ALCOHOLISM CLINICAL & EXPERIMENTAL RESEARCH

The Impact of Alcohol Outlet Density on the Geographic Clustering of Underage Drinking Behaviors within Census Tracts

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Background: The regulation of alcohol outlet density has been considered as a potential means of reducing alcohol consumption and related harms among underage youth. Whereas prior studies have examined whether alcohol outlet density was associated with an individual's alcohol consumption and related harms, this study examines whether it is related to the co-occurrence, or clustering, of these behaviors within geographic areas, specifically census tracts.

Methods: The Enforcing Underage Drinking Laws Randomized Community Trial provided cross-sectional telephone survey data in 2006 and 2007 from 10,754 youth aged 14 to 20 from 5 states residing in 1,556 census tracts. The alternating logistic regression approach was used to estimate pairwise odds ratios between responses from youth residing in the same census tract and to model them as a function of alcohol outlet density.

Results: Riding with a drinking driver, making an alcohol purchase attempt, and making a successful alcohol purchase attempt clustered significantly within census tracts with the highest off-premise alcohol outlet density while frequent drinking clustered within census tracts with the greatest on-premise density. Driving after drinking and experiencing nonviolent alcohol-related consequences clustered marginally within census tracts with the greatest on-premise and off-premise alcohol outlet density, respectively.

Conclusions: Although youth primarily receive alcohol from social sources, commercial alcohol access is geographically concentrated within census tracts with the greatest off-premise outlet density. A potentially greater concern is the clustering of more frequent drinking and drinking and driving within census tracts with the greatest on-premise outlet density which may necessitate alternative census tract level initiatives to reduce these potentially harmful behaviors.

Key Words: Alcohol Outlet Density, Alternating Logistic Regression, Geographic Clustering, Underage Drinking.

DESPITE THE POSITIVE effects of public policies such as the 21-year-old drinking age (Jones et al., 1992; O'Malley and Wagenaar, 1991) and higher excise taxes (Chaloupka et al., 2002; Grossman et al., 1994) on underage drinking, large numbers of persons under the age of 21 drink, and many experience negative consequences associated with underage drinking. More recently, community intervention trials focused on local initiatives such as responsible beverage service training and increased enforcement of underage sales laws have demonstrated that such efforts can reduce underage drinking (Treno et al., 2007; Wagenaar et al., 2000, 2005). Even with these successes, studies employing underage or underage-appearing confederates continue to demonstrate a widespread propensity for off-premise outlets to sell alcohol to youth. In the first systematic study of alcohol purchase attempts, conducted in New York and Washington, DC, in the early 1990s, nearly three-quarters of purchase attempts in grocery stores were successful (Preusser and Williams, 1992). More recent studies have yielded successful purchase attempt rates between 35 and 40% (Freisthler et al., 2003; Paschall et al., 2007a; Toomey et al., 2008). Although this is a significant decrease since the early 1990s, youth still have relatively easy access to alcohol from off-premise outlets. Youth also perceive that alcohol is readily available to them; 62% of 8th graders, 81% of 10th graders, and 92% of 12th graders think it would be "fairly easy" or "very easy" to get alcohol (Johnston et al., 2009).

An alternative community-level approach that has been considered to reduce excessive alcohol consumption and alcohol-related harms is to regulate the density of retail alcohol outlets, that is, the number of physical locations in which

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Received for publication July 23, 2010; accepted January 6, 2011.

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Funding for this study was provided by NIAAA grant AA016806 and OJJDP grant 2005-AHFX-011.

DOI: 10.1111/j.1530-0277.2011.01491.x

alcohol is available for purchase per area or population. Under state jurisdiction, alcohol outlet density may be regulated at the local level through licensing and zoning regulations, as well as through restrictions on the use and development of land (Ashe et al., 2003). Although underage youth overwhelmingly obtain alcohol through social (e.g., parents, peers, relatives) rather than commercial sources (Harrison et al., 2000; Hearst et al., 2007; Paschall et al., 2007b), higher alcohol outlet density may increase an underage youth's access to alcohol by increasing the availability of alcohol to their social contacts. In addition, opportunities for "shoulder tapping," whereby an underage youth asks an adult stranger outside of an off-premise outlet to purchase alcohol for them, may be greater in areas with higher alcohol outlet density. Although fewer youth get alcohol from commercial sources, it has been shown that off-premise outlets are more likely to sell to underage drinkers if they have similar outlets nearby (Chen et al., 2009; Paschall et al., 2007b), thereby making successful purchases more likely among underage youth who attempt them. In fact, many studies have found a positive association between alcohol outlet density and underage alcohol consumption (Kypri et al., 2008; Treno et al., 2003, 2008; Truong and Strum, 2009; Weitzman et al., 2003). A few have found mixed or negative results (Huckle et al., 2008; Kuntsche et al., 2008; Pasch et al., 2009; Scribner et al., 2008).

Whereas the aforementioned studies examined the association between an individual's drinking and alcohol outlet density, in this study we examine the extent to which underage drinking co-occurs within geographically defined areas (e.g., census tracts), herein referred to as clustering, and whether it is associated with geographic area characteristics (e.g., alcohol outlet density). The intraclass correlation coefficient (ICC) is most often used to characterize the magnitude of clustering between continuous outcomes. However, many of the outcomes measuring underage drinking behaviors (e.g., past 30-day drinking, alcohol purchase attempt) and alcohol-related harms (e.g., driving after drinking) are binary (yes/no). While the ICC can be used to measure the clustering of binary outcomes within geographically defined areas, it can be severely constrained by the outcome prevalence and can result in underestimation (Prentice, 1988).

Alternating logistic regression (ALR) was developed as an alternative to the ICC for studying the clustering of binary outcomes. It uses pairwise odds ratios (PWORs) to quantify the extent to which binary outcomes co-occur within geographically defined areas (Carey et al., 1993). In the simplest case, the PWOR is calculated from a 2×2 table containing all possible pairs of youth residing in the same geographic area and is the ratio of the number of concordant (both youth have the same outcome) to discordant pairs. If, as an example, we take heavy episodic drinking as the outcome and census tracts as the geographic area of interest, a within-census-tract PWOR is interpreted as the odds of heavy episodic drinking for a youth given that another randomly chosen youth residing in the same census tract reports heavy episodic drinking relative to the odds if that randomly chosen youth does not report heavy episodic drinking. A youth's heavy episodic drinking can be thought of as the "exposure" for another randomly chosen youth living in the same census tract. Consistent with odds ratios from logistic regression analysis, the PWOR takes a value of 1.0 when there is no clustering of the outcome of interest. A PWOR greater than 1.0 indicates that the underage drinking behavior of 1 youth is statistically dependent upon the underage drinking behavior of another randomly chosen youth residing in the same geographic area, over and above the expectation based upon randomly paired selections of youth without respect to area of residence.

An additional advantage of ALR over other approaches is that the PWOR can be modeled as a function of cluster-level covariates (association model) while jointly modeling the marginal probability of response (mean model); the ALR estimation algorithm "alternates" between the mean model and the association model until convergence (for estimation details, see Carey et al., 1993). Modeling the PWOR with and without covariate adjustment in the mean model can help identify factors that might mitigate or explain the magnitude of clustering while the separate model for the association can be used to estimate the magnitude of clustering as a function of cluster-level characteristics (e.g., alcohol outlet density). Both of these aspects of ALR can help identify individual and environmental risk factors for targeting prevention and intervention strategies in local communities. We will use ALR and data from a randomized community trial of underage drinking to examine whether underage drinking behaviors cluster within census tracts and whether the magnitude of the clustering depends on census tract level off-premise and on-premise alcohol outlet density.

MATERIALS AND METHODS

Population and Sample

The Enforcing Underage Drinking Laws (EUDL) Program was a national initiative, funded by the United States Office of Juvenile Justice and Delinquency Prevention (OJJDP), intended to increase enforcement of underage drinking laws and reduce underage drinking. The focus on enforcement of underage drinking laws was supported by prior studies demonstrating that strategies aimed at retailers of alcohol are effective and efficient in preventing youth access to alcohol (Grube, 1997; Holder et al., 2000). Each year since 1998, each of the 50 states was awarded a block grant to support and enhance state and local efforts to prohibit the sale and consumption of alcoholic beverages to and by minors (Wolfson et al., 2005). In addition, each year since the program began, discretionary grants have been awarded on a competitive basis to a subset of the states to expand the number of communities taking a comprehensive approach to prevention of underage drinking. States were free to establish criteria for deciding which communities would receive funding in their state under the discretionary grant program.

The Enforcing Underage Drinking Laws Randomized Community Trial (EUDL-CT) was funded under the Fiscal Year 2003 appropriation. States responding to a solicitation for the EUDL-CT were required to provide a list of 14 to 28 cities/towns that were interested in and eligible for, participation in the EUDL-CT should the state be funded. Eligibility requirements included: (i) being an incorporated city or town with population between 25,000 and 200,000 and (ii) not

having engaged in high levels of certain programmatic activities to reduce underage drinking in the 2 years preceding the date of the solicitation (OJJDP, 2003). Based on their proposals, 5 states were funded to participate in the EUDL-CT: California, Connecticut, Florida, Missouri, and New York (Wolfson et al., 2005). Communities within each state were matched based on population, median family income, and the percentages of the population that were Black, Hispanic, spoke Spanish, and were currently in college. Following creation of pairs, communities were randomly assigned to either the intervention or comparison condition. This process resulted in good balance on a variety of community-level characteristics (Wolfson et al., 2005). Thirty-four intervention communities were funded to participate in the EUDL-CT and matched to 34 comparison communities.

Youth Outcome Data

In this study, we use youth self-report data from a repeated cross-sectional telephone survey of 14- to 20-year-olds conducted as part of the national evaluation of the EUDL-CT in 2006 and 2007. The survey included questions on underage alcohol use and alcohol-related consequences, perceived availability of alcohol to youth, and sources of alcohol. The target sample size for each repeated cross-section was 100 youth per community in 68 communities (34 intervention and 34 matched comparison communities). Given the relatively low incidence of households that included a youth in the targeted age range, selecting a sample by random digit dialing and then screening to reach an eligible household would have been prohibitively expensive. As a result, an age-targeted sample was drawn, with the initial samples selected by Survey Sampling, Inc. (SSI; Westport, CT). SSI has developed a methodology based on records derived from multiple secondary sources that enables it to draw samples in which the telephone numbers selected have a higher probability of reaching a household that will include a respondent in a particular age group. This selection process greatly increases the efficiency of the sample. The principal drawback to this approach is that unlisted telephone numbers are not included in the sampling frame, so that there is a potential for bias resulting from the lack of complete coverage. In several areas, the SSI sampling frame did not produce a sufficient quantity of numbers to achieve the desired number of completions. For these areas, a supplemental sample of numbers was obtained from Marketing Systems Group (MSG; Fort Washington, PA), which uses similar procedures for identifying households that are more likely to include someone in the targeted age range. These numbers from MSG were checked for duplicates against those from SSI, and call attempts were made to those nonduplicated numbers. In those areas in which the addition of the MSG numbers was still not sufficient to achieve the desired number of completions, a random sample of numbers was selected from telephone exchanges in the service area. After removing any duplicate numbers from the previous steps, calls were made to these numbers. When a household was contacted, the informant was asked whether there was anyone living in the household who was aged 14 to 20. If no one in the targeted age range lived at that number, the household was classified as ineligible. If more than 1 person age 14 to 20 lived in the household, a respondent was randomly selected using the next birthday method of respondent selection. The same sampling method was used in all states. The response rates in 2006 and 2007 using an estimate of eligibility for cases of unknown eligibility (AAPOR, 2008) were 41 and 34%, respectively. All protocols for the study were approved by the Wake Forest University School of Medicine Institutional Review Board and verbal informed consent was obtained by the interviewers prior to proceeding with the survey. The survey took an average of 20 minutes to complete and participants were not compensated. The telephone survey was completed (or partially completed) by 6,133 youth in 2006 and 5,639 youth in 2007. Of these 11,772 youth, 10,754 (91%) had complete data for this analysis.

Youth were asked during the telephone survey "Could you please tell me what your current address is?" If the respondent did not give their address, we used the address provided by the commercial firm that provided the telephone numbers for the survey sample. Addresses were then geocoded by The Population Research Institute of Pennsylvania State University. The geocoding rate for youth addresses at the census tract level was 99%. The addition of address data permitted the estimation of the geographic clustering of youth drinking behaviors at the level of the census tract. The 10,754 youth with complete data for analysis resided in 1,556 census tracts.

Within-census-tract clustering will be examined based on yes/no responses constructed from the following survey questions:

1. *Past 30-day drinking*. "When was the last time you drank any alcohol?" A response of "Sometime in the last 7 days" or "Sometime in the last 30 days" classified an adolescent as a current drinker. Alcohol included any beer, wine coolers, wine, liquor, and mixed drinks. Drinking alcohol meant drinking more than a single sip at any 1 occasion.
2. *Heavy episodic drinking*. "Think back over the last 2 weeks. How many times have you had 5 or more drinks in a row? A drink is a glass of wine, a bottle of beer, a shot glass of liquor, a mixed drink, or wine cooler." Respondents who reported binge drinking 1 or more times in the past 2 weeks were contrasted with all other respondents.
3. *Frequent drinking*. Respondents were asked "On how many occasions have you had alcohol to drink in the last 30 days?" Respondents who reported drinking on 10 or more occasions in the past 30 days were contrasted with all other respondents.
4. *Nonviolent alcohol-related consequence*. Respondents who ever reported drinking were asked "Have you had any of the following experiences after you had been drinking?" These included being cited or arrested for drinking, possessing, or trying to buy alcohol; being cited or arrested for driving under the influence of alcohol; missing any school because of drinking; being warned by a friend about your drinking; passing out; being unable to remember what happened while drinking; breaking or damaging something; having a headache or hangover; being punished by a parent or guardian; having sex without using a condom; and being involved in a motor vehicle crash. Drinkers who reported at least 1 nonviolent alcohol-related consequence during the past year were contrasted with all other respondents who reported ever drinking alcohol.
5. *Riding with a drinking driver*. "During the past 30 days, how many times (if any) have you ridden in a car after the driver had been drinking?" Respondents who reported riding in a car after the driver had been drinking were contrasted with all other respondents.
6. *Driving after drinking*. Youth who reported ever drinking alcohol and having ever driven a motor vehicle were asked "During the past 30 days, how many times (if any) have you driven after drinking 2 or more drinks in an hour or less?" Respondents who reported driving after drinking at least once were contrasted with all other respondents who were lifetime drinkers and drove a motor vehicle.
7. *Alcohol purchase attempt*. "In the last 30 days, how many times did you try to buy alcohol from a bar, restaurant, or store (whether you were successful or not)?" Respondents who reported attempting to purchase alcohol at least once during the past month were contrasted to all other respondents.
8. *Successful purchase attempt*. Respondents who reported making at least 1 successful purchase attempt from a bar, restaurant, or store were compared to all other respondents.

Individual Level Covariates

Because research suggests that individuals from the same socioeconomic status tend to reside in like neighborhoods (Coulton et al., 1996; Jencks and Mayer, 1990), it is important to examine whether

any observed clustering can be explained by the characteristics of the individuals who live in the same census tract, that is, whether clustering is an artifact of the composition of the census tract. This may provide evidence as to whether alcohol outlet density adds collective or environmental disadvantage to the individual disadvantage of youth that predisposes them to drink (Massey, 1996; Wilson, 1996). Several individual-level characteristics of the participants, some of which mark varying levels of vulnerability, predisposition, or risk of underage drinking, which were found in our previous analyses of these data to be important (Reboussin et al., 2010; Song et al., 2009), were considered. These include age, gender, race, mother's education, and family structure. Because our sample included youth in different developmental stages, age was characterized as (i) mid-adolescence (ages 14 to 15, typically a time when youth have limited independence and cannot legally drive), (ii) late adolescence (ages 16 to 18 during which time independence increases and most youth are driving, and (iii) early adulthood (ages 19 to 20 when some youth may be living away from home). Race compared whites and non-whites (including Hispanics). Mother's education compared those with and without a college-degree while family structure compared youth living in a single-parent/guardian household to those living in a 2-parent/guardian household.

Current job status, perceptions of peer drinking, and perceived difficulty of obtaining alcohol were included as factors that might be associated with youth access to alcohol. Job status was measured by asking youth whether they were currently working at a job for pay. Perceived peer drinking was indicated by a dummy variable representing youth who believed the majority of their friends drank alcohol during the past 30 days. Perceived difficulty to obtain alcohol was indicated by a dummy variable to represent youth who believed it would be "not too difficult" or "not at all difficult" to those who believed it would be at least "somewhat difficult" to obtain alcohol.

Census Tract Level Data

Because alcohol outlet density tends to be greater in more disadvantaged and disordered areas (Pollack et al., 2005), we adjusted for census tract level median household income and residential mobility in our models. Residential mobility is defined as percentage of residents living in a different county in the United States 5 years earlier. Data were obtained from the 2000 US. Census Summary Files 1 and 3 using American Factfinder at http://factfinder.census.gov. Census data were extracted for all census tracts in the study. The 2000 US Census and Youth survey data were merged using city and state Federal Information Processing Standards (FIPS) codes. All census tract level characteristics were divided into tertiles based on percentiles of the distribution of the 1,556 study census tracts. We also included a variable to indicate whether the census tract was located within an EUDL-CT intervention or comparison community as a measure of increased enforcement activities that may limit youth access to alcohol. Finally, a dummy variable for survey year was included to adjust for any trends in use over time.

Alcohol Outlet Density Data

Alcohol outlet density was defined as the number of outlets per square mile area at the census tract level. Alcohol outlet data were obtained from each of the 5 state government's alcohol licensing boards and reflected all establishments holding active licenses in 2008 in their respective states. ArcGIS Network Analyst extension and ESRI StreetMapPro data were used to geocode the alcohol outlets based on premise address within a 5-mile buffer of the 68 EUDL-CT study communities. The geocoding rates for alcohol outlets were 97.3% in New York and Connecticut, 98.7% in California, 96.8% in Florida, and 98.7% in Missouri. Counts of the number of outlets for each census tract within the EUDL-CT study communities were then created. Off-premise outlets included stores that sell carry-out alcoholic beverages such as liquor stores, convenience stores, and grocery stores; on-premise outlets included bars, restaurants, and clubs that sell alcohol on the premises. Tertiles of off-premise and on-premise alcohol outlet density were created based on percentiles of the distribution for the 1,556 census tracts. Geocoding of the alcohol outlet data and the youth addresses was completed by The Population Research Institute of Pennsylvania State University.

Data Analysis

Clustering of underage drinking behaviors was estimated within census tracts using the ALR method described earlier (Carey et al., 1993). We began by estimating the within-census-tract clustering for each outcome in a model without adjusting for covariates. We then conducted a series of ALRs that estimated the PWORs while simultaneously modeling the underage drinking behavior as a function of the individual-level covariates and survey year. The model, referred to earlier as the mean model, is given by

$$\text{Logit P}(Y_{ij} = 1) = \beta_0 + \sum \beta_l X_l, \qquad (1)$$

where Y_{ij} takes a value of 1 if youth j in census tract i reports heavy episodic drinking and 0 otherwise, and X_{jl} are covariates l associated with heavy episodic drinking. The parameter β_l is the log odds ratio for the risk of heavy episodic drinking associated with the lth covariate. The inclusion of individual-level covariates in the mean model is interpreted as adjusting the PWOR for the composition of census tracts with respect to individual-level factors (Petronis and Anthony, 2003).

To address the question of whether the magnitude of the clustering of underage drinking behaviors within census tracts varies as a function of alcohol outlet density, we then modeled the PWOR using a log odds ratio regression model given by

$$\text{Log PWOR}(Y_{ijk}, Y_{ilm}) = \alpha_0 + \sum \alpha_k Z_{ijklm}, \quad j \neq l \qquad (2)$$

where $Y_{ijk} = 1$ if the jth youth in the ith census tract in alcohol-density tertile k reports heavy episodic drinking, Y_{ilm} is the corresponding response for the lth youth in the ith census tract in alcohol-density tertile m and $Z_{ijklm} = 1$ if $k = m$ (i.e., youth j and l reside in the same census tract in alcohol-density tertile k). It follows that $\exp(\alpha_0)$ is the PWOR for census tracts in the alcohol-density reference tertile and $\exp(\alpha_0 + \alpha_k)$ is the PWOR within census tracts in alcohol-density tertile k. Because alcohol outlet density tends to be greater in more disadvantaged and disordered areas (Pollack et al., 2005), the model in Eq. (2) is fit simultaneously with the model in Eq. (1) adjusting for these census tract level factors and whether the census tract resides in an EUDL-CT intervention community in addition to the individual-level factors. This allows us to examine whether alcohol outlet density is associated with the clustering of underage drinking over and above the influence of census tract level disadvantage and disorder. ALR then alternates between 2 steps: estimation of the logistic regression parameters for the covariates in the mean model in Eq. (1), and an offset logistic regression for estimation of the PWORs in the association model in Eq. (2) (for estimation details, see Carey et al., 1993). Wald tests were computed to test the equality of the PWORs across alcohol outlet density tertiles in the PWOR association model in Eq. (2). All models were fit using SAS PROC GENMOD with the LOGOR option on the REPEATED statement.

RESULTS

In our sample of 10,754 youth from 1,556 census tracts, half were women and the majority were white (79%). As shown in Table 1, approximately 36% of youth were 14 to

Table 1. Individual Characteristics and Drinking Behaviors for Youth Aged 14 to 20 Participating in the EUDL-CT, 2006–2007 (N = 10,754)

Variable	
Individual characteristics	%
Male	48.8
White	78.9
Living in a single-parent or guardian household	17.5
Mother college-educated	57.5
Age	
14–15	36.3
16–18	53.0
19–20	10.7
Currently work at a job for pay	37.5
Believe that most friends drink	22.1
Perceive alcohol at least somewhat difficult to obtain	41.8
Drinking behaviors	%
Past-30 day drinking	29.6
Heavy episodic drinking	11.2
Frequent drinking	2.5
Nonviolent consequence (drinkers only)[a]	47.2
Riding with a drinking driver	12.7
Driving after drinking (drivers and drinkers only)[b]	5.6
Alcohol purchase attempt	5.7
Successful purchase attempt	5.0

EUDL-CT, The Enforcing Underage Drinking Laws Randomized Community Trial.
[a]N = 6,310.
[b]N = 4,971.

Table 2. Census Tract Characteristics Based on the 2000 US Census and Alcohol-Outlet Density for the 1,556 Census Tracts in the 68 EUDL-CT Communities

Variable	Mean (SD) Range (min-max)
Off-premise alcohol-outlet density (outlets per square mile area)	4.0 (8.8)
First tertile	0.0–0.6
Second tertile	0.7–2.7
Third tertile	2.8–111.0
On-premise alcohol-outlet density (outlets per square mile area)	5.8 (12.3)
First tertile	0.0–0.8
Second tertile	0.9–3.6
Third tertile	3.7–125.1
Median household income ($)	54,571 (24,572)
First tertile	7,171–41,633
Second tertile	41,688–60,566
Third tertile	60,618–182,739
Lived in a different county in the United States in 1995 (%)	46.0 (12.3)
First tertile	19.7–39.8
Second tertile	39.9–50.0
Third tertile	50.1–97.4

EUDL-CT, The Enforcing Underage Drinking Laws Randomized Community Trial.

Table 3. Estimated within Census Tract Pairwise Odds Ratios (PWORs) for Youth Aged 14 to 20 Participating in the EUDL-CT, 2006–2007

Behavior	Unadjusted PWOR (95% CI) p-value[a]	Adjusted PWOR (95% CI) p-value
Past-30 day drinking	1.17 (1.10, 1.24)* $p < 0.0001$	1.17 (1.09, 1.25)* $p < 0.0001$
Heavy episodic drinking	1.14 (1.05, 1.25)* $p = 0.003$	1.08 (0.99, 1.18)** $p = 0.095$
Frequent drinking	1.23 (0.95, 1.60) $p = 0.120$	1.06 (0.82, 1.37) $p = 0.649$
Nonviolent consequence[b]	1.07 (1.02, 1.13)* $p = 0.005$	1.07 (1.01, 1.13)*** $p = 0.014$
Riding with a drinking driver	1.05 (0.99, 1.13) $p = 0.130$	1.02 (0.96, 1.09) $p = 0.469$
Driving after drinking[c]	1.37 (1.00, 1.87)*** $p = 0.049$	1.34 (0.97, 1.85)** $p = 0.078$
Alcohol purchase attempt	1.35 (1.20, 1.53)* $p < 0.001$	1.26 (1.09, 1.45)* $p = 0.002$
Successful purchase attempt	1.31 (1.16, 1.48)* $p < 0.001$	1.18 (1.02, 1.36)*** $p = 0.028$

EUDL-CT, The Enforcing Underage Drinking Laws Randomized Community Trial.
[a]Test that PWOR is different than 1.0.
[b]Drinkers only.
[c]Drinkers and drivers only.
*$p < 0.01$, **$p < 0.10$, ***$p < 0.05$.

15 years old, 53% were 16 to 18 years old, and 11% were 19 to 20 years old. More than half had a mother with a college education and 18% came from single-parent or guardian households. More than one-third currently worked at a job for pay (38%). Although only 22% believed most of their friends drank, less than half (42%) believed it would be at least somewhat difficult to obtain alcohol. Almost one-third of youth reported drinking during the past 30 days and 11% reported heavy episodic drinking during the past 2 weeks. Frequent drinking (drinking on 10 or more occasions in the past month) was reported by 3% of the sample. Among lifetime drinkers, almost half reported experiencing a nonviolent alcohol-related consequence in the past year. In the past month, 13% of youth reported getting in the car with a driver after the driver had been drinking. Among lifetime drinkers who also drive, 6% drove after drinking in the past 30 days. At least 1 alcohol purchase attempt was made by 6% of youth in the past month and 5% of youth had at least 1 successful attempt. Forty-nine percent of youth resided in EUDL-CT intervention communities. As seen in Table 2, alcohol outlet densities varied widely across census tracts. On average, there were 4 off-premise outlets per square mile area with a range of 0 to 111 off-premise outlets. On-premise outlets were slightly more common with on average 6 on-premise outlets per square mile area with a range of 0 to 125 on-premise outlets. Other characteristics also varied widely across census tracts.

Reported in Table 3 are the ALR estimates of within-census-tract clustering for each youth outcome. All outcomes clustered significantly within census tracts except frequent drinking and riding with a drinking driver. Among those that clustered significantly within census tracts, the magnitude of the clustering was greatest for driving after drinking (PWOR = 1.37; 95% CI = 1.00, 1.87); youth have a 37% increased risk of driving after drinking if a randomly selected youth residing in the same census tract reports driving after drinking. Making an alcohol purchase attempt and making a

successful alcohol purchase attempt also clustered strongly within census tracts (PWOR = 1.35; 95% CI = 1.20, 1.53 and PWOR = 1.31; 95% CI = 1.16, 1.48, respectively). Alcohol consumption behaviors clustered to a lesser, but statistically significant, degree within census tracts. The same is true of nonviolent alcohol-related consequences. After adjustment for age, gender, race, mother's education, family structure, job status, perceptions regarding peer drinking, perceived difficulty to obtain alcohol, and survey year, results remained unchanged except that the clustering of heavy episodic drinking and driving after drinking within census tracts became marginally significant ($p = 0.095$ and $p = 0.078$, respectively).

The PWOR model presented in Eq. (2) was then fit for each outcome to examine whether the magnitude of the clustering depended on tertiles of off-premise and on-premise alcohol outlet density while simultaneously adjusting for the individual-level characteristics described above, as well as census tract level median income, residential mobility, and enforcement activities as indicated by EUDL-CT community intervention status. As shown in Table 4, the magnitude of the clustering of past 30-day drinking and heavy episodic drinking did not depend on off-premise or on-premise alcohol outlet density. However, more frequent drinking clustered significantly within census tracts with the greatest on-premise alcohol outlet density (PWOR = 2.20; 95% CI = 1.02, 4.74) and did not cluster within census tracts in the lower tertiles of on-premise alcohol outlet density. Therefore, among youth residing in census tracts with the greatest on-premise alcohol outlet density, a youth has a 220% increased likelihood of reporting frequent drinking if a randomly chosen youth from the same census tract reports frequent drinking relative to the likelihood if that youth does not report frequent drinking. Clustering of riding with a drinking driver, making an alcohol purchase attempt, and making a successful alcohol purchase attempt was greatest in census tracts with the highest off-premise alcohol outlet density (PWORs = 1.20, 1.79, and 1.85, respectively); clustering was nonsignificant (or marginally significant) for the lower tertiles of off-premise alcohol outlet density. Driving after drinking (PWOR = 2.10; 95% CI = 0.96, 4.59) and nonviolent alcohol-related consequences (PWOR = 1.14; 95% CI = 0.97, 1.34) clustered marginally within census tracts with the greatest on-premise and off-premise alcohol outlet density, respectively.

Table 4. Estimated within Census Tract Pairwise Odds Ratios (PWORs) by Off-Premise and On-Premise Alcohol Outlet Density Tertile for Youth Aged 14 to 20 Participating in the EUDL-CT, 2006–2007

Behavior	Off-premise outlet density PWOR (95% CI) Overall *p*-value[a]	On-premise outlet density PWOR (95% CI) Overall *p*-value
Past-30 day drinking	$p = 0.837$	$p = 0.340$
First tertile	1.16 (1.07, 1.26)*	1.20 (1.09, 1.32)*
Second tertile	1.11 (1.01, 1.22)**	1.09 (1.02, 1.18)**
Third tertile	1.14 (1.01, 1.30)**	1.11 (0.97, 1.26)
Heavy episodic drinking	$p = 0.822$	$p = 0.321$
First tertile	1.01 (0.90, 1.13)	1.07 (0.95, 1.20)
Second tertile	1.05 (0.93, 1.19)	0.96 (0.87, 1.07)
Third tertile	1.08 (0.87, 1.34)	1.11 (0.89, 1.39)
Frequent drinking	$p = 0.662$	$p = 0.065$
First tertile	0.89 (0.64, 1.24)	0.87 (0.62, 1.22)
Second tertile	1.01 (0.66, 1.55)	0.83 (0.59, 1.15)
Third tertile	1.31 (0.59, 2.87)	2.20 (1.02, 4.74)**
Nonviolent consequence[b]	$p = 0.564$	$p = 0.955$
First tertile	1.04 (0.96, 1.12)	1.05 (0.98, 1.14)
Second tertile	1.06 (0.97, 1.15)	1.07 (0.98, 1.17)
Third tertile	1.14 (0.97, 1.34)***	1.07 (0.94, 1.21)
Riding with a drinking driver	$p = 0.145$	$p = 0.598$
First tertile	0.98 (0.90, 1.07)	1.00 (0.92, 1.10)
Second tertile	1.00 (0.92, 1.09)	1.00 (0.91, 1.09)
Third tertile	1.20 (1.00, 1.43)**	1.10 (0.93, 1.30)
Driving after drinking[c]	$p = 0.911$	$p = 0.318$
First tertile	1.27 (0.89, 1.82)	1.10 (0.76, 1.61)
Second tertile	1.43 (0.82, 2.50)	1.42 (0.87, 2.33)
Third tertile	1.44 (0.74, 2.82)	2.10 (0.96, 4.59)***
Alcohol purchase attempt	$p = 0.051$	$p = 0.920$
First tertile	1.05 (0.89, 1.25)	1.20 (0.99, 1.46)***
Second tertile	1.23 (0.98, 1.56)***	1.15 (0.94, 1.40)
Third tertile	1.79 (1.20, 2.67)*	1.24 (0.86, 1.80)
Successful purchase attempt	$p = 0.019$	$p = 0.510$
First tertile	0.97 (0.81, 1.16)	1.11 (0.91, 1.34)
Second tertile	1.11 (0.90, 1.37)	1.05 (0.86, 1.28)
Third tertile	1.85 (1.23, 2.79)*	1.37 (0.92, 2.04)

EUDL-CT, The Enforcing Underage Drinking Laws Randomized Community Trial.

[a]Overall test of any difference in the PWORs between alcohol-density tertiles.

[b]Drinkers only.

[c]Drinkers and drivers only.

*$p < 0.01$, **$p < 0.05$, *** $p < 0.10$.

DISCUSSION

While other studies have focused on whether the density of alcohol outlets within geographically defined areas is associated with an individual's underage drinking, we consider whether it is related to the co-occurrence, or clustering, of these behaviors within geographically defined areas. This study describes the use of PWORs to estimate the magnitude of the clustering of underage drinking behaviors within census tracts and by level of alcohol outlet density. In contrast to individual risk factor epidemiology, modeling the clustering of behaviors within geographic areas considers the broader context of etiology. First, we tried to determine whether there was evidence of a geographic concentration of underage drinking behaviors within census tracts and whether this concentration depended upon characteristics of the individuals residing in these areas. If the clustering was not an artifact of census tract composition, then in an attempt to better understand the geographic concentration of underage drinking, we examined whether it depended upon the characteristics of the census tracts in which individuals reside. Research on the geographic concentration of adolescent problems, and in particular substance use, has focused on living in disadvantaged neighborhoods and is driven primarily by 2 theories to explain the pathways through which neighborhood structure operates. The first is social disorganization theory (Shaw and McKay, 1942). Social disorganization theory and models of neighborhood influence focusing on social capital (Coleman,

1988), collective efficacy (Sampson et al., 1997), and social cohesion (Duncan et al., 2002) view community social organization as a process which allows communities to maintain formal and informal social controls, as well as monitor and control youth activities. The second theory linking neighborhoods and adolescent problems is the stress reduction perspective (Lindenberger et al., 1994; Rhodes and Jason, 1990). This framework suggests that the experience of stressors in the neighborhood (such as violence) may contribute to adolescent problems (such as substance use) to the extent that individuals use substances as a means of coping. In this study, we examined whether the magnitude of the clustering was associated with alcohol outlet density over and above the influence of individual-level factors and measures of census tract disadvantage, disorder, and enforcement activities.

Before interpreting the results from this study, we should emphasize that clustering as estimated by the PWOR reflects the tendency of individuals residing within the same geographical areas to be more alike than that of individuals residing in different geographical areas. A PWOR greater than 1 indicates how many times more often the outcome (either positive or negative) co-occurs among respondents compared with what one would expect if the outcome occurred randomly. The PWOR is therefore not merely a function of prevalence rates; areas with a lower rate of underage drinking could have a higher degree of clustering. It should also be noted that all tests of significance were performed at the nominal level. Therefore, because of the large number of outcomes considered, all results should be considered exploratory.

Using data from a large sample of youth living in 1,556 census tracts in the United States, we found evidence for within-census-tract clustering of past 30-day drinking, heavy episodic drinking, nonviolent alcohol-related consequences, driving after drinking, making an alcohol purchase attempt, and making a successful alcohol purchase attempt. After adjustment for individual-level covariates, the clustering of heavy episodic drinking was no longer statistically significant, suggesting that the clustering was an artifact of the composition of census tracts with respect to individual-level characteristics. Interestingly, the magnitude of the clustering of frequent drinking, although nonsignificant in the unadjusted model (PWOR = 1.23), decreased substantially in magnitude after adjustment for individual-level covariates (PWOR = 1.06). Therefore, census tract composition with respect to individual-level factors explained the clustering of quantity (e.g., heavy episodic drinking) and frequency of drinking within census tracts but not the prevalence of drinking (i.e., past 30-day drinking). Although driving after drinking became marginally significant ($p = 0.078$) after adjustment for individual-level covariates, the magnitude of the clustering changed very little.

The clustering of alcohol purchase attempts and successful alcohol purchase attempts within census tracts were significantly associated with off-premise alcohol outlet density. Youth residing in census tracts with the greatest off-premise density (highest tertile) have an approximately 80% increased risk for making an alcohol purchase attempt and making a successful attempt if another youth residing in the same census tract reports those behaviors. Even though youth are more likely to get alcohol from social sources, in census tracts with the greatest off-site commercial availability of alcohol, there is a greater concentration of underage youth attempting to purchase alcohol and making successful purchase. This supports the findings of others that off-premise outlets are more likely to sell to underage drinkers if they have similar outlets nearby (Chen et al., 2009; Paschall et al., 2007b), therefore resulting in the geographic concentration of successful purchase attempts within census tracts with high densities of off-premise alcohol outlet densities in particular.

The magnitude of the clustering of alcohol consumption behaviors did not depend on the density of off-premise alcohol outlets. However, while individual-level characteristics explained the clustering of more frequent drinking within census tracts in general, it did not explain the clustering within census tracts with the greatest density of on-premise alcohol outlets in particular. Youth residing in census tracts with the greatest density of on-premise outlets are at a 220% increased risk of reporting frequent drinking if another youth residing in the same census tract also reports frequent drinking (PWOR = 2.20; 95% CI = 1.02, 4.74). Therefore, although the clustering of the prevalence of drinking (past 30 days) that we observed within census tracts was not explained by individual-level characteristics nor was it associated with alcohol outlet density, our data suggest that the presence of more on-premise outlets within a census tract may increase opportunities for drinkers to drink more regularly. In a study of individual risk, Schonlau and colleagues (2008) found no association between the prevalence of drinking and off-premise alcohol outlet density in census tracts in Louisiana but did find an association with the quantity of drinking among drinkers. Based on our data, the question remains as to what explains the clustering of past 30-day drinking within census tracts. One possible explanation is the epidemic (or social contagion) model proposed by Jencks and Mayer (1990). In this framework, problem behaviors, such as substance use, are assumed to be contagious and operate mainly through peer influences; adolescents engage in problem behaviors because peers living in the same neighborhood also exhibit these behaviors. In other words, beliefs and behaviors are transmitted from neighbor to neighbor. This type of social contagion has been reported as an explanation for the spread of heroin use in a London suburb in the 1960s (De Alarcon, 1969).

With regard to consequences, clustering of nonviolent consequences was not significantly associated with alcohol outlet density; it clustered marginally within census tracts with the greatest off-premise density. Riding with a drinking driver, however, was significantly concentrated within census tracts with the greatest off-premise outlet density. This finding supports that of Treno and colleagues (2003), who found that off-premise alcohol outlet density was associated with youth riding with drinking drivers. This may be a result of youth

obtaining alcohol from off-premise outlets and drinking at off-site locations such as parties where there would be an increased likelihood of youth leaving a party with other youth who have been drinking and providing transportation home. Although only marginally significant, the magnitude of the effect for driving after drinking and on-premise outlets (PWOR = 2.10; 95% CI = 0.96, 4.59) suggests that an increase in the physical availability of alcohol at venues that an individual accesses by car (e.g., restaurants, bars) may lead to an increase in drinking and driving among drinkers.

Limitations in our study should be noted. First, our sample was restricted to communities in 5 states. Therefore, our inferences may only be valid for the population of communities from which we sampled. In addition, as is typical of telephone surveys, non-whites and lower socioeconomic status individuals are underrepresented in our sample as are older adolescents (i.e., 19- and 20-year-olds). Our analyses also relied on the 2000 US Census to measure census tract level characteristics, specifically census tract disadvantage and disorder. While providing measures of census tract structure, it did not directly measure the underlying processes through which these measures may have acted to influence both alcohol outlet density and underage drinking. These might have included social, cultural, and physical aspects of the census tract, as well as social and cultural characteristics of the families which comprise the census tracts. At a minimum, census data provide crude proxies of census tract characteristics. Also, the geographic area that we considered was determined by the EUDL-CT study communities which comprised an area defined as a city or town with population between 25,000 and 200,000 and the census tracts lying within those communities. It is not clear, however, what geographic area is most relevant to underage drinking and it may be difficult to define. As Diez-Roux (1998) has discussed, an individual's neighborhood (or census tract in our study) may be much broader than a geographically defined area of residence.

A significant strength of the present study is the application of an innovative statistical approach to study the geographic concentration of underage drinking within census tracts and its relationship to alcohol outlet density. ALR has only recently been applied to drug use, despite a growing number of studies focused on the influence of census tracts or neighborhoods and contextual factors on drug use. An advantage of the ALR approach over other approaches is that it fits a separate model for the association (clustering) thereby permitting direct control over model specification for the PWORs. In other extant approaches, such as multilevel models, the model for the association is implicit in the model for the mean. Separate models for the clustering and the mean allow us greater flexibility and can help us to target our prevention and intervention strategies to different factors or levels (individual vs. census tract) more accurately. Finally, our estimates of the quantitative clustering of underage drinking are based on one of the largest randomized community trials to reduce youth alcohol use and problems. Randomization of 68 communities is a significant increase in size over most community trials (Holder et al., 1997; Perry et al., 1996; Wagenaar et al., 2000) and increased the precision of our estimates. Further, the availability of youth addresses for geocoding allowed us to examine clustering at the census tract level within a sample of 1,556 census tracts.

In summary, these findings provide evidence that although youth primarily receive alcohol from social sources, commercial alcohol access is geographically concentrated within census tracts with the greatest density of off-premise outlets. In particular, the concentration of successful purchase attempts only within census tracts with the greatest off-premise density suggests that prevention efforts are needed to limit the density of off-premise outlets with the goal of either reducing opportunities for youth to purchase alcohol or to limit competition between outlets so that they are less likely to sell to underage youth. While limiting the density of on-premise alcohol outlets (e.g., restaurants and bars) may prove more difficult than limiting off-premise density (e.g., liquor stores, convenience stores), our findings that more frequent drinking and drinking and driving are related to on-premise density may necessitate an alternative strategy such as responsible beverage service training, which has been shown to reduce underage drinking. Finally, the geographic concentration of past 30-day drinking within census tracts requires further study to determine what individual or census tract level processes that we did not measure in this study are operating within census tracts that might explain this phenomenon.

ACKNOWLEDGMENTS

The authors thank Stephen A. Matthews, Ph.D. and Yosef Bodovski, B.A. at The Population Research Institute of Pennsylvania State University for geocoding the youth addresses and alcohol outlets and for preparing the data for spatial analysis.

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