations apply for this study. First, despite paramedics' clinical training and the extended time spent with patients, assessments of alcohol intoxication may be subject to error (Rubenzer, 2011). Provided this error was not spatially structured, any misclassification would have attenuated results towards null. Second, the assignment of crashes and roadways from SA1 borders into one unit may have biased estimates in either direction. Third, all crashes may not fully account for background crash risks. If residual crash risks are related to outlet density, results may be biased. Fourth, the different spatial structures for urban compared to rural areas may mean our results cannot be generalized to rural settings (Morrison, 2015). Further investigation of these relationships in rural areas is warranted, as per capita crash rates are substantially higher in rural areas (Czech et al., 2010).

This study, conducted using highly resolved spatial units, suggests that increased risks for alcohol-related crashes are found in geographic regions very close to areas with greater bar density. Consistent with previous studies, effect sizes are very small (Ponicki et al., 2013).

This may be because alcohol consumers are willing to travel well beyond their local areas to purchase alcohol (e.g., across the extent of a city, rather than just within local and adjacent SA1 units). If this is the case, spatial relationships between alcohol outlet density and alcohol-related crashes may be weaker within small spatial units, but relatively stronger within large spatial units. Future studies from our group will use multi-city data in multi-level analyses to examine possible multi-scale effects.

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References

Anderson P, Chisholm D, Fuhr DC. Effectiveness and cost-effectiveness of policies and programmes to reduce the harm caused by alcohol. Lancet. 2009; 373:2234–2246. [PubMed: 19560605]

Campbell CA, Hahn RA, Elder R, Brewer R, Chattopadhyay S, Fielding J, Naimi TS, Toomey T, Lawrence B, Middleton JC. The effectiveness of limiting alcohol outlet density as a means of reducing excessive alcohol consumption and alcohol-related harms. Am J Prev Med. 2009; 37:556–569. [PubMed: 19944925]

Colon I. The influence of state monopoly of alcohol distribution and the frequency of package stores on single motor vehicle fatalities. Am J Drug Alcohol Abuse. 1982; 9:325–331. [PubMed: 7185277]

Colón I, Cutter HSG. The relationship of beer consumption and state alcohol and motor vehicle policies to fatal accidents. J Safe Res. 1983; 14:83–89.

Cox S, Martin R, Somaia P, Smith K. The development of a data-matching algorithm to define the “case patient”. Aust Health Rev. 2013; 37:54–59. [PubMed: 23257311]

Czech S, Shakeshaft AP, Byrnes JM, Doran CM. Comparing the cost of alcohol-related traffic crashes in rural and urban environments. Accid Anal Prev. 2010; 42:1195–1198. [PubMed: 20441831]

ESRI. ArcGIS Desktop: Release 10.1. Environmental Systems Research Institute; Redlands, CA: 2011.

Giacopassi D, Winn R. Alcohol availability and alcohol-related crashes: does distance make a difference? Am J Drug Alcohol Abuse. 1995; 21:407–416. [PubMed: 7484988]

Gruenewald PJ, Johnson FW. Drinking, driving, and crashing: a traffic-flow model of alcohol-related motor vehicle accidents. J Stud Alcohol Drugs. 2010; 71:237–248. [PubMed: 20230721]

Gruenewald PJ, Millar AB, Treno RJ, Yang Z, Ponicki WR, Roeper P. The geography of availability and driving after drinking. Addiction. 1996; 91:967–983. [PubMed: 8688823]

Jewell RT, Brown RW. Alcohol availability and alcohol-related motor vehicle accidents. Appl Econ. 1995; 27:759–765.

Kelleher KJ, Pope SK, Kirby RS, Rickert VI. Alcohol availability and motor vehicle fatalities. J Adolesc Health. 1996; 19:325–330. [PubMed: 8934292]

Lunn DJ, Thomas A, Best N, Spiegelhalter D. WinBUGS - a Bayesian modelling framework: concepts, structure, and extensibility. Stat Comput. 2000; 10:325–337.

McCarthy P. Alcohol-related crashes and alcohol availability in grass-roots communities. Appl Econ. 2003; 35:1331–1338.

Morrison C. Exposure to alcohol outlets in rural towns. Alcohol Clin Exp Res. 2015; 39:73–78. [PubMed: 25515926]

Ponicki WR, Gruenewald PJ, Remer LG. Spatial panel analyses of alcohol outlets and motor vehicle crashes in California: 1999–2008. Accid Anal Prev. 2013; 55:135–143. [PubMed: 23537623]

Popova S, Giesbrecht N, Bekmuradov D, Patra J. Hours and days of sale and density of alcohol outlets: impacts on alcohol consumption and damage: a systematic review. Alcohol Alcohol. 2009; 44:500–516. [PubMed: 19734159]

Rubenzer S. Judging intoxication. Behav Sci Law. 2011; 29:116–137. [PubMed: 20623796]

Scribner R, MacKinnon DP, Dwyer J. Alcohol outlet density and motor vehicle crashes in Los Angeles County cities. J Stud Alcohol. 1994; 55:447–453. [PubMed: 7934052]

Treno AJ, Johnson FW, Remer LG, Gruenewald PJ. The impact of outlet densities on alcohol-related crashes: a spatial panel approach. Accid Anal Prev. 2007; 39:894–901. [PubMed: 17275773]

Waller, LA.; Gotway, CA. Applied Spatial Statistics for Public Health Data. Wiley; New Jersey: 2004.

WHO. Global Status Report on Alcohol and Health. World Health Organization; Geneva: 2011.

Highlights

- Spatial relationships with crashes differ for bars and off-premise outlets
- Motor vehicle crashes are positively related to bar density in adj acent areas
- Spatial analyses must consider origins and destinations of alcohol-affected journeys

Table 1

Descriptive statistics for 9214 Statistical Area level 1 units in Melbourne, Australia

Mean	Mean	SD	Min	Max
Road Crashes				
Alcohol-related crashes (Ambulance Victoria)	0.162	0.467	0.000	7.000
Injury crashes (Victoria Police)	3.291	6.137	0.000	155.000
Land Use				
Bar density	1.385	11.991	0.000	447.582
Bar density – adjacent	1.176	7.180	0.000	225.207
Restaurant density	2.903	19.865	0.000	671.373
Restaurants density – adjacent	2.467	11.064	0.000	307.342
Off-premise outlet density	0.923	4.122	0.000	136.232
Off-premise outlet density – adjacent	0.851	1.725	0.000	45.687
Proportion land area zoned retail	3.023	10.509	0.000	100.000
Proportion land area zoned retail – adjacent	3.844	8.622	0.000	99.922
Population Demographics				
Population density	3100.142	4400.776	0.279	158817.100
Population density – adjacent	2511.660	1906.149	4.448	70448.730
Proportion male	49.322	5.153	0.000	100.000
Proportion English speakers	66.143	20.257	0.000	100.000
Age (years)	37.086	8.420	0.000	87.000
SES index (decile)	6.172	2.764	1.000	10.000
Roadway Network				
Total length (kms)	1.641	2.596	0.000	77.181
Proportion highway/freeway	2.242	8.873	0.000	100.000
Proportion arterials	11.396	17.343	0.000	100.000
Intersections (count)	16.040	8.063	0.000	166.000
Proportion “T” intersections	84.073	15.712	0.000	100.000

Table 2

Bayesian conditional autoregressive Poisson model for counts of alcohol-related road crashes within 9214 Statistical Area level 1 units in Melbourne, Australia

Variable	IRR	(95% CI)
Land Use		
Bar density [a]	0.997	(0.923, 1.074)
Bar density – adjacent [a]	**1.387**	**(1.098, 1.755)**
Restaurant density [a]	0.973	(0.917, 1.026)
Restaurants density – adjacent [a]	0.866	(0.731, 1.018)
Off-premise outlet density [a]	**0.843**	**(0.704, 0.999)**
Off-premise outlet density – adjacent [a]	0.608	(0.343, 1.071)
Proportion land area zoned retail [b]	0.997	(0.941, 1.055)
Proportion land area zoned retail – adjacent [b]	1.000	(0.999, 1.000)
Population Demographics		
Population density [c]	0.992	(0.956, 1.025)
Population density – adjacent [c]	1.027	(0.973, 1.084)
Proportion male [b]	0.974	(0.894, 1.058)
Proportion English speakers [b]	1.004	(0.999, 1.008)
Age (years) [d]	1.019	(0.952, 1.088)
SES index (decile)	**0.950**	**(0.921, 0.981)**
Roadway Network		
Total length (kms)	1.011	(0.992, 1.029)
Proportion highway/freeway [b]	0.959	(0.910, 1.010)
Proportion arterials [b]	0.981	(0.946, 1.017)
Intersections (count) [d]	0.938	(0.871, 1.013)
Proportion “T” intersections [b]	**1.793**	**(1.123, 2.892)**
CAR random effect		
Proportion of variance explained by CAR	0.054	(0.014, 0.167)
Global Moran's I	0.894	

Bolded parameter estimates do not include values of 1.000, indicating associations are well-supported

[a] per 10 outlets/km^2 increase

[b] per 10% increase

[c] per 1,000 people/km^2 increase

[d] per 10 unit increase