

It Is More Than Just Alcohol: A Criminological Perspective on Routine Drinking Activities, Opportunity, and Alcohol-Related Crashes

Journal of Drug Issues

1–21

© The Author(s) 2019

Article reuse guidelines:

sagepub.com/journals-permissions

DOI: 10.1177/0022042619865011

[journals.sagepub.com/home/jod](http://jod.sagepub.com/home/jod)

Richard Stringer¹ , Garland White², Randy Gainey²,
and Ruth Triplett²

Abstract

This project expands on the “routine drinking activities” perspective by examining alcohol outlets, alcohol-related crashes, and theoretically derived contextual measures. Using census tract-level data from two U.S. cities, we draw on the prevention literature and routine activities theory to develop measures of alcohol availability and context. Spatially lagged regression models examined both direct and conditional relationships between alcohol outlets and alcohol-related crashes. Results indicate that the alcohol outlet and crash relationship was moderated by contextual factors (e.g., driving under the influence [DUI] enforcement and environmental hazards). Thus, alcohol availability may be just a part of a broader community system that affects the opportunity for alcohol-related crashes to occur.

Keywords

alcohol outlets, automobile crashes, drunk driving, spatial analysis, routine activities

Despite considerable efforts to prevent alcohol impaired driving, a substantial portion of the public chooses to drive while under the influence of alcohol (Jewett, Shults, Banerjee, & Bergen, 2015). As a result, thousands of people are injured or killed in alcohol-related automobile crashes every year, and millions of crashes result in property damage (Blincoe, Miller, Zaloshnja, & Lawrence, 2015). Reduction of drinking and driving and the harms caused by it remain an important issue for public policy and thus for research. A great deal of research attention has been given to individual-level factors related to drinking, driving, and the resulting injury to person and property. Less often found in the research, though of critical importance, are area characteristics and their influence on the alcohol outlet and alcohol-related crash relationship.

¹Kennesaw State University, GA, USA

²Old Dominion University, Norfolk, VA, USA

Corresponding Author:

Richard Stringer, Department of Sociology and Criminal Justice, Kennesaw State University, 402 Bartow Ave., Kennesaw, GA 30144, USA.

Email: rstring7@kennesaw.edu

The main focus within area or environmental research on alcohol-related crashes is the relationship between alcohol outlet density in an area, such as bars and restaurants, and alcohol-related crashes in and around these areas. Alcohol outlets are the focus of attention as research has shown that more than half (54%) of driving under the influence (DUI) trips originate at restaurants, bars, and taverns (Moulton, Peterson, Haddix, & Drew, 2010). Research in this area draws largely on availability theory. Gruenewald, Mitchell, and Treno (1996; Stockwell & Gruenewald, 2004) extend this theory to focus explicitly on drinking behaviors and its consequences. Specifically, they argue that alcohol outlets increase crashes by increasing the availability of alcohol, particularly when establishments affect whether the drinking is done socially or alone, and the level of consumption prior to getting behind the wheel.

Research on contextual effects of alcohol outlets has generally found that an increase in density or number of alcohol outlets leads to an increase in crashes (Gruenewald et al., 2010; Gruenewald & Johnson, 2010; Gruenewald, Johnson, & Treno, 2002; Gruenewald, Stockwell, Beel, & Dyskin, 1999; McCarthy, 2003; Ponicki, Gruenewald, & Remer, 2013; Treno, Johnson, Remer, & Gruenewald, 2007). Much of the research is limited, however, in that researchers rarely go beyond an examination of the demographic composition of the area, and perhaps some characteristics of roads. Researchers have called for theoretical development to better understand the more complex role of alcohol outlets in automobile crashes (see Gruenewald, 2007; Livingston, Chikritzhs, & Room, 2007) as well as identifying contextual factors that shape the effect (see Stockwell & Gruenewald, 2004).

Although criminologists have shown limited interest in this area (see Bouffard, Bergeron, & Bouffard, 2007 for an exception), in this article, we draw on availability theory and Cohen and Felson's (1979) routine activities theory to expand theoretical perspectives on alcohol outlet density and crashes to include consideration of two sets of factors related to the opportunity for alcohol-related crashes to occur—those factors related to crashes overall and guardianship. Thus, this study utilizes three diverse types of quantitative data to explore the relationship between alcohol outlets and automobile crashes and the moderation of this relationship across social context.

Literature Review

Two independent but overlapping literatures can be drawn on to better understand and predict alcohol-related harms associated with automobile travel. The first comes from the drug and alcohol prevention literature that focuses the availability of alcohol and the unhealthy consequences of alcohol use and the behaviors that surround its use (see, for example, the large body of work associated with Gruenewald, 2007; Gruenewald, et al., 1996; Gruenewald, Mitchell, & Treno, 1996; Stockwell & Gruenewald, 2004; Treno et al., 2000). The second comes from sociology and criminology and is based on routine activities theory (Cohen & Felson, 1979) and emphasized by others to focus on the influence of drinking establishments (see Bouffard et al., 2007; Roncek & Bell, 1981; Roncek & Maier, 1991).

The prevention literature has historically drawn on "availability theory" which perhaps overly deterministically has emphasized that the more that alcohol is readily available, the more it will be consumed, resulting in more alcohol-related harms. Early adaptations of the theory and research surrounding it were perhaps overly simplistic ignoring the many different uses of alcohol and the wide variety of contexts in which it is used. The policy implications of the theory and research are clear though: limiting the availability of alcohol by virtually any means (e.g., increase cost, regulate distribution areas and hours of sales, etc.) is likely to decrease the social harms associated with alcohol (Single, 1988).

Expanding availability theory to form what they call routine drinking activities theory (see also Gruenewald et al., 1996; Gruenewald, Mitchell, & Treno, 1996; Livingston et al., 2007),

Stockwell and Gruenewald (2004) offer four basic propositions related to alcohol availability, consumption, drinking patterns, and alcohol-related harms. Relevant to this inquiry is the second proposition as it is related to alcohol availability and alcohol-related harms (in this case automobile crashes). It asserts that

Greater availability of alcohol in a society will directly affect alcohol-related harm when such changes affect the distribution of “routine drinking activities”; behaviors that drinkers engage in when consuming alcohol (e.g. drinking at bars vs. at home; drinking socially vs. alone). (Stockwell & Gruenewald, 2004, p. 217).

Applying their ideas to the issue of alcohol outlets and automobile crashes, the basic prediction is that an increase in alcohol outlets (availability) will lead to increased harms (crashes) when the presence of the outlet impacts the “routine drinking activities” of members of society, what Livingston and colleagues (2007) call a “proximity effect”.

The focus of routine drinking activities theory, then, is on the factors that shape the relationship between availability, consumption, and harms such as alcohol-related crashes. Availability is important because it affects one key dimension of the occurrence of alcohol-related crashes—the existence of drunk drivers or the offender. However, as Gruenewald (2007) and others have argued, “the theoretical foundation of outlet studies have not been developed fully” (Livingston et al., 2007, p. 560). Thus, while Stockwell and Gruenewald’s (2004) theory advances theory beyond availability and alcohol-related harms, it remains unclear what factors shape the ability of alcohol availability to “affect the distribution of routine drinking activities” upon which alcohol-related crashes are conditional (Stockwell & Gruenewald, 2004, p. 217).

As some scholars have noted, the use of term “routine activities” is reminiscent of sociology and criminology’s routine activities theory (see Bouffard et al., 2007). In fact, some suggest the theorists may be moving toward integrating criminological theory of routine activities with availability theory (Livingston et al., 2007). Only a few studies that we are aware of have explicitly bridged these two similar bodies of literature (see Livingston et al., 2007) and brought the prevention literature into the criminological literature (Bouffard et al., 2007; Livingston et al., 2007). We suggest that such an integration can be fruitful and now elaborate on how routine activities theory can be utilized to better understand the relationship between alcohol outlets and alcohol-related crashes.

As originally developed in sociological criminology (Cohen & Felson, 1979), routine activities theory was developed to explain changes across time in levels of direct contact predatory crimes in the United States by focusing on what has to happen in order for a crime to occur. Drawing on the work of Hawley (1950), Cohen and Felson (1979) argued that much of existing theory in criminology ignored “the fundamental human ecological character of illegal acts as *events* which occur at specific locations in *space and time*” (p. 598 emphasis in the original). They further argued that when a motivated offender and a suitable target come together in time and space, where there lacks capable guardians, the opportunity exists for crimes to occur—it is then a theory of opportunity. They grounded the theory in an understanding of how the changing patterns of daily routine interactions and movements had led to changes in the coming together in space and time of these three factors. Since its introduction, a number of theoretical developments have also occurred (see Hollis et al., 2011; Hollis, Felson, & Welsh, 2013; Felson & Boba, 2010). For example, routine activities theory has been expanded to include consideration of crime types other than direct contact predatory crimes (see Felson, 1987) and has frequently used an area-level analyses to examine “hot spots” of crime (see Sherman, Gartin & Beurger, 1989) and the effect of businesses, such as bars on crime levels (see Roncek & Maier, 1991).

Researchers interested in developing and examining a routine activities theory of alcohol-related crashes cannot simply take the theory as it exists in criminology to explain predatory

offenses as a whole. Consider the concepts of motivated offender and guardianship. We are first struck by the very nature of the dependent variable as it not like predatory crimes as commonly understood, be they violent or property in nature. Very few people, we imagine, are motivated to drink until intoxicated, secure an automobile to obtain the valued objective—driving into a building, tree, ditch, person(s), or other automobile. Rather what is most useful is to think of the offender in terms of the underlying assumptions of the theory. These are that individuals make the decision to offend using a level of rationality. In the case of alcohol-related crashes, though rationality is affected by alcohol, a decision is being made. Not to cause harm but simply, perhaps to get home (see Bouffard & Exum, 2013; Bouffard, Niebuhr, & Exum, 2017).

Also related to the concept of the motivated offender is the fact that in the research on routine activities, the presence of motivated offenders has, by and large, has been considered a given. That is, given a suitable or attractive target in the absence of a capable guardian, there is an ample number of potentially motivated offenders—be that measured by the total population at risk, males, young males, or any other specific potentially motivated demographic group. Note that we carefully use the phrase “potentially motivated offender” and most research in this vein fails to distinguish between potential offenders from motivated offenders. Mustaine and Tewksbury (2009) take issue with this combination or lack of distinction in their efforts to test routine activities theory using sex offenders. They argue that at the aggregate or neighborhood level (i.e., census tracts), more than just a large number of registered sex offenders (potential offenders) are needed for the commission of a sex crime. Rather it is the interaction of the number of potential offenders with readily available temptation in the community (e.g., alcohol outlets and sexually oriented businesses) that best predicts crime rates. In this sense, we might think more about the demographics of people who frequent certain types of establishments and their drinking and driving routines, which are already developing (see Gruenewald et al., 1996).

While applying the concepts of the theory literally to the problem of alcohol-related crashes is problematic, two aspects of this theory are key to developing an understanding of the role of alcohol outlets in alcohol-related crashes. The first is the emphasis in the theory on seeing crimes as events that occur in time and space. If we think of alcohol-related crashes as events that occur in time and space, it is clear that individuals who have been drinking are essential to the occurrence of alcohol-related crashes. However, other environmental factors are also necessary for a crash to occur and these are factors that cause crashes in general such as roadways, traffic, vehicle, and atmospheric conditions among others (National Highway Traffic Safety Administration [NHTSA], 2008; see also Gusfield, 1996; Haddon, 1972; Stringer, 2018a). Thus, some drivers and areas will have greater crash risks/frequencies apart from alcohol and its availability.

A second aspect of routine activities theory, guardianship, is also necessary when considering alcohol-related automobile crashes. While the original work by Cohen and Felson (1979) did not define capable guardians which has resulted in some controversy over time, more recent work has proposed a definition as “the presence of a human element which acts—whether intentionally or not—to deter the would be offender from committing a crime . . .” (Hollis, Felson, & Welsh, 2013, p. 76). Two forms of guardianship can be considered here—formal and informal. In terms of formal control, Stockwell and Gruenewald (2004) argue that physical availability of alcohol is affected by liquor laws and their enforcement. This includes laws such as age restrictions on drinking and closing times. Although the term capable guardian usually refers to ordinary citizens as the police are not likely to be present when a crime occurs (Felson & Boba, 2010), the presence of police officers would be an extreme deterrent and they would also qualify as a capable guardians (Hollis et al., 2013). As such, variation in the level of police presence across areas may shape the relationship between alcohol outlets and DUI crashes as potentially motivated offenders may either choose another type of transportation, alcohol outlet, or stay home rather than drink and drive in areas with increased police presence. In addition, informal social control at bars and taverns may play a role in understanding the relationship between alcohol outlets and

alcohol-related crashes. Specifically, variation in social norms governing drinking and driving as well as a lack of intimate handlers who impose informal control (Bouffard et al., 2007; Felson, 1987) may well affect the level of drinking and driving.

Routine activities theory then encourages thinking about alcohol-related automobile crashes as events that occur in time and space. In order for them to occur there must be an inebriated individual, with access to a vehicle under varying atmospheric and road conditions, in a context of a certain level of law enforcement presence and informal social control. As we will see in the following, existing research on density/number of alcohol outlets and alcohol-related crashes incorporates few of these factors in either the theoretical discussion or analysis.

There are now several cross-sectional studies that examine the relationship between alcohol outlets and alcohol-related automobile crashes. Generally, these studies find a positive relationship between on-premise alcohol outlet density and alcohol-related crashes in the area (Gruenewald et al., 2010; Gruenewald & Johnson, 2010; Gruenewald et al., 2002; Gruenewald et al., 1999) or adjacent area (Morrison, Ponicki, Gruenewald, Wiebe, & Smith, 2016). There are some exceptions to these findings (see Cameron, 2013), and Ponicki and colleagues (2013) conclude that “Although these models have identified statistically well-supported associations between alcohol outlet densities and injury crash rates, the estimated effect sizes are too small to recommend physical availability reductions as a powerful policy to reduce traffic injuries” (p. 13). Furthermore, studies of off-premise-licensed alcohol outlets have found mixed results in that some find they are related to decreases in DUI crashes (Morrison et al., 2016), while others indicate they are related to increases (Cameron, 2013).

While the majority of the research into the relationship between alcohol outlets and DUI-related crashes has been cross-sectional, a few have used longitudinal designs. Treno and colleagues (2007) conducted the first study we are aware of that employed a longitudinal design. Using California ZIP codes 1995–2000, they found that off-premise alcohol outlets and on-premise outlets defined as bars were positively related to alcohol-related crashes; however, on-premise outlets, classified as restaurants, had no impact on alcohol-related crashes and a positive effect on overall crashes. Ponicki et al. (2013) conducted a similar study using California ZIP codes from 1999–2008. This study found, and thus controlled for, spatial autocorrelation between adjacent ZIP codes as well. Their results were similar to those of Treno and colleagues (2007) for on-premise outlets, but off-premise outlets were negatively related to alcohol-related crashes. In addition, McCarthy (2003) found that off-premise outlets were negatively related to both fatal and nonfatal alcohol-related crashes, although on-premise outlets only showed a statistically significant positive relationship with nonfatal alcohol-related crashes.

It is important to note the theoretical importance of spatial autocorrelation in the social context of alcohol-related crashes when utilizing small units of analysis that increase the probability drivers will move outside of the area of analysis prior to crashing (see Cameron, 2013; Gruenewald et al., 2010; Gruenewald & Johnson, 2010; Ponicki et al., 2013; Treno et al., 2007). Interestingly, Morrison and colleagues (2016) illustrate the need to control for the surrounding area and suggest that alcohol outlets may have a greater influence on the surrounding area than areas where the actual alcohol outlets exist. Specifically, their findings (Morrison et al., 2016) indicate there is no relationship between bars and alcohol-related crashes in local areas (mean land area = 0.5 km²) but a significant positive relationship in adjacent areas.

Another characteristic of the geography and ecology that affects the “opportunity” for alcohol-related crashes is the background crash risk (such as roadway, vehicle, traffic, and weather conditions). While many have attempted to capture these using measures such as the percent of roads that are primary, traffic flow, road network density (Giacopassi & Winn, 1995), and Class 1 or 2 highway (Ponicki et al., 2013), locating direct measures of many of the other factors are quite difficult to come by at the geographic level. In fact, it is often hard to measure conditions of the driver, and the road as well. Is there a reasonable way to capture and control for key

dimensions of the opportunity at an aggregate level when we look at the effect of alcohol outlet density? To this end, we follow the logic of Morrison et al. (2016, p. 242) and argue that controlling for other types of crashes (nonalcohol-related crashes) “serves as an estimate of background crash risks due to road conditions, prevailing weather, traffic volume, driver behavior or other factors” (see also Ponicki et al., 2013).

Another dimension surrounding opportunity that receives some attention in the literature is guardianship. Several prior studies on the alcohol outlet and crash relationship included controls for measures that involve formal control such as the number of police per mile or police per capita (Giacopassi & Winn, 1995) and DUI arrests (McCarthy, 2003). Although police per mile and per capita were not significantly related to crash numbers (Giacopassi & Winn, 1995), McCarthy (2003) found that DUI arrests are significantly and negatively related to DUI crashes (see also Stringer, 2019). However, despite the considerable theoretical relevance of guardianship, no prior research has examined the interaction between alcohol outlets and DUI arrests when predicting alcohol-related crashes. That is, theory would suggest that the presence of alcohol establishments that encourage social drinking and that often seem to require driving increases alcohol-related harms such as crashes. However, active police enforcement may signal capable guardians on the roads that inhibit drinking and driving and alcohol-related crashes.

In conclusion, the extant literature on alcohol outlets indicates that increases in alcohol availability, particularly availability for on-premise consumption, may contribute to alcohol-related crashes. However, while there is an increase in concern about theoretical models and measurement of factors beyond availability that may contribute to “routine drinking activities” (see Stockwell & Gruenewald, 2004), even when other factors are included there is often little said about their inclusion and they are not examined as moderators. As such, using the logic of Cohen and Felson’s (1979) routine activities theory, we argue that the opportunity for an alcohol-related crash requires the coming together in time and space of an inebriated individual motivated to drive, with access to a vehicle, in the context where there is a lack of capable guardianship. As these factors can vary by local context, three questions are the focus of this study:

1. Are the number of alcohol outlets related to alcohol-related crashes within and around the census tracts they are found in?
2. To what extent do other factors that are causally related to crashes, as measured by non-alcohol-related crashes, moderate the relationship between alcohol outlets and alcohol-related crashes?
3. Are DUI arrests directly related to alcohol-related crashes and do they moderate the relationship between alcohol outlets and alcohol-related crashes?

Method

To address the research questions, this inquiry analyzed census tracts within the cities of Norfolk and Virginia Beach, VA from 2013 through 2016. A total of 176 census tracts were used in the analysis out of the 180 that exist in the two cities. Four census tracts were excluded from the analysis. Two tracks were excluded from the analyses because they have no land within them and only contain water. While alcohol-related crashes and DUI arrests could theoretically occur in boats on the water, the lack of land precludes the existence of alcohol outlets which are central to the analysis here. In addition, two census tracts for the Naval base were also excluded because they have an unstable population, many of which reside on ships that may or not be in port, and DUI offenses in these areas are likely handled by the military police and not represented in the Norfolk Police Department data (see White, Gainey, & Triplett, 2015).

Table 1. Descriptive Statistics ($n = 176$).

	<i>M</i>	<i>SD</i>	Min	Max
Alcohol-related crashes per 1,000 of the population (LN)	0.97	0.72	-1.33	3.60
Bars/taverns (LN)	0.57	0.70	0	3.22
Restaurants (LN)	1.15	1.04	0	4.16
DUI arrests (LN)	2.22	0.93	0.69	6.82
Nonalcohol crashes (LN)	4.8	0.85	2.2	6.86
100% Urban	0.97	0.18	0	1
Median age	35.61	7.53	17	57
SES component	11.29	0.91	7.85	13.30

Note. LN = logarithmic transformation; DUI = driving under the influence; SES = socioeconomic status.

Data

This project combined data from several sources to measure the dependent, independent, and control variables of interest. Data were obtained from the Virginia Department of Transportation's (VDOT) online data visualization software to obtain information on the location of automobile crashes (VDOT, 2017a). These data provide information on all automobile crashes within the commonwealth of Virginia and include measures of crash severity ranging from property damage only, nonvisible injury, visible injury, ambulatory injury, and fatal injury. In addition, other information such as the police-reported alcohol involvement and location of the crash (latitude and longitude) is also provided.

Data from the Virginia Alcoholic Beverage Control (ABC) Authority (2016) were used to measure alcohol outlets within these cities. These data provide the location of all licensees within the commonwealth of Virginia with a license to sell alcohol. Licenses are broken into three categories of banquet, retail licenses, and industry licenses. Retail licenses are also divided into subcategories of on-premise, off-premise, and on- and off-premise outlets. Data on DUI arrests were obtained directly from the Norfolk and Virginia Beach Police Departments. In the state of Virginia, drivers can be arrested for DUI if their blood alcohol concentration (BAC) is above .08. These data included all DUI arrests in the cities and the location by hundred blocks (e.g., "1700 Cool Avenue"). Sociodemographic data were obtained at the tract level from the 2015 American Community Survey 5-Year Estimates (U.S. Census Bureau, 2015).

Measures

Table 1 presents descriptive statistics for the dependent, independent, and control measures included in this project. The dependent variable is alcohol-related crashes per 1,000 of the population in each census tract.¹ The use of the crash rate per population accounts for varying exposure across census tracts and has been used by prior studies (see e.g., Treno et al., 2007). While others may prefer to utilize a count variable and perform a Poisson or negative binomial analysis (see e.g., DeMichele & Payne, 2013; DeMichele, Lowe, & Payne, 2014), the ability of these generalized linear models (GLM) to adequately incorporate spatially lagged predictors to account for these disturbances is very limited both statistically and by software availability. Thus, given the plethora of prior research that illustrated the importance of spatial spillover as well as our research questions, we chose not to use a GLM approach.

This project focused on alcohol outlets with licenses for on-premise consumption because spatial assessment of off-premise outlets and crashes can be difficult as consumers will likely travel to another location prior to consuming alcohol acquired from an off-premise outlet (see

Morrison et al., 2016). In addition, like many states, to serve alcohol, establishments must sell a certain amount of food and thus the data do not provide a clear distinction between restaurants and bars. To discern places designated as restaurants versus those that emphasize alcohol and drinking, this measure was coded manually. Generally, restaurants have earlier closing times than bars and taverns. While family dining is usually completed in the early evening (e.g., 5:00 p.m. to 8:00 or 9:00 p.m.), drinking often occurs into the late evening and early hours of the morning. In Virginia, all establishments with an on-premise license to sell alcohol must close by 2:00 a.m. (Virginia Administrative Code, 1994). Therefore, we operationalized bars/taverns as those establishments that remain open until 2:00 a.m. to cater to the drinking customer and restaurants as those that close earlier in the evening. The former variable is expected to be positively related to alcohol-related crashes, the later (as family-oriented nonalcohol-related businesses) are likely to have no effect or even a negative effect on alcohol-related crashes.

DUI arrests were used as a measure of police presence and DUI enforcement to compare areas that may be more and less “guarded” against DUI by police. It is measured as the frequency count of DUI arrests within each census tract.¹ To be clear, we have no intention of empirically testing routine activities and acknowledge this is not how those testing this theory would be likely to operationalize a direct measure of this concept (see Hollis et al., 2013). However, as we are applying the logic of routine activities theory to help inform and possibly aid in the further development of theory of routine drinking activities, we argue that this measure does indirectly capture this idea as it relates to diversity in police presence across place and the social context in which routine drinking activities and crashes occur.

With that said, there is significant literature illustrating that policing varies greatly across place (see e.g., Klinger, 1997; Koper, 1995; Sobol, Wu, & Sun, 2013; Taniguchi & Salvatore, 2018; Weisburd & Telep, 2014; Wells, Falcone, & Rabe-Hemp, 2003), and police attention to DUI is no exception to this diversity (Erickson et al., 2015). However, unlike other crimes, DUI offenses are very rarely detected by citizens’ reports, crashes, and so on that result in an officer responding to an area (Snortum, et al., 1990). Instead, DUI offenders are generally located through an officer’s own observations of erratic driving or during ordinary traffic stops for other offenses (Snortum, et al., 1990). Thus, the prior presence of police officers in an area makes DUI detection and arrests possible, and arrest is used as an indirect measure of police presence that may “deter the would-be offender from committing a crime . . .” (Hollis et al., 2013, p. 76).

In addition, because driver, vehicle, and environmental factors might all contribute to automobile crashes, following Morrison and colleagues (2016) and Stringer (2018b, 2019), we controlled for these factors with a global measure of the frequency count of nonalcohol-related crashes.¹ This measure is used as a proxy for a plethora of other contextual factors that can cause automobile crashes aside from the blood alcohol content (BAC) of the driver (see also, Gusfield, 1985, 1996; Haddon, 1972; Stringer, 2018a) and is used to examine how drinking drivers interact with other contextual factors in time and space that make the crash possible.

Several sociodemographic control variables were also included based on the prior literature. Specifically, because alcohol consumption and alcohol outlets are greatest in areas with lower socioeconomic status (SES; Morrison, Gruenewald, & Ponicki, 2015; Pollack, Cubbin, Ahn, & Winkleby, 2005), a composite measure of the SES of each neighborhood was included. This measure of SES included percent below the poverty level, percent married, percent with a bachelor’s degree or more, the percent Caucasian, unemployment rate, and the median household income.² An exploratory factor analysis showed that these items measure one underlying construct, a singular vector within the matrix, so they were combined into a weighted composite measure of SES.² As DUI (Drew, 2010) and alcohol-related crashes (Peck, Gebers, Voas, & Romano, 2008) are most prevalent among young people, the median age was also controlled. This project also incorporated a control for the population that lived in an urban area similar to

others who have found it to be a significant predictor of alcohol-related crashes (see e.g., Zwerling et al., 2005). As the initial data exploration revealed that 97% of the sample lived in census tracts that were 100% urban, this measure was operationalized as a dichotomous measure which compared census tracts that are 100% urban to those that are less than 100% urban.

Finally, we considered including a control for city. Preliminary analyses suggested that Norfolk and Virginia Beach are different cities in terms of the variables examined in this study. For example, Virginia Beach is larger in terms of population size and geography, as a tourist city has more restaurants and bars, and makes more DUI arrests than Norfolk. In large part, because of the large geographic size of the city, the number of alcohol-related crashes is larger in Virginia Beach (1,495 alcohol-related crashes in Virginia Beach compared with 1,248 in Norfolk across the 3 years examined). Average levels of resident SES is also significantly higher in Virginia Beach ($M = 11.71$) than in Norfolk ($M = 10.76$). While the two cities are somewhat different, z tests of the main direct effects of the variables examined are remarkably consistent across the two cities. Only the negative relationship of SES and alcohol-related crashes is statistically stronger (more negative) in Virginia Beach than in Norfolk (where it is not statistically significant), but even in Virginia Beach, the effect is relatively small (independent $r^2 = .01$). The dummy variable for city is also not statistically significant, so to maintain an adequate sample size and degrees of freedom, the data were pooled.

Spatial Analysis

The crash data contained latitude and longitude information that were used for geocoding. However, the DUI arrest and alcohol outlet data required the use of an address locator to facilitate geocoding of these data. The address locator was able to geocode approximately 90% of DUI arrests, and the remaining 10% were located manually through maps and visual inspection. While all the crash and alcohol outlet data were successfully geocoded, about 4% of the DUI arrest data were unusable due to ambiguous or missing address information. However, there did not appear to be any systematic distinctions between these cases and those that were included other than the location and therefore do not appear to be a threat to the validity of the measure.

The extant literature suggests that spatial autocorrelation may play a substantive role in the alcohol outlet and alcohol-related crash relationship (see Morrison et al., 2016). Therefore, a spatial weight matrix was created to assess autocorrelation among the census tracts. The weight is a binary ($N \times N$) contiguity matrix which measures borders along edges and corners (Queen's case in chess) among neighboring census tracts. Furthermore, row standardization (each weight was divided by its row sum) was used to account for diverse polygon size of the census tracts. Descriptive statistics for the weights are minimum (2), maximum (12), and mean (5.84), and the histogram indicates they are normally distributed. Thus, the lowest number of neighbors was 2, the highest was 12, and the average was approximately 6. A Moran's I analysis indicates that there is significant autocorrelation among census tracts on alcohol-related crash rate (Moran's Index = .309, Expected Index = -.006, Variance = .002, z score = 7.695, $p < .001$).

Multivariate Analysis

As there is significant spatial dependence/autocorrelation in alcohol-related crash rate, further diagnostics were performed, and the analytical method was amended to account for spatial dependencies in the residuals to prevent violations of the assumptions of independence and heteroscedasticity among the model residuals (see Ward & Gleditsch, 2018). Specifically, a Moran's I analysis used the aforementioned continuity matrix weight to explore autocorrelation among the residuals from a preliminary ordinary least squares (OLS) model. While the value of Moran's index indicates that there is a low level of autocorrelation (Moran's I =

.091, E.I. = $-.007$, $SD = .046$, $z = 2.143$, $p < .05$), it is statistically significant and indicative of autocorrelation among the residuals. Therefore, this project utilized spatial regression models that account for spatial dependence as recent research has done (see Morrison et al., 2016; Ponicki et al., 2013).

Spatial lag models were used for the multivariate analysis as they provide superior fit to these data. These models account for spatial interdependence by including the frequency of alcohol outlets both within and in neighboring census tracts with the weighted mean of these values into the right side of the regression equation (Ward & Gleditsch, 2018). Thus, spatial lag equation is as follows:

$$y = X\beta + \mu WX + \varepsilon$$

where μWX is the spatially weighted matrix mean of alcohol outlets in neighboring areas to the focal area y , β is the regression coefficient, X is the parameter value, and ε is the error or residual term (see Bernasco & Elffers, 2010). In contrast, the spatial error model reflects autocorrelation among unmeasured missing variables (Ward & Gleditsch, 2018), and the superior fit of the spatial lag model indicates that alcohol outlets in neighboring areas have more influence on alcohol-related crashes than any omitted variables.

All models were weighted by the previously created spatial weight matrix. Because no data were missing, the sample size is constant at 176. Multicollinearity was assessed with variance inflation factors (VIF) and a correlations matrix and none was detected (e.g., all VIF < 2.3). Furthermore, residual scatterplots and Q-Q plots indicate that assumption of linearity was met. While additive models are presented in Table 2, the remaining tables present the multiplicative models and one-way analysis of variance (ANOVA) models which compare additive and multiplicative models. The multiplicative models test the theoretical interactions of alcohol outlets, DUI enforcement, and other factors that contribute to crash risk.

Findings

Table 2 presents additive spatially lagged regression models predicting alcohol-related crashes per 1,000 population. Model I presents parameter estimates for alcohol outlets while controlling for alcohol outlets in neighboring census tracts. These factors account for approximately 17% of the variance in alcohol crashes per 1,000 population. Although the coefficient for restaurants and bars/taverns is not significantly related to the dependent variable in this model, increases in bars and/or taverns in neighboring areas are related to an increase in alcohol crash rate of about 53% for each percentage increase in bars/taverns in neighboring areas. However, the spatial lag parameter for restaurants was not significantly related to the criterion. Thus, these results indicate that the number of restaurants in neighboring census tracts is not significantly related to alcohol crash rate in the focal area. While the spatial lag improves model fit compared to the OLS model, the significance of the Wald statistic indicates that it has not removed all of the spatial effects.

Model II introduces the additional independent variables of theoretical interest. The proportion of variance explained by this model is about 39%, and the Akaike information criterion (AIC) was reduced indicating superior model fit to these data. The additional theoretical measures account for an additional 22% of the variance in alcohol crash rate compared to Model I, which only examines alcohol outlets. There is little change in parameter estimates for bars/taverns in this model; however, restaurants are now significant and negatively related to the criterion, and increases in the restaurant percentage are related to a 13% decrease in alcohol-related crash rate. This is suggestive of a suppression effect on the restaurant estimates by the introduction of the nonalcohol-related crashes (measuring other causes of crashes), which increases the partial correlations for the restaurant parameter ($-.01$ to $-.13$).

Table 2. Spatial Regression Model Results Predicting DUI Crash Rate.

	Model I	Model II	Model III
Bars/taverns	0.17 (.10)	0.13 (.09)	0.12 (.08)
Restaurants	-0.01 (.07)	-0.13* (.06)	-0.11 (.06)
DUI arrests	—	-0.01 (.06)	-0.03 (.06)
Nonalcohol crashes	—	0.46*** (.05)	0.45*** (.06)
SES	—	—	-0.07 (.06)
Median age	—	—	0.01 (.01)
Urban	—	—	0.77*** (.23)
Constant	0.47*** (.12)	-1.40*** (.26)	-0.18 (.77)
Bar spatial lag	0.53* (.21)	0.49*** (.13)	0.51*** (.13)
Restaurant spatial lag	0.09 (.13)	—	—
Wald spatial test	18.88***	13.72***	15.67***
AIC	365.29	312.64	307.25
BIC	384.32	334.83	338.96
R ²	.17	.39	.43

Note. DUI = driving under the influence; SES = socioeconomic status; AIC = Akaike information criterion;

BIC = Bayesian information criterion.

* $p < .05$. *** $p < .001$.

The coefficient for DUI arrests is negative as predicted, though it failed to achieve statistical significance. Alternatively, nonalcohol-related crashes are an important predictor of alcohol crash rate, and the model predicts that each percentage increase in nonalcohol crashes is related to a 46% increase in alcohol-related crash rate. This finding makes sense given that nonalcohol-related crashes serves as a proxy for the host of “unmeasured” variables—road conditions and design for example—that very likely increase the amount of crashes of any type. Model III adds the additional control variables with little change in the theoretical variables of interest except for the reduced statistical significance of restaurants.

With the exception of Model I, which is additive and included for comparative purposes, Table 3 presents multiplicative interaction models, which examine theoretical interaction between the frequencies of bars/taverns, nonalcohol crashes, and DUI arrests within each census tract. Two-way interactions were examined in Models II and III followed by a three-way interaction between all three variables in Model IV. Models II, III, and IV have lower AIC and greater r^2 values than Model I, which are indicative of superior model fit and greater explained variance compared to the additive model.

To statistically examine the model fit between the additive and multiplicative models, three one-way ANOVA models were estimated that compare the additive model (Model I) to the theoretical multiplicative models (Models II, III, and IV). The results from these analyses are presented in Table 4. The statistically significant F -test indicates that two of the three multiplicative theoretical models achieve a better statistical fit to these data than the additive model. Although the model testing interaction between bars/taverns and nonalcohol-related crashes did not fit better than the additive model, the three-way interaction model that included a moderation by non-alcohol-related crashes did lead to significant improvements in model fit.

The main coefficients in Model II indicate that more bars and taverns are associated with fewer alcohol-related crash rate when DUI arrests are zero and DUI arrests are negatively related to alcohol-related crashes when there are no bars or taverns in the census tract. The interaction term, however, is strong and positive suggesting that these slopes significantly change with one another. Figure 1 illustrates this interaction by plotting alcohol-related crash rate on the y axis, bars/taverns on the x axis, and plotting separate lines for the median of the lower, middle, and

Table 3. Spatial Regression Models Results Predicting DUI Crash Rate.

	Model I	Model II	Model III	Model IV
Bars/taverns	0.04 (.07)	-0.48* (.19)	-0.80 (.44)	2.74 (1.29)
DUI arrests	-0.05 (.06)	-0.16* (.07)	-0.07 (.06)	0.34 (.33)
Nonalcohol crashes	0.43*** (.06)	0.44*** (.06)	0.36*** (.07)	0.72*** (.21)
SES	-0.10 (.06)	-0.10 (.06)	-0.11 (.06)	-0.09 (.06)
Median age	0.01 (.01)	0.01 (.01)	0.01 (.01)	0.01 (.01)
Urban	-0.82*** (.23)	-0.88*** (.23)	-0.88*** (.24)	0.90*** (.23)
Bars × DUI arrests	—	0.14** (.05)	—	-0.91* (.42)
Bars × Nonalcohol crashes	—	—	0.17† (.09)	-0.58* (.28)
DUI arrests × nonalcohol crashes	—	—	—	-0.10 (.15)
DUI arrests × nonalcohol crashes × bars	—	—	—	0.19* (.08)
Constant	0.31 (.73)	0.58 (.72)	0.84 (.77)	-0.83 (1.22)
Bar spatial lag	0.51*** (.13)	0.48*** (.13)	0.52*** (.13)	0.49***
Wald spatial test	15.41***	14.04***	16.52	14.99***
AIC	308.89	302.59	307.23	301.71
R ²	.41	.44	.43	.46

Note. DUI = driving under the influence; SES = socioeconomic status; AIC = Akaike information criterion.

† $p = .055$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Table 4. One-Way ANOVA Comparing Additive and Multiplicative Models From Table 4.

	Residual df	RSS	df	Sum of squares	F
Model I	169	10.58	—	—	—
Model II	168	9.97	1	0.60	10.26**
Model III	168	10.43	1	0.15	2.29
Model IV	165	9.53	4	1.05	4.55**

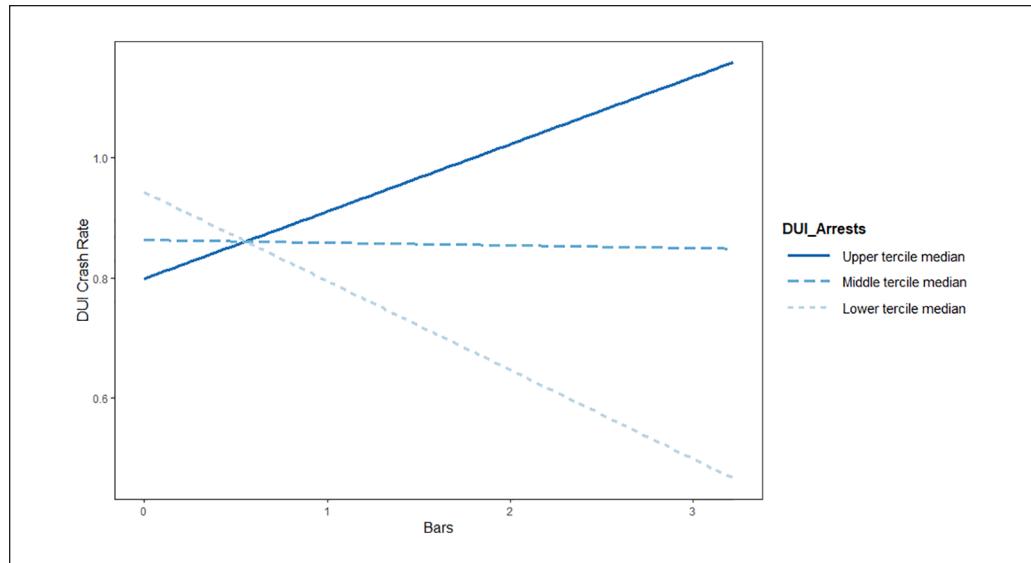
Note. ANOVA = analysis of variance; RSS = residual sum of squares.

** $p < .01$.

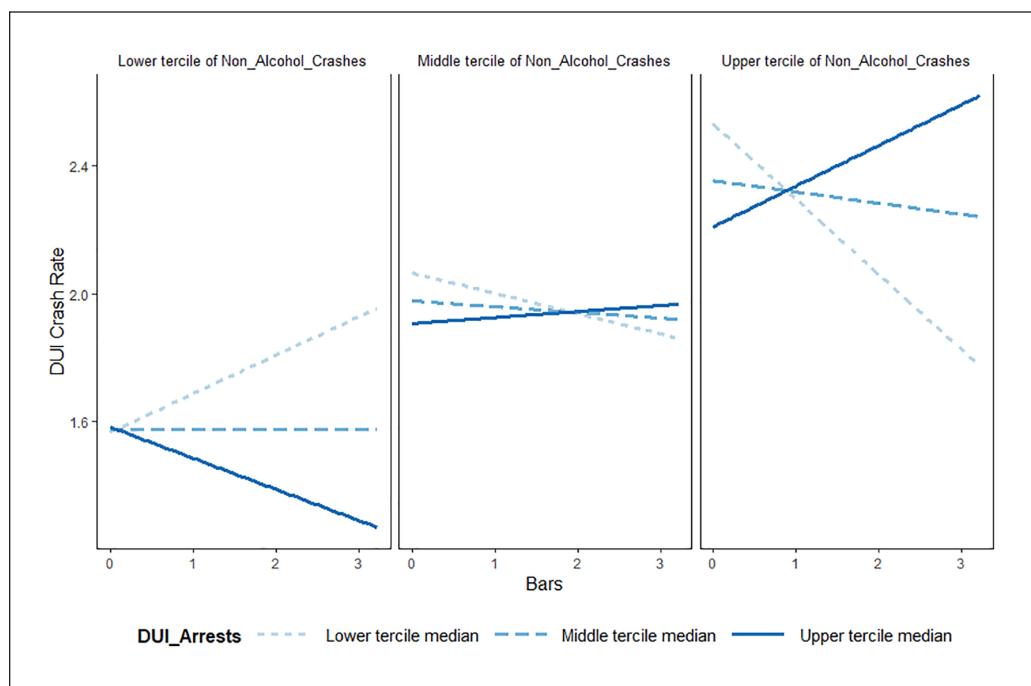
upper terciles of the DUI arrests distribution. Thus, bars and taverns are related to the greatest increases in alcohol-related crash rate when there are high levels of DUI arrests (see Model II), and that rate of increase is dampened in those areas with lower DUI arrests. While this may appear counterintuitive, future models help to explain this discrepancy.

Model III estimates interaction model for nonalcohol-related crashes with bars and taverns. Although the interaction between bars/taverns and nonalcohol-related crashes approached significance ($p = .055$), it failed to achieve statistical significance, and the ANOVA results suggest that this model is not significantly improved by including this interaction. However, the parameter estimates suggest that when there is a greater number of nonalcohol-related crashes near a bar/taverns, there may be a small but insignificant increase in crashes.

The three-way interaction between bars/taverns, nonalcohol crashes, and DUI arrests presented in Model IV indicates that there is significant moderation among all three of these predictors. This interaction is also plotted using terciles in Figure 2. Similar to Figure 1, alcohol-related crash rate, bars/taverns, and the DUI arrest terciles make up the y axis, x axis, and the three lines, respectively. However, this figure further illustrates these factors across the lower, middle, and upper terciles of the nonalcohol crash distribution. While this additional interaction term certainly adds to the complexity of bar/tavern and crash rate relationship, it also helps to explain how this relationship varies greatly across other contextual factors. Figure 2 illustrates that when

**Figure 1.** Bar/tavern and DUI arrest interaction.

Note. DUI = driving under the influence.

**Figure 2.** Three-way interaction of bars/taverns, DUI arrests, and non-DUI crashes.

Note. DUI = driving under the influence.

nonalcohol crashes are low (see far left side of the figure), increases in bars/taverns are related to increased alcohol-related crashes when DUI arrests are also low; however, when DUI arrests are high, increase in bars/taverns is negatively related to alcohol crash rate. Conversely, on the far right of the figure which illustrates high levels of nonalcohol-related crashes, the interaction between bars and DUI arrests is similar to Figure 1 in that the highest crash rate is predicted in areas with high DUI arrests and bars. It should also be noted that the intercept is higher in areas with greater nonalcohol-related crashes—that is, in areas where other factors that contribute to crashes (e.g., traffic volume, bad road conditions, speed limits, etc.) are highest. Thus, there is a higher baseline level of alcohol crashes when there are greater nonalcohol crashes independent of bars and DUI arrests.

In sum, the number of alcohol outlets in each area is related to alcohol-related crash rate; however, the relationship varies greatly across the types of alcohol outlets (e.g., bars/taverns vs. restaurants). Furthermore, there is also significant moderation of the alcohol outlet/alcohol-related crash rate relationship by DUI arrests. The results also show that other factors such as road conditions and design, traffic flow, and speed limits (all measured by nonalcohol-related crashes) are related to alcohol-related crashes as well. While this may appear obvious and almost tautological (crashes cause crashes), the use of nonalcohol-related crashes is a useful proxy for a plethora of other factors other than alcohol that cause automobile crashes. Furthermore, while the bar/tavern and alcohol crash rate vary significantly across both DUI enforcement and other factors that cause crashes as expected, it also appears that the baseline (intercept) of alcohol-related crashes varies greatly across other contextual factors which may be independent of alcohol availability, although their role in the process is difficult to discern here.

Discussion

A major goal of this article was to link the literature from prevention theory and research on “alcohol availability” to the larger theory of routine activities. The voluminous research from the prevention field brings a very focused literature specific to alcohol and its problematic consequences. Routine activities theory brings a very general system of concepts that linked together have been found to predict and explain violent and other predatory crimes such as burglary and theft (see Hollis-Peel, Reynald, van Bavel, Elffers, & Welsh, 2011; Pratt & Cullen, 2005). Only rarely has the theory been tied to drinking and driving and its potential consequences. To our knowledge, the only real attempt to bring these two literatures together was done by Bouffard and colleagues (2007). They recognized that work in the alcohol prevention literature, notably by Gruenewald and his colleagues, had moved from problems stemming from the sheer availability of alcohol to a more refined theory focused on “routine drinking activities.” To criminologists, this approach obviously resonates well with Cohen and Felson’s (1979) more general “routine activities theory” and in particular lifestyle routine activities. Lifestyle routine activities theory emphasizes the patterns of everyday life that make crime and in particular victimization more likely as they shape opportunity (Felson, Savolainen, Berg, & Ellonen, 2013; Felson, 1994; Lemieux & Felson, 2012).

The findings in this study support the need to consider factors that affect “opportunity” for alcohol-related crashes to occur as routine activities theory suggests research should. In terms of the first research question, regarding the relationship of the number of alcohol outlets to alcohol-related crashes within and around the census tracts, the focus was on the role of access to alcohol as a key factor in the opportunity for alcohol-related crashes. Here, a number of interesting findings emerged. While the main effects of bars and taverns did not achieve statistical significance, the interaction of these alcohol outlets with other contextual measures indicated that their relationship with alcohol-related crashes is dependent on other factors extending beyond alcohol availability. However, consistent with past research (see Morrison et al., 2016), the frequency of

bars in one neighborhood may not be related to alcohol-related crashes in that area, but is related to increases in neighboring areas. This supports the importance of controlling for spatial autocorrelation and DUI offender mobility, and future researchers may wish to use individual-level data to assess the idea that DUI offenders may not crash right away, but rather get some distance away from an alcohol outlet before crashing.

Another interesting finding regarding the role of alcohol outlets emerged from the findings. While alcohol is available at both bars and restaurants, the results indicate these types of alcohol outlets contribute to the alcohol-related crash problem in a very different manner. This diversity is consistent with much of the prior research indicating that these outlet types are not similarly related to alcohol-related crashes (Morrison et al., 2016; Ponicki et al., 2013; Treno et al., 2007) and suggest that alcohol availability may be less important than social setting. While the results for bars are both consistent with much of the prior research (Morrison et al., 2016; Ponicki et al., 2013; Treno et al., 2007) and availability theory, this is not the case for restaurants. Thus, these venues likely play very different roles in the routine drinking activities (Stockwell & Gruenewald, 2004) of the drunk driver. This is not surprising given the differences in social context between bars that sell high amounts of alcohol and therefore generate more drunk drivers (Gruenewald et al., 1999) and have less informal social control (Bouffard et al., 2007; Gusfield, Kotarba, & Rasmussen, 1981; Gusfield, Rasmussen, & Kotarba, 1984; Roncek and Maier, 1991), compared to restaurants which sell less alcohol and represent a more “family-style” environment which is less conducive to heavy drinking and more informal social control of potential drunk drivers.

This study provides empirical support for alcohol availability as an important factor to consider in understanding alcohol-related crashes and the importance of policies aimed at reducing drinking and driving. The findings also suggest that alcohol availability only comprises a portion of a much larger and complex social context that contributes to alcohol-related crashes which is supportive of the second research question. Thus, social and environmental hazards that affect the opportunity for a crash (measured by nonalcohol-related crashes) also come together in time and space after offenders choose to drive, sober, or under the influence contribute to alcohol-related crashes. Although it is often assumed that alcohol-related crashes are caused by an intoxicated driver, known as the assumption of malevolence, this is not always the case (Gusfield, 1985, 1996). In fact, most DUI trips do not lead to alcohol-related crashes (Ross, 1992; Zaloshnja, Miller, & Blincoe, 2013) especially at low BAC levels (Stringer, 2018a). Therefore, the robust effects of the measure of nonalcohol-related crashes are consistent with the multicausal nature of alcohol-related crashes (Gusfield, 1985; Haddon, 1972). As such, a multipronged approach aimed at reducing all crashes, such as improving traffic and road conditions may lead to lower alcohol-related crashes as well.

Furthermore, in terms of our research questions, we also considered the role of guardianship as measured by DUI arrests. Here, DUI arrests did not have the direct effect on crashes illustrated by McCarthy (2003). However, the moderating effects of this measure are consistent with the idea of guardianship put forth by routine activities theorists like Hollis-Peel and colleagues (2011, p. 53), who argue that “Capable guardians can serve as a key actor in the crime event model; one who can disrupt, either directly or indirectly, the interaction between a motivated offender and a suitable target”—a much more explicit and complex suggestion than hypothesizing a direct effects of guardianship on drinking and driving. Specifically, although alcohol outlets generate potential DUI offenders motivated to get home or another location, the presence of capable guardians appears to reduce the frequency of those who choose to drive after drinking. Thus, the relationship between bars and alcohol-related crashes depends largely on the levels of guardianship (DUI enforcement) in that area and further supports the implication that the sole focus on alcohol availability may be an oversimplification of a much more multifaceted social process (Zylman, 1968), upon which the effects of availability are conditional.

Environmental crash hazards were also an important moderator of the alcohol outlet, guardianship, and alcohol-related crash relationship. The heightened baseline level of alcohol-related crashes illustrated across the increased levels of environmental hazards illustrated in Figure 2 is consistent with the multicausal logic of alcohol-related crashes noted above. In addition, the figure indicates that guardianship is most influential when environmental hazards are lowest. Thus, the mitigation of the bar/tavern and alcohol-related crash relationship by guardianship is also conditional on environmental hazards. As such, some areas may have few bars and high guardianship, so few people drink and drive in this area; however, because of increased environmental hazards, a greater proportion of drunk drivers may crash. Although this example may appear to contradict theories of availability and guardianship, it illustrates that some of the causes of alcohol-related crashes may operate independent of factors that predict drunk driving itself. Unlike other crimes (e.g., Murder), the act of drunk driving and the harms associated with it (crashes) are not one in the same (see Jacobs, 1989). Thus, in areas where the harm (crashes) is caused by environmental hazards rather than the crimes (DUI; unlike other crimes), efforts to reduce the crimes (e.g., reducing availability or increasing guardianship) will be less effective at reducing the harms associated with it (alcohol-related crashes).

This project focused largely on bars and taverns as well as their interaction with other contextual measures; however, some of the findings for restaurants were also worth noting given the mixed results from the prior studies (see Gruenewald et al., 2010, 1996, 1996; Morrison et al., 2016; Ponicki et al., 2013; Treno et al., 2007). Specifically, a potential suppression effect for restaurants was discovered once environmental hazards were controlled. While suppression originally required that a suppressor variable have zero correlation with the criterion and correlation with other independent variables (Friedman & Wall, 2005), others argue that a measure may act as a suppressor without being a suppressor (see Ludlow & Klein, 2014). This may be the case here as the measure of environmental hazards appears to suppress some of the irrelevant variance in the restaurant vector, thus increasing the partial correlation with alcohol-related crashes, while at the same time having its own partial correlation with the criterion. These effects are difficult to interpret (Thompson & Levine, 1997) and undoubtedly require more research, but as the noise in the model is cleared up by the measure of environmental hazards, and Treno and colleagues' (2007) also found a similar potential protective factor of restaurants, the underlying cause may not be alcohol related.³

In conclusion, given the lack of information about the specific social mechanisms that underlay much of the observed relationships between alcohol outlets and traffic crashes and the need for further investigation (Treno et al., 2007), this article sought to examine other theoretical factors that may be related to routine drinking activities. Because traffic crashes are largely generated by a community system (Holder, Treno, & Levy, 2005), and the routine drinking activities perspective draws largely from the criminological theory of routine activities (Bouffard et al., 2007; Livingston et al., 2007), these measures were largely drawn from the logic of Cohen and Felson's (1979) theory of routine activities. While both DUI arrests (McCarthy, 2003) and non-alcohol-related crashes (Morrison et al., 2016) have both been used by two prior studies of alcohol outlets and crashes, their interaction has never been empirically explored. The incorporation of these measures into the theoretical model of routine drinking activities has produced noteworthy results consistent with both routine drinking activities (Stockwell & Gruenewald, 2004) and the logic of routine activities (Cohen & Felson, 1979; Felson, 1987). As such, this project has further expounded upon the research and theory which seeks to explain complex social mechanisms within the community that generate alcohol-related crashes.

Although this project makes a considerable contribution to the discussion of routine drinking activities and alcohol-related crashes, it is not without its limitations. Keep in mind that we are drawing from routine activities theory the insight that the opportunity for an offense to occur requires certain elements come together in space and time rather than attempting to

empirically test the theory itself. The data also did not provide information on fault in causing crashes, and the concept of guardianship was limited to police enforcement. The use of nonalcohol-related crashes as a proxy for environmental crash hazards does allow one to distinguish between types of hazards. The sample size and frame also limit the generalizability. Finally, the unit of analysis limits conclusions to the aggregate and the authors cannot be sure that DUI trips originated at any one bar in an area (or adjacent areas) and future research may wish to use microlevel data to better explore DUI offender mobility. Despite its limitations, this project considerably complements the theory and research on alcohol outlets, alcohol-related crashes, and the context of occurrence.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Richard Stringer  <https://orcid.org/0000-0002-1111-560X>

Notes

1. Several measures were transformed using the natural log to achieve a normal distribution. These measures include the DUI crash rate (Skew = 5.47), nonalcohol-related crashes (Skew = 1.88), bars/taverns (Skew = 4.59), restaurants (Skew = 4.06), DUI arrests (Skew = 8.67), and total population (Skew = 1.53). This transformation resulted in acceptable skewness and kurtosis values. Due to zero values in both alcohol outlet measures, one unit was added prior to the logarithmic transformation ($\ln + 1$) to prevent errors.
2. The SES variables have factor loadings greater than .70: the percent with a bachelor's degree or more (.747), married (.858), below poverty level (−.870), Caucasian (.834), unemployment rate for population 16 and above (−.837), and median income (\ln ; .949). The eigenvalues above were used to weight each measure, and after weighting Cronbach's Alpha statistic (.842) indicates a reliable scale (see Cronbach, 1947).
3. Some of the preliminary analysis indicated that the SES component significantly moderated the restaurant and alcohol-related crash relationship. In fact, in areas with low SES, the relationship between restaurants and crashes was positive; however, it was negative in areas with higher SES. We note this interaction as it is likely related to diverse drinking activities, affluent communities being less affected by the negative conditions of alcohol outlets (Treno et al., 2007), or different cultural concerns or norms about drinking and driving across these communities (Stringer, 2018b; Treno et al., 2007).

References

- Bernasco, W., & Elffers, H. (2010). Statistical analysis of spatial crime data. In A. Piquero & D. Weisburd (Eds.), *Handbook of quantitative criminology* (pp. 699-724). New York, NY: Springer.
- Blincoe, L. J., Miller, T. R., Zaloshnja, E., & Lawrence, B. A. (2015). *The economic and societal impact of motor vehicle crashes, 2010 (revised)* (Report No. DOT HS 812 013). Washington, DC: National Highway Traffic Safety Administration. Retrieved from <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812013>
- Bouffard, J. A., & Exum, M. L. (2013). Rational choice beyond the classroom: Decision making in offenders versus college students. *Journal of Criminal Justice*, 41, 438-447.
- Bouffard, J. A., Niebuhr, N., & Exum, M. L. (2017). Examining specific deterrence effects on DWI among serious offenders. *Crime & Delinquency*, 63, 1923-1945.

- Bouffard, L. A., Bergeron, L. E., & Bouffard, J. A. (2007). Investigating the impact of extended bar closing times on police stops for DUI. *Journal of Criminal Justice*, 35, 537-545.
- Cameron, O. M. (2013). *Reducing DUI-related collisions: Evaluating the effectiveness of enhanced DUI enforcement* (Doctoral dissertation). Retrieved from <http://130.17.111.21/handle/011235813/267>
- Cohen, L. E., & Felson, M. (1979). Social change and crime rate trends: A routine activity approach. *American Sociological Review*, 44(4), 588-608.
- Cronbach, L. J. (1947). Test "reliability": Its meaning and determination. *Psychometrika*, 12(1), 1-16.
- DeMichele, M., Lowe, N. C., & Payne, B. K. (2014). A criminological approach to explain chronic drunk driving. *American Journal of Criminal Justice*, 39, 292-314.
- DeMichele, M., & Payne, B. (2013). If I had a hammer, I would not use it to control drunk driving. *Criminology & Public Policy*, 12, 213-225.
- Drew, L. (2010). *National survey of drinking and driving attitudes and behaviors: 2008*. Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration.
- Erickson, D. J., Farbakhsh, K., Toomey, T. L., Lenk, K. M., Jones-Webb, R., & Nelson, T. F. (2015). Enforcement of alcohol-impaired driving laws in the United States: A national survey of state and local agencies. *Traffic Injury Prevention*, 16, 533-539.
- Felson, M. (1987). Routine activities and crime prevention in the developing metropolis. *Criminology*, 25, 911-932.
- Felson, M. (1994). *Crime and everyday life: Insight and implications for society*. Thousand Oaks, CA: Sage.
- Felson, M., & Boba, R. L. (Eds.). (2010). *Crime and everyday life*. Thousand Oaks, CA: Sage.
- Felson, R., Savolainen, J., Berg, M., & Ellonen, N. (2013). Does spending time in public settings contribute to the adolescent risk of violent victimization? *Journal of Quantitative Criminology*, 29, 273-293.
- Friedman, L., & Wall, M. (2005). Graphical views of suppression and multicollinearity in multiple linear regression. *The American Statistician*, 59, 127-136.
- Giacopassi, D., & Winn, R. (1995). Alcohol availability and alcohol-related crashes: Does distance make a difference? *The American Journal of Drug and Alcohol Abuse*, 21, 407-416.
- Gruenewald, P. J. (2007). The spatial ecology of alcohol problems: Niche theory and assortative drinking. *Addiction*, 102, 870-878.
- Gruenewald, P. J., Freisthler, B., Remer, L., LaScala, E. A., Treno, A. J., & Ponicki, W. R. (2010). Ecological associations of alcohol outlets with underage and young adult injuries. *Alcoholism: Clinical and Experimental Research*, 34, 519-527.
- Gruenewald, P. J., & Johnson, F. W. (2010). Drinking, driving, and crashing: A traffic-flow model of alcohol-related motor vehicle accidents. *Journal of Studies on Alcohol and Drugs*, 71, 237-248.
- Gruenewald, P. J., Johnson, F. W., & Treno, A. J. (2002). Outlets, drinking and driving: A multilevel analysis of availability. *Journal of Studies on Alcohol*, 63, 460-468.
- Gruenewald, P. J., Millar, A. B., Treno, R. J., Yang, Z., Ponicki, W. R., & Roeper, P. (1996). The geography of availability and driving after drinking. *Addiction*, 91, 967-983.
- Gruenewald, P. J., Mitchell, P. R., & Treno, A. J. (1996). Drinking and driving: Drinking patterns and drinking problems. *Addiction*, 91, 1637-1650.
- Gruenewald, P. J., Stockwell, T., Beel, A., & Dyskin, E. V. (1999). Beverage sales and drinking and driving: The role of on-premise drinking places. *Journal of Studies on Alcohol*, 60(1), 47-53.
- Gusfield, J., Kotarba, J., & Rasmussen, P. (1981). The public society of intimates: Friends, wives, lovers, and others in the drinking-driving drama. *Research in the Interweave of Social Roles*, 2, 237-257.
- Gusfield, J. R. (1985). Social and cultural contexts of the drinking-driving event. *Journal of Studies on Alcohol and Drugs*, 10, 70-77.
- Gusfield, J. R. (1996). *Contested meanings: The construction of alcohol problems*. Madison: University of Wisconsin Press.
- Gusfield, J. R., Rasmussen, P., & Kotarba, J. A. (1984). The social control of drinking-driving: An ethnographic study of bar settings. *Law & Policy*, 6, 45-66.
- Haddon, W. J. (1972). A logical framework for categorizing highway safety phenomena and activity. *Journal of Trauma and Acute Care Surgery*, 12, 193-207.
- Hawley, A. (1950). *Human ecology: A theory of community structure*. New York, NY: Ronald Press.
- Holder, H. D., Treno, A., & Levy, D. (2005). Community systems and ecologies of drug and alcohol problems. In T. Stockwell, P. J. Gruenewald, J. W. Toumbourou, & W. Loxley (Eds.), *Preventing harmful*

- substance use: The evidence base for policy and practice (pp. 149-162). West Sussex, UK: John Wiley & Sons.
- Hollis, M. E., Felson, M., & Welsh, B. C. (2013). The capable guardian in routine activities theory: A theoretical and conceptual reappraisal. *Crime Prevention and Community Safety*, 15, 65-79.
- Hollis-Peel, M. E., Reynald, D. M., van Bavel, M., Elffers, H., & Welsh, B. C. (2011). Guardianship for crime prevention: A critical review of the literature. *Crime, Law and Social Change*, 56, 53-70.
- Jacobs, J. B. (1989). *Drunk driving: An American dilemma*. Chicago, IL: University of Chicago Press.
- Jewett, A., Shults, R. A., Banerjee, T., & Bergen, G. (2015). Alcohol-impaired driving among adults: United States, 2012. *MMWR Morbimortal Wkly Rep*, 64, 814-817.
- Klinger, D. A. (1997). Negotiating order in patrol work: An ecological theory of police response to deviance. *Criminology*, 35(2), 277-306.
- Koper, C. S. (1995). Just enough police presence: Reducing crime and disorderly behavior by optimizing patrol time in crime hot spots. *Justice Quarterly*, 12, 649-672.
- Lemieux, A. M., & Felson, M. (2012). Risk of violent crime victimization during major daily activities. *Violence and Victims*, 27, 635-655.
- Livingston, M., Chikritzhs, T., & Room, R. (2007). Changing the density of alcohol outlets to reduce alcohol-related problems. *Drug and Alcohol Review*, 26, 557-566.
- Ludlow, L., & Klein, K. (2014). Suppressor variables: The difference between "is" versus "acting as." *Journal of Statistics Education*, 22(2), 1-28.
- McCarthy, P. (2003). Alcohol-related crashes and alcohol availability in grass-roots communities. *Applied Economics*, 35, 1331-1338.
- Morrison, C., Gruenewald, P. J., & Ponicki, W. R. (2015). Socioeconomic determinants of exposure to alcohol outlets. *Journal of Studies on Alcohol and Drugs*, 76, 439-446.
- Morrison, C., Ponicki, W. R., Gruenewald, P. J., Wiebe, D. J., & Smith, K. (2016). Spatial relationships between alcohol-related road crashes and retail alcohol availability. *Drug and Alcohol Dependence*, 162, 241-244.
- Moulton, B. E., Peterson, A., Haddix, D., & Drew, L. (2010). *National survey of drinking and driving, attitudes and behaviors: 2008—Volume II: Findings report* (Report No. HS 811 343). Washington, DC: National Highway Traffic Safety Administration.
- Mustaine, E. E., & Tewksbury, R. (2009). Transforming potential offenders into motivated ones: Are sex offenders tempted by alcohol and pornography? *Deviant Behavior*, 30, 561-588.
- National Highway Traffic Safety Administration. (2008). *National motor vehicle crash causation survey: Report to congress*. Washington, DC: U.S. Department of Transportation, National Highway Safety Administration.
- Peck, R. C., Gebers, M. A., Voas, R. B., & Romano, E. (2008). The relationship between blood alcohol concentration (BAC), age, and crash risk. *Journal of Safety Research*, 39, 311-319.
- Pollack, C. E., Cubbin, C., Ahn, D., & Winkleby, M. (2005). Neighbourhood deprivation and alcohol consumption: Does the availability of alcohol play a role? *International Journal of Epidemiology*, 34, 772-780.
- Ponicki, W. R., Gruenewald, P. J., & Remer, L. G. (2013). Spatial panel analyses of alcohol outlets and motor vehicle crashes in California: 1999–2008. *Accident Analysis & Prevention*, 55, 135-143.
- Pratt, T. C., & Cullen, F. T. (2005). Assessing macro-level predictors and theories of crime: A meta-analysis. *Crime and Justice*, 32, 373-450.
- Roneck, D. W., & Bell, B. (1981). Bars, blocks and crime. *Journal of Environmental Systems*, 11(1), 35-47.
- Roneck, D. W., & Maier, P. A. (1991). Bars, blocks, and crime revisited: Linking the theory of routine activities to the empiricism of hot spots. *Criminology*, 29, 725-753.
- Ross. (1992). *Confronting drunk driving: Social policy for saving lives*. New Haven, CT: Yale University Press.
- Sherman, L. W., Gartin, P. R., & Beurger, M. E. (1989). Hot spots of predatory crime: Routine activities and the criminology of place. *Criminology*, 27, 27-56.
- Single, E. W. (1988). The availability theory of alcohol-related problems. In C. D. Chaudron & D. A. Wilkinson (Eds.), *Theories on alcoholism* (pp. 325-351). Toronto, Ontario, Canada: Addiction Research Foundation.
- Snortum, J. R., Riva, P. R., Berger, D. E., & Mangione, T. W. (1990). Police documentation of drunk-driving arrests: Jury verdicts and guilty pleas as a function of quantity and quality of evidence. *Journal of Criminal Justice*, 18(2), 99-116.

- Sobol, J. J., Wu, Y., & Sun, I. Y. (2013). Neighborhood context and police vigor: A multilevel analysis. *Crime & Delinquency, 59*, 344-368.
- Stockwell, T., & Gruenewald, P. (2004). Controls on the physical availability of alcohol. In N. Heather, & T. Stockwell (Eds.), *The essential handbook of treatment and prevention of alcohol problems* (pp. 213-234). West Sussex, UK: John Wiley & Sons.
- Stringer, R. J. (2018a). Are buzzed drivers really the problem: A quasi-experimental multilevel assessment of the involvement of drivers with low blood alcohol levels in fatal crashes. *Criminal Justice Policy Review, 29*, 464-488.
- Stringer, R. J. (2018b). Exploring traffic safety culture and drunk driving: An examination of the community and DUI related fatal crashes in the U.S. (1993–2015). *Transportation Research Part F: Traffic Psychology and Behaviour, 56*, 371-380.
- Stringer, R. J. (2019). Policing the drunk driving problem: A longitudinal examination of DUI enforcement and alcohol related crashes in the US (1985–2015). *American Journal of Criminal Justice, 44*, 474-498. doi:10.1007/s12103-018-9464-4
- Taniguchi, T. A., & Salvatore, C. (2018). Policing a negotiated world: A partial test of Klinger's ecological theory of policing. *Journal of Quantitative Criminology, 34*, 345-366.
- Thompson, F. T., & Levine, D. U. (1997). Examples of easily explainable suppressor variables in multiple regression research. *Multiple Linear Regression Viewpoints, 24*(1), 11-13.
- Treno, A. J., Alaniz, M. L., & Gruenewald, P. J. (2000). The use of drinking places by gender, age and ethnic groups: An analysis of routine drinking activities. *Addiction, 95*, 537-551.
- Treno, A. J., Johnson, F. W., Remer, L. G., & Gruenewald, P. J. (2007). The impact of outlet densities on alcohol-related crashes: A spatial panel approach. *Accident Analysis & Prevention, 39*, 894-901.
- U.S. Census Bureau. (2015). *2011-2015 American community survey 5-year estimates*. American Factfinder. Retrieved from <https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk>
- Virginia Administrative Code. (1994). *3VAC5-50-30. Restricted hours; exceptions* (Title 3, Alcoholic Beverages, Agency 5, Alcoholic Beverage Control Board, Chapter 50, Retail Operations). Retrieved From <http://law.lis.virginia.gov/admincode/title3/agency5/chapter50/section30/>
- Virginia Alcoholic Beverage Control Authority. (2016). *Licensee download*. Retrieved from <https://www.abc.virginia.gov/library/licenses/other-documents/valicjune2019.xlsxla=en>
- Virginia Department of Transportation. (2017). *Online crash analysis tool*. Retrieved from https://public.tableau.com/profile/tien.simmons#!/vizhome/Crashtools8_2/Main
- Ward, M. D., & Gleditsch, K. S. (2018). *Spatial regression models* (Vol. 155). Thousand Oaks, CA: Sage.
- Weisburd, D., & Telep, C. W. (2014). Hot spots policing: What we know and what we need to know. *Journal of Contemporary Criminal Justice, 30*, 200-220.
- Wells, L. E., Falcone, D. N., & Rabe-Hemp, C. (2003). Community characteristics and policing styles in suburban agencies. *Policing: An International Journal of Police Strategies and Management, 26*, 566-590.
- White, G. F., Gainey, R. R., & Triplett, R. A. (2015). Alcohol outlets and neighborhood crime: A longitudinal analysis. *Crime & Delinquency, 61*, 851-872.
- Zaloshnja, E., Miller, T. R., & Blincoe, L. J. (2013). Costs of alcohol-involved crashes, United States, 2010. *Annals of Advances in Automotive Medicine, 57*(3), 3-12.
- Zwerling, C., Peek-Asa, C., Whitten, P. S., Choi, S. W., Sprince, N. L., & Jones, M. P. (2005). Fatal motor vehicle crashes in rural and urban areas: Decomposing rates into contributing factors. *Injury Prevention, 11*, 24-28.
- Zylman, R. (1968). Accidents, alcohol and single-cause explanations: Lesions from the Grand Rapids study. *Quarterly Journal of Studies on Alcohol, 4*, 212-233.

Author Biographies

Richard Stringer, PhD, is an assistant professor of Criminal Justice. His research interests include drug & alcohol policy, courts & sentencing, policing, and advanced quantitative methods. His prior research has been funded by the US Department of Justice and has appeared in outlets such as the Journal of Drug Issues, American Journal of Criminal Justice, and the Journal of Crime and Justice.

Garland White, PhD, is an associate professor in the Department of Sociology and Criminal Justice at Old Dominion University. His current research interests include Animals and Society and Crime and Neighborhoods.

Randy Gainey, PHD, is professor of Sociology and Criminal Justice at Old Dominion University. His research interests include neighborhood characteristic as they related to crime and social control, program and policy evaluation especially in the courts, and racial/ethnic disparities in the criminal justice system.

Ruth Triplett is a professor in the Department of Sociology and Criminal Justice at Old Dominion University. Her interests are in the area of criminological theory, in particular Labeling theory, Social Learning theory, and Social Disorganization theory.