I, Robert Chaney, hereby submit this original work as part of the requirements for the degree of Doctor of Philosophy in Health Education.

It is entitled:
A Spatial Epidemiological Approach to Adolescent Drug Use for Health Promotion and Education

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This work and its defense approved by:

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A Spatial Epidemiological Approach to Adolescent Drug Use for
Health Promotion and Education

A dissertation submitted to
the Graduate School
of the University of Cincinnati
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in the Department of Health Promotion & Education
of the College of Education, Criminal Justice & Human Services

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M.S. Health Education, University of Cincinnati, 2012
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Defense: March 13, 2014
Abstract

Using a multi-disciplinary approach, this dissertation research examines using spatial epidemiological methods in the discipline of health promotion and education. This set of methods are particularly apt for identifying geographic inequalities in health outcomes, contextualizing health data, and describing health outcomes in terms of access. Health promotion and education is a discipline of public health that focuses on prevention and intervention in order to promote community and public health. Presented in this dissertation are three manuscripts: (1) A systematic review of spatial epidemiological methods of drug use which examines the use of these methods in public health research; (2) Spatial patterns of adolescent drug use across the 5-county Cincinnati region; and (3) Spatial epidemiological methods for health promotion and education. The results presented here include spatial patterns of several drug types (See Manuscript 1) as well as perceptions and risk by area (See Manuscript 2). Suggestions and guidance is also made for the application of spatial epidemiological methods in health promotion and education.
Acknowledgements

I would like to thank my dissertation committee chair, Dr. Liliana Rojas-Guyler for her support, encouragement, and mentoring in finishing my dissertation. I would also like to thank Dr. CJ Kim for his collaborative support and guidance during my doctoral training. I appreciate the time and efforts of Drs. Brad Wilson and Becky Vidourek for serving on my dissertation committee. Nicole Schisler’s insight and collaboration was a very valuable part of my research and I gratefully acknowledge her contribution. I would like to thank my family, Lindsay and Harvey for loving and encouraging me; this work is a reflection of their support.
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Introduction

The essence of health geography is to examine the relationship of health and place. This type of investigation lends itself well to health promotion and education research because it is community-based in nature. This dissertation explores the spatial epidemiology of adolescent drug use in the Cincinnati area. It is segmented into three manuscripts.

A systematic review of spatial epidemiological methods used in public health drug use research is the first manuscript. This review sought to answer (1) What drugs or drug-related topics are most commonly studied, (2) What spatial analysis methods were used, (3) At what geographic level was the research conducted (e.g. zip code), and (4) What were the salient findings of this research using a spatial epidemiological approach. The second manuscript utilizes adolescent drug use data to determine spatial inequality of drug use and related perceptions. This study examined (1) If a spatial pattern of adolescent drug use exists across the Cincinnati region, (2) What the nature of clusters are of drug use, and (3) What neighborhoods pose excess risk for adolescent drug use. The third manuscript describes the utility of spatial epidemiological in health promotion and education efforts. It also outlines the most common spatial analysis methods used in public health research.
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Abstract

Substance abuse is a pressing public health issue. Much of prior research has focused on identifying risk factors and populations of users. Comparatively little research has focused on examining drug use from a spatial epidemiological perspective. Utilizing this methodology allows for the identification of geographic patterns and contextualizing data. This review summarizes and reflects upon drug use research to date that has utilized spatial epidemiological methods. Specifically, this review examines (1) what drugs were studied, (2) what methodology was used, (3) at what geographic setting was the study conducted, and (4) what the salient results were. This review validates there is a geographic relationship with drug use and related topics (e.g. clean syringe access). Specific research discussed includes methamphetamine, prescription drugs, alcohol, injection drugs, and others. The specific nature of each geographic pattern is somewhat unique to each drug type, but this review demonstrates the existence of inequalities in use and related behaviors across a variety of regions. Understanding this approach can be useful for community health needs assessment and in allocating resources for prevention/intervention efforts.

Keywords: Spatial epidemiology, geography, drug use, patterns
Introduction

Substance abuse is one of the most important public health issues today because of risk for dependence, relationship with other risky behaviors and interference with adolescent development (Squeglia, Jacobus, & Tapert, 2009). Harmful patterns of substance abuse have been studied using a variety of research methods and have led to a characterization of how substance abuse varies between ethnic groups and ages; but until recently the relationship between substance abuse and geographical place has been relatively unexplored (McLafferty, 2008; Swendsen et al., 2012). Drug use is a public health concern because of its relationship with risky behavior, poorer academic achievement, and or interference with cognitive development (Birckmayer, Holder, Yacoubian, & Friend, 2004; O’Connell, Boat, & Warner, 2009; Squeglia et al., 2009; Swendsen et al., 2012).

The epidemiology of substance abuse describes the interplay between the drug, the environment (e.g. exposure or access) and individual user characteristics (e.g. sex or ethnicity) (Merikangas & Avenevoli, 2000). Prior research has primarily focused on drug and user related topics. Much of prior research exploring the drug-related environment has described inter- or intra-personal environments. McLafferty describes the examination of drug use in geographical context as an important and emerging area of research (2008). Spatial analysis seeks to contextualize data within its geographical environment. This moves beyond group observations about health outcomes and contextualizes them within their social and geographical environment. Research questions answered by this review include (1) What drugs or drug-related topics are most commonly researched using a spatial epidemiological approach? (2) What spatial epidemiology methods were used? (3) At what geographic level was the research conducted (e.g.
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zip code)? and (4) What were the salient findings of this research using a spatial epidemiological approach?

This research reviews and summarizes prior research in the area of spatial epidemiology of drug use and drug-related topics. The results of this study are beneficial for two major reasons. First, research using spatial epidemiology to address drug use and related topics is emergent. This review provides significant contribution to the literature by reviewing and summarizing prior work in this area. Second, the results of this study are insightful in identifying gaps and future areas of research based on methods used and topics studied. This review also serves as a resource for researchers seeking to address public health issues by contextualizing them using spatial epidemiology.

**Method**

Eligibility criteria included the following: (1) Research studies needed to be public health research; (2) involve spatial analysis (e.g. data mapping, spatial regression, etc.); (3) research topics of drug use or drug-related topics; (4) be based in the United States of America; (5) examine non-medical use of drugs (i.e. not include pharmacology research); (6) be primary research and not reviews or commentaries; and (7) not include environmental health research related to water contamination by drugs. Figure 1 depicts the systematic flow of article selection and inclusion.

Articles were obtained from the NCBI PubMed database during fall 2013, and include articles up through December of the same year. Keyword searches yielded the following search hits: spatial analyses and drug use (87); spatial analyses and drug abuse (84); GIS and drug use (9); GIS and drug abuse (2); spatial analyses and drug use (7); and spatial analyses and drug abuse (388). These keyword searches yielded a total of 577 articles.
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The process utilized for article inclusion in summary and review was as follows: a) Studies were selected first by reading titles of articles from the initial keyword search. b) The abstracts of those appearing to meet the inclusion criteria were then read. c) Those studies still meeting the inclusion criteria after reading the abstract were read. Specifically, all 577 titles were read from the initial keyword searching. Of these, 84 abstracts were read. Abstract reading reduced the included articles further to 37, which were read in-full. Reading the articles in-full reduced the total studies included in this review to 30.

Data garnered from these articles included the following: (1) drug type or drug-related topic; (2) spatial analysis methods used; (3) the geographic level where the study was conducted; and (4) salient results from using spatial analysis.

Results

The two most common drug or drug-topic studied using spatial epidemiology methods were alcohol and injection drugs. Table 1 presents the drugs and drug-topics observed in this review. Other drugs and topics included general drugs, cocaine or crack, access to drug services or treatment, methamphetamine, opiates, prescription drugs, drug-related crime, illegal drugs and GHB (gamma-hydroxybutyrate).

The two most frequently used spatial analysis methods were spatial autocorrelation and descriptive maps. Table 2 presents a list of spatial analysis techniques used in drug related research. Other methods include Bayes modeling, spatial regression, modeling not accounting for spatial relationships, spatial scan statistic, kernel density estimation, multi-level modeling, and several others. Spatial autocorrelation is the spatial version of bivariate correlation coefficient (e.g. Person Correlation Coefficient). Descriptive maps are a visual and spatial presentation of data. The purpose of modeling is to explain and predict specific variables. The varieties recorded
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in this review included Bayes, which accounts for prior information contributed to the current analysis; spatial regression that accounts for the spatial relationship of data points; and non-spatial regression, which includes examples such as simple linear regression, multiple regression and logistic regression; multi-level modeling allows for different levels of data (e.g. individual [lower] and geographic area [upper]) in the same model by accounting for variation between the upper level and explaining the lower level; kernel density estimation is a non-parametric method of estimation across a region. The spatial scan statistic is a technique used to detect clusters of points within a given region by using a moving detection window.

The different geographic settings used in studies included national, state, county, municipality, and neighborhood. Municipality was the most frequently used geographic setting and New York City was the most common locale of study. The next most common geographic setting was state, which most commonly occurred in California. Table 3 presents detailed information for studies meeting the inclusion criteria. Many studies were also conducted using the administrative unit, or a geographic boundary that was created for other administrative purposes. The most commonly use administrative units were zip code and county. Other geographic levels included neighborhood, census tracts and blocks, and point/locations.

Drug use and behavior

The results of this review show there is geographic variation in drug use and drug-related behavior. For example, Latkin, Glass and Duncan described how this variation in drug type and use was present after accounting for socio-demographic characteristics (1998). The researchers found that cocaine, crack and injection drug use varied within the municipality of Baltimore, MD. This relationship between place and drug use was also characterized by Petronis and
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Anthony who articulated that significant clusters of first-time cocaine use was present in U.S. cities particularly in neighborhoods in poverty (2003).

Several studies utilized to used a state-wide scope. These studies primarily used zip code or county as the geographic area of interest. For example, in a study by Anderson et al., a spatial relationship was demonstrated between socioeconomic status and gamma-hydroxybuterate (GHB) poisoning case severity by zip code in California; higher socioeconomic status zip codes were positively related to more severe GHB cases (2009).

**Methamphetamine**

Three studies also described the state-wide spatial pattern of methamphetamine use. Gruenewald et al. explain how methamphetamine was more prevalent in specific areas of California, how it dispersed and changed through time, and how different communities were more susceptible to methamphetamine problems (2013). Communities with large White or Latino populations, low-income levels, with small household sizes and that had easy access to highways/interstates were found to be particularly susceptible. Other research in California demonstrated how changes in health policy altered growth of methamphetamine related arrests and hospital discharges, and how this pattern changed as policies were implemented. The widespread availability of bulk precursors, ephedrine and pseudoephedrine products increased state-wide spread of methamphetamine arrests and treatment; laws regulating access to precursors suppressed the growth of methamphetamine arrests and treatments (Ponicki, Waller, Remer, & Gruenewald, 2013). Sadakin and Power likewise observed geographic differences in methamphetamine incidents across Oregon and identified counties most at risk (2009).
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**Prescription drugs**

Brownstein, Green, Cassidy and Butler examined prescription drug abuse across regions of New Mexico and found significant patterns of treatment admissions for prescription drug abuse; Vicoden cases clustered in South East New Mexico; opioids clustered around Albuquerque and North-Central New Mexico; and all prescription drugs combined clustered around Albuquerque (2010). Another study noted this spatial variance in national prescription drug use. Methadone and oxycodone were predominately clustered in the Appalachian region, while hydrocodone showed most clusters in California and others throughout the country (Smith, Irish, Wang, Haddox, & Dart, 2008). Paulozzi and Ryan also noted the geographic variability in nationwide sales of opioid prescription drugs (fewest were in South Dakota—218 mg/person—and the most was in Maine—798 mg/person) and related poisonings (the lowest rate was in Iowa—1.6/100,000—and the highest rate was in New Mexico—12.4/100,000) (Paulozzi & Ryan, 2006).

**Alcohol**

Ward and Spronz described a significant spatial relationship between location of residence, alcohol access and driving under the influence (DUI) cases; Persons charged with DUI tended to live nearer alcohol outlets (Ward & Spronz, 1976). Grueneald et al. also described this relationship as a positive relationship between availability and alcohol-related crashes in neighboring areas (Gruenewald et al., 1996). Hanson and Wieczerok similarly described significant clusters of alcohol related mortality rates across the state of New York (2002). Zip codes with greater local and neighboring bar densities were found to also have higher completed suicide rates across California (Johnson, Gruenewald, & Remer, 2009).
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Patterns of alcohol-related crimes also presented spatial variation. Brower and Carrol described a clear distribution of alcohol-related crimes: liquor law violations, noise complaints, assault/battery, vandalism (Brower & Carroll, 2007). Another study described violent crimes being more spatially related to drug-related crimes than alcohol outlet density (Gorman, Zhu & Horel, 2005; Zhu, Gorman & Horel, 2006).

**Drug-related infectious disease**

One study found that a large cluster of HIV cases in downtown Atlanta coincided with increase in odds of also finding specific risk factors for reporting injection drug use and being a man who had sex with men who were also injection drug users. The cluster identified has issues with access to medical and drug treatment related to poverty (Hixson, Omer, del Rio, & Frew, 2011). Likewise, Hepatitis C Virus clusters corresponded to major metropolitan areas in Connecticut with high levels of known injection drug use and existing syringe exchange programs (Trooskin, Hadler, St. Louis, & Navarro, 2005).

**Police presence**

Two studies demonstrated how police presence can influence injection drug use behavior. Bohnert et al. described how increased police presence corresponded to an increase in overdose mortality in New York City (2011). Similarly, local arrest rates increase the odds of injection drug users using unclean needles (Cooper et al., 2012).

**Child well-being**

Some of Freisthler’s work has described how neighborhood drug and alcohol activity is positively related to child well-being. Results from one study showed that neighborhoods with more bars and drug possession incidents translate to more child maltreatment cases (Freisthler,
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Needell, & Gruenewald, 2005). In another study, more drug arrests positively related to more referrals to child protective services (Freisthler & Weiss, 2008).

Sales and use

Although research demonstrates spatial variation in drug use and related behavior, it does not illuminate the location where drugs are being acquired. One study demonstrated discord between location of purchase and location of use. Specifically, results showed that areas where drugs are used are not typically where they are acquired (i.e. sold/purchased) and that this can vary by age group (Freisthler, Gruenewald, Johnson, Treno, & Lascala, 2005).

Access to treatment and services

Several studies describe the spatial relationship of drug use and access to treatment or services. For example, Archibald and Putnam Rankin demonstrated the that areas with higher levels of socioeconomic privation and less health care infrastructure also had less substance abuse treatment access (Archibald & Putnam Rankin, 2013).

Access to syringes

Cooper et al. examined injection drug users across New York City and indicated that users in that city were more likely to use clean needles if they were spatially accessible (2012). Cooper’s other work has further supported this research. One study explained that spatial access to pharmacies selling syringes over the counter was related to community need and ethnicity; Non-Latino, white neighborhoods had greater spatial access despite not necessarily having the greatest need (Cooper, Bossak, Tempalski, Friedman, & Des Jarlais, 2009). This neighborhood-based discrimination is problematic when considering clusters with large Latino populations and far street distances to the closes facility offering Spanish-language services (Guerrero, Kao, & Perron, 2013). A disconnect between treatment and minority populations is exemplified in the
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reported lack of women-only needle exchange programs (Kim et al., 2009). Another study by Cooper explains that greater spatial access to syringe exchange programs and pharmacies selling syringes over the counter improved the likelihood that injectors would engage in harm reduction practices to reduce HIV and Hepatitis C transmission (Cooper et al., 2012). Other research also demonstrates the positive spatial relationship between neighborhood, over the counter syringe access and injection drug use; neighborhoods with high injection drug use had limited access to over the counter syringes (Stopka et al., 2012).

Discussion

This systematic review summarizes prior research in the area of the spatial epidemiology of drug use and drug-related topics. The most common drugs researched using this methodology were alcohol and injection drugs. The spatial analysis methods most frequently used were descriptive maps and spatial autocorrelation analysis. Municipality-based research was more common than other geographic levels (e.g. county, state, etc.), and was most common municipalities studied were in New York and California. There is spatial variation of drug use and drug-related topics (e.g. using clean syringes). This finding was present across several drug types and geographies. It also supports and encourages future research in the spatial epidemiology of drug use and related topics. It also demonstrates the utility of this work for informing prevention and intervention efforts in that specific communities’ needs can be assessed and targeted.

Alcohol and injection drug related research were the most common topics of investigation and are the foundational studies in this area. These only represent 15 studies; a number which suggests further research is needed to verify what has already been observed and
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to further determine the spatial nature of these phenomena. The lack of research investigating other drugs or topics is an indication of the need for future research in these areas.

The explanation for the two most common methods used is likely elucidated in two ways. First, spatial autocorrelation is a standard measure that accounts for the spatial relationship between observations, neighboring observations and their physical space on the earth (Anselin, 1995; Moran, 1948). This measurement can be used to account for spatial relationships while modeling, which is why two common methods in Table 2 are spatial modeling methods. Descriptive mapping is a common method to visualize spatial results and the relationship between health and place, identify areas of inequality, and access to resources.

The research conducted in New York and California provides groundwork examples for research in other geographical locations. Although research in these places provides important contributions to the literature, their results need to be verified in other locations. The essence of health geography is examining the relationship between health and place. Cultural values, physical geography, demographics, socioeconomics and other factors can cause variation between larger geographic regions (e.g. California vs. Midwest). There is wide opportunity for exploring spatial drug issues in other geographies.

The results of this review indicate there is a geographic relationship with drug use and drug-related topics. For example, methamphetamine differences statewide (Gruenewald et al., 2013; Sudakin & Power, 2009); clear spatial patterns of prescription drug abuse (Paulozzi & Ryan, 2006; Smith et al., 2008); and proximal relationship between alcohol access, residence and traffic crashes (Gruenewald et al., 1996; Ward & Spronz, 1976). This research suggests that drug use and drug-related behaviors occur across geographic regions; in other words, there is a geographic relationship between place and drug use. As this is an emerging area of research,
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future research would benefit from characterizing the geographic relationship of other drugs; examining other locales; and the translation of this type of research into intervention and prevention efforts.

This review has inherent limitations and such should be considered when reviewing these results. The author was the sole collector of articles, decided on inclusion/exclusion decision, and summarized findings from this research. There may be inherent bias in his interpretation and choices. In order to limit this bias the systematic approach was used as outlined in Figure 1. Articles were also only collected via the NCBI PubMed database. This database has subscriptions to most journals that publish public health research. It also allows for users to save searches and download titles, abstracts, and full-text articles from these searches. Every effort was made to use keywords that would capture research in this field, which included reading keywords from known works. However, these keywords may have not captured some articles. Despite these limitations, the summary of this review is a valuable contribution to the literature because it sheds light on a growing research area and provides insight on what findings have been discovered using this approach.

The results of this review have shown there is a geographic relationship to drug use and drug-related topics (e.g. clean syringe use among injection drug users). There are common methods and geographies that research has utilized thus far. This approach has the potential to influence decision-making and resource allocation with respect to intervention and prevention efforts. This can be particularly beneficial for identifying inequalities; describing the relationship between geographic area and drug use and drug-related topics; and identifying access to treatment and services. Further, using a spatial approach addresses some of the underlying causal factors of these issues by placing them in their social contexts.
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References


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doi:10.1016/S0306-4603(00)00129-5


doi:10.1016/j.amepre.2006.08.017


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Tables and Figures

**Figure 1.** Systematic review of drug use literature using spatial epidemiological methods.

**Table 1.** Drugs and drug-related topics studied using spatial epidemiological methods.

<table>
<thead>
<tr>
<th>Drug, drug-related topic</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol</td>
<td>9</td>
</tr>
<tr>
<td>Injection drugs</td>
<td>6</td>
</tr>
<tr>
<td>All drugs (not explicit)</td>
<td>5</td>
</tr>
<tr>
<td>Cocaine, crack</td>
<td>4</td>
</tr>
<tr>
<td>Access to services/treatment</td>
<td>3</td>
</tr>
<tr>
<td>Methamphetamine</td>
<td>3</td>
</tr>
<tr>
<td>Opiates</td>
<td>2</td>
</tr>
<tr>
<td>Prescription drugs</td>
<td>2</td>
</tr>
<tr>
<td>Drug-related crime</td>
<td>1</td>
</tr>
<tr>
<td>Illegal drugs (not explicit)</td>
<td>1</td>
</tr>
<tr>
<td>GHB (gamma-hydroxybutyrate)</td>
<td>1</td>
</tr>
</tbody>
</table>
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Table 2.

Spatial analysis methods used in drug research.

<table>
<thead>
<tr>
<th>Spatial method</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial autocorrelation</td>
<td>8</td>
</tr>
<tr>
<td>Descriptive maps</td>
<td>7</td>
</tr>
<tr>
<td>Bayes modeling</td>
<td>5</td>
</tr>
<tr>
<td>Spatial regression</td>
<td>5</td>
</tr>
<tr>
<td>Modeling (non-spatial)</td>
<td>4</td>
</tr>
<tr>
<td>Spatial scan statistic</td>
<td>4</td>
</tr>
<tr>
<td>Kernel density estimation</td>
<td>2</td>
</tr>
<tr>
<td>Hierarchical, multi-level modeling</td>
<td>2</td>
</tr>
<tr>
<td>Odds ratios</td>
<td>1</td>
</tr>
<tr>
<td>Spatial misalignment modeling</td>
<td>1</td>
</tr>
<tr>
<td>Cluster analysis</td>
<td>1</td>
</tr>
<tr>
<td>Network analysis</td>
<td>1</td>
</tr>
<tr>
<td>Local Indicators of Spatial Autocorrelation (LISA)</td>
<td>1</td>
</tr>
<tr>
<td>Getis-Ord cluster detection</td>
<td>1</td>
</tr>
<tr>
<td>Nearest neighbor analysis</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 3: Summary of results from systematic review of spatial epidemiology of drug use and drug-related topics.

<table>
<thead>
<tr>
<th>Author, Date</th>
<th>Drug Topic</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anderson, 2009</td>
<td>GHB (gamma-hydroxybuterate)</td>
<td>Positive relationship between area-level SES and GHB case severity.</td>
</tr>
<tr>
<td>Archibald, 2013</td>
<td>Access to treatment</td>
<td>Increase in SES privation and less health care infrastructure related to less substance abuse treatment access.</td>
</tr>
<tr>
<td>Bohnert, 2011</td>
<td>All drugs; cocaine; opiates</td>
<td>Increase in police presence related to increase overdose mortality.</td>
</tr>
<tr>
<td>Brower, 2007</td>
<td>Alcohol</td>
<td>Spatial patterns with respect to alcohol-related crimes: liquor law violations, noise complaints, assault/battery, and vandalism.</td>
</tr>
<tr>
<td>Brownstein, 2010</td>
<td>RxOTC: vicodin, oxycontin, MS</td>
<td>Spatial clusters observed at state-level: Vicodin (SE New Mexico); opioids (Albuquerque/N. Central NM); All Rx's (Albuquerque).</td>
</tr>
<tr>
<td>Cooper, 2012</td>
<td>Injection drugs</td>
<td>Spatial access decreases odds of using unclean needles. Arrest rates increase odds of using unclean needles.</td>
</tr>
<tr>
<td>Cooper, 2011</td>
<td>Injection drugs</td>
<td>Greater spatial access to syringe exchange programs and pharmacies selling syringes improved likelihood that injectors would engage in harm reduction practices to reduce HIV and Hep C transmission.</td>
</tr>
<tr>
<td>Cooper, 2009</td>
<td>Injection drugs</td>
<td>Spatial access of pharmacies selling syringes is related to community need and ethnicity. Non-Latino white neighborhoods had greater access regardless of need.</td>
</tr>
<tr>
<td>Cooper, 2011</td>
<td>Injection drugs</td>
<td>Spatial access of pharmacies selling syringes is related to community need and ethnicity. Non-Latino white neighborhoods had greater access regardless of need.</td>
</tr>
<tr>
<td>Freisthler, 2005</td>
<td>Illegal drugs</td>
<td>Areas where drug users are the greatest may not be where drugs are sold. There is some variability between youth and adults.</td>
</tr>
</tbody>
</table>

**Primary drug:** GHB (gamma-hydroxybuterate)

**Setting:** Municipalities (NYC), State (CA)

**Level:** Area-level, zip code

**Measurement:** Surveyed behavior, survey results, arrest rates, survey data

**Findings:** Increase in SES privation and less health care infrastructure related to less substance abuse treatment access. Spatial access decreases odds of using unclean needles. Greater spatial access to syringe exchange programs and pharmacies selling syringes improved likelihood that injectors would engage in harm reduction practices to reduce HIV and Hep C transmission.
<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Setting</th>
<th>Level</th>
<th>Measurement type</th>
<th>Drug topic</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freisthler, 2005</td>
<td></td>
<td>Neighbourhoods</td>
<td>Municipality (N. CA)</td>
<td>Census – block</td>
<td>Alcohol and drugs</td>
<td>Neighborhoods with more bars and drug possession incidents equate to more child maltreatment cases.</td>
</tr>
<tr>
<td>Freisthler, 2008</td>
<td></td>
<td>State (CA)</td>
<td>Admin unit – counties</td>
<td>Arrests, referrals, treatment centers</td>
<td>Alcohol and drugs</td>
<td>More drug arrests positively related to more referrals to child protective services. More treatment centers (drug/alcohol) available fewer referrals to child protective services.</td>
</tr>
<tr>
<td>Gorman, 2005; Zhu, 2006</td>
<td></td>
<td>Neighbourhoods</td>
<td>Municipality (Houston, TX)</td>
<td>Census – tracts</td>
<td>Alcohol, drug crime</td>
<td>Drug crime explained more variation than alcohol outlet density in violent crime rates.</td>
</tr>
<tr>
<td>Gruenewald, 1996</td>
<td></td>
<td>Neighborhoods</td>
<td>Neighborhood/ community</td>
<td>Neighborhood/census (CA)</td>
<td>Alcohol</td>
<td>Positive relationship between alcohol availability and crashes locally and in neighboring areas.</td>
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<tr>
<td>Gruenewald, 2013</td>
<td></td>
<td>State (CA)</td>
<td>Admin unit – 5-digit zip code</td>
<td>Meth discharge data</td>
<td>Alcohol and drugs</td>
<td>Spatial pattern of meth use statewide. Meth was more prevalent in areas with large white or Hispanic populations, low-income, small household sizes, and easy access to highways.</td>
</tr>
<tr>
<td>Guerrero, 2013</td>
<td></td>
<td>County</td>
<td>Admin unit – county</td>
<td>Access to treatment services</td>
<td>Alcohol and drugs</td>
<td>Clusters with large Latino populations and far street distances to the closest facility offering Spanish-language services.</td>
</tr>
<tr>
<td>Hanson, 2002</td>
<td></td>
<td>State (NY)</td>
<td>Admin unit – counties</td>
<td>Mortality rate</td>
<td>Alcohol</td>
<td>Significant clusters of alcohol related mortality detected.</td>
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<tr>
<td>Hanson, 2009</td>
<td></td>
<td>State (CA)</td>
<td>Admin unit – 5-digit zip code</td>
<td>Alcohol outlets, suicide/attempts</td>
<td>Alcohol</td>
<td>Completed suicide rates were higher in zip code areas with greater local and lagged bar densities and higher in areas with greater local but not lagged off-premise outlet densities.</td>
</tr>
<tr>
<td>Hixson, 2011</td>
<td></td>
<td>Municipality</td>
<td>Census – tracts</td>
<td>Treatment data</td>
<td>Injection drugs</td>
<td>Cluster of HIV cases downtown Atlanta also coincided with increased odds of injection drug use, men who have sex with men who inject drugs. The clusters identified have issues of access to treatment and poverty.</td>
</tr>
<tr>
<td>Johnson, 2009</td>
<td></td>
<td>State (CA)</td>
<td>Admin unit – 5-digit zip code</td>
<td>Alcohol outlets, completed suicide</td>
<td>Alcohol</td>
<td>Completed suicide rates were higher in zip code areas with greater local and lagged bar densities and higher in areas with greater local but not lagged off-premise outlet densities.</td>
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<tr>
<td>Author</td>
<td>Date</td>
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<td>Findings</td>
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<td>Kim</td>
<td>2008</td>
<td>Drugs</td>
<td>Disconnect between substance abuse treatment client density and women only needle exchange programs.</td>
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<td>Latkin</td>
<td>1998</td>
<td>Injection drugs</td>
<td>Drug type and use patterns are related to geographic areas, independent of neighborhood characteristics.</td>
<td></td>
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<td>Paulozzi</td>
<td>2006</td>
<td>Prescription drugs</td>
<td>Geographic variability in sales of opioid analgesics and drug poisonings. Drug poisonings were related to specific RXOTC drugs.</td>
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<td>Petronis</td>
<td>2003</td>
<td>Cocaine</td>
<td>Clusters of first-time cocaine users within US census tracts.</td>
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<td>Smith</td>
<td>2008</td>
<td>Opioid analgesics</td>
<td>Spatial relationship between residence, alcohol access, and DUI charges.</td>
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<td>Trooskin</td>
<td>2005</td>
<td>Injection drugs</td>
<td>Patterns of Hep. C correspond to major metro areas in the state. Clusters also corresponded to known injection drug use areas and needle exchange programs.</td>
<td></td>
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<td>Sudakin</td>
<td>2009</td>
<td>Methamphetamine</td>
<td>Counties at highest risk of meth incidents were identified. Spatial pattern of meth incidents statewide.</td>
<td></td>
<td></td>
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<tr>
<td>Warden</td>
<td>1976</td>
<td>Alcohol</td>
<td>Spatial relationship between residence, alcohol access, and DUI charges.</td>
<td></td>
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Abstract

Adolescent drug use is individually and socially harmful in terms of disrupting adolescent development and social cohesion. Prior research has identified populations at risk and risk factors for adolescent drug use. This research sought to contextualize adolescent drug use by examining this behavior from a geographic perspective. The specific objectives were to identify patterns, local clusters and excess spatial risk for zip codes within the 5-county Cincinnati region. Adolescents (n = 57,241) were recruited within local school by the Coalition for a Drug-free Greater Cincinnati. Results of this research show spatial clusters for perceived safety of marijuana; peer approval of alcohol, tobacco and marijuana; and age of onset for other drugs. The location and nature of these clusters are discussed and displayed in-text. Further, zip codes that were in excess risk compared to the 5-county region were identified. The utility of this research is two-fold: (1) It identifies the geographic variability in adolescent drug use and correlated factors of use, and (2) It provides a methodological framework for future research in spatial epidemiology of drug use.

Keywords: Adolescent; GIS; Spatial epidemiology; Patterns; Mapping; Drugs
Introduction

Substance abuse is a pressing public health issue today. Substance abuse poses several risks, including risk for dependence, involvement with other risky behaviors, and interference with adolescent development (Squeglia, Jacobus, & Tapert, 2009; Vidourek & King, 2010). Prior research has shown that the likelihood of substance use and abuse increases with age and varies between ethnic groups (Swendsen et al., 2012). Harmful patterns of substance abuse have been studied using a variety of research methods, but until relatively recently the relationship between substance abuse and geography has been comparatively unexplored (McLafferty, 2008).

The traditional epidemiologic triangle of disease (See Figure 1) describes the relationship between agent, environment, host, and the interplay between these factors (and vectors in some cases) determine the development and spread of disease (Merrill, 2013). Merikangas and Avenevoli adapted this model to substance abuse: the agent is the drug; the environment consists of exposure and access related factors such as parental, peer, family and neighborhood influences; and the host as characteristics related to the user or users such as sex, age, cohort, ethnicity, genetic factors, etc. (2000). Prior research has mainly attended to host and agent related topics. Research that has explored environment has generally explained on inter- and intra-personal environments. The examination of the influence of geographic environment, such as community or neighborhood, on substance abuse was considered by McLafferty to be an emerging area of research, and since then only a limited number of research studies have been conducted using methods to address this issue (2008).

Prior research of the spatial epidemiology of drug abuse has examined the relationship between neighborhood drug availability and drug use among adults (Freisthler, Gruenewald, Johnson, Treno, & Lascala, 2005); relationship of alcohol consumption and neighborhood
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availability (Pasch, Hearst, Nelson, Forsyth, & Lytle, 2009; Pridemore & Grubesic, 2012); regional distribution of opioid use (Brownstein, Green, Cassidy, & Butler, 2010); spatial patterns of drug-related behaviors (Brouwer, Weeks, Lozada, & Strathdee, 2008; Stopka et al., 2012); and risk based on social and geographical networks and protective settings (Walker, Mason, & Cheung, 2006).

Adolescent drug use has been shown to be related to problem and risky behavior, poorer academic achievement, and interference with cognitive development, as well as vary in patterns of use among ethnic and age groups (Birckmayer, Holder, Yacoubian, & Friend, 2004; O’Connell, Boat, & Warner, 2009; Squeglia et al., 2009; Swendsen et al., 2012). Prior research has also shown some geographic variability in drug use patterns (Brownstein et al., 2010; Stahler et al., 2007).

The present study was designed to address geographic variability in adolescent drug use. The findings are instrumental in providing specific focus to drug prevention efforts among adolescents. In other words, examining inequalities between communities and using that information to prevent adolescents from beginning drug use. Specifically, the purpose of this

Figure 1. Epidemiologic Triangle of Disease and Epidemiologic Triangle of Drug Use

Adolescent drug use has been shown to be related to problem and risky behavior, poorer academic achievement, and interference with cognitive development, as well as vary in patterns of use among ethnic and age groups (Birckmayer, Holder, Yacoubian, & Friend, 2004; O’Connell, Boat, & Warner, 2009; Squeglia et al., 2009; Swendsen et al., 2012). Prior research has also shown some geographic variability in drug use patterns (Brownstein et al., 2010; Stahler et al., 2007).

The present study was designed to address geographic variability in adolescent drug use. The findings are instrumental in providing specific focus to drug prevention efforts among adolescents. In other words, examining inequalities between communities and using that information to prevent adolescents from beginning drug use. Specifically, the purpose of this
study was to examine spatial patterns of adolescent drug use in the Cincinnati metropolitan region.

The following research questions were examined: (1) What is the spatial pattern of adolescent drug use in the Cincinnati metropolitan region (i.e. random, uniform, clustered)? (2) Are there areas with significantly high or low levels of adolescent drug use while including influence of neighboring areas (e.g. areas with high levels of adolescent drug use surrounded by low level neighbors or areas with high levels of adolescent drug use surrounded by high level neighbors)? and (3) Are there differences in excess risk between neighborhoods for drug use? Drug use was operationally defined as the following: 30-day use, perceived safety, perceived peer/parental approval, and age of onset for tobacco, alcohol, marijuana and other drugs.

By identifying spatial patterns of adolescent drug use in the Cincinnati region the findings from this research directly supports local drug prevention efforts. The results of this study are beneficial for two major reasons. First, the sub-research area of the spatial epidemiology of drug use is emergent. As this area of research is relatively new, findings from this study provide a significant contribution to the research knowledge base by documenting adolescent drug use across a spatial region. Second, the results of this study were anticipated and are to be directly utilized by local coalitions for drug prevention efforts (e.g. preventing drug use from occurring).

**Background**

**Adolescent Drug Use**

The results of the National Comorbidity Survey indicate that roughly two thirds of teenagers have consumed alcohol in their lifetime (Swendsen et al., 2012). There is notable variation between age and ethnic groups, but not between sexes. There is a positive correlation
between age and lifetime consumption of adolescents. Hispanic and non-Hispanic white youth had the highest prevalence of use (60.0% and 62.1% respectively), while non-Hispanic black and other had the lowest prevalence of lifetime use (49.3% and 50.2% respectively). These findings parallel the use of illicit drugs among adolescents. Specifically, there is a positive relationship between lifetime use and age; and Hispanic and non-Hispanic white youth were the most likely to have used (Swendsen et al., 2012). Showing that approximately one quarter of adolescents has used marijuana, 2.3% has used cocaine, 5.4% has used prescription drugs, and 3.2% of adolescents have used other drugs.

The literature establishes common risk and protective factors related to adolescent drug and alcohol use. Drug and alcohol use tend to begin in mid-to-late adolescence, and earlier age of onset is related to greater risk of drug and alcohol related problems later in life (Chou & Pickering, 1992; O’Connell et al., 2009). Parental approval and low parental monitoring have also been shown to be a risk factor for drinking and drug use (Donovan, 2004; Shillington et al., 2005). Similarly, drug and alcohol use in the family is a strong predictor of adolescent use (Birckmayer et al., 2004). Other non-parental social problems can pose greater risk for adolescents. For example, youth who make friends with drug and alcohol users, are rejected by their peers, are exposed to peer problem behaviors, and those who are involved in social alcohol and drug use are more likely to experience behavior problems and substance abuse problems later in life (Beck & Treiman, 1996; Dishion & Skaggs, 2000; O’Connell et al., 2009). The majority of drugs and alcohol are consumed via social avenues, and greater availability is related to increased use (Birckmayer et al., 2004; Hawkins, Catalano, & Miller, 1992). Likewise, high perceived safety among adolescents is indicative of a higher likelihood of alcohol use (Henry, Slater, & Oetting, 2005). Drug use has been shown to be related to academic involvement and
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performance as well. Additionally, youth who are less involved and who perform more poorly academically are more likely to use (Birckmayer et al., 2004).

Spatial Epidemiology of Drug Use

In health geography the notion of environment refers to any space outside the body (McLafferty, 2008). Place environment is often what is being thought of when we think about environmental health. Although environment and place environment are used interchangeably, place environments are these environments that we live in and have meaning attached to them (Kearns, 1993). The essence of health geography is in exploring the relationship between these place environments and health. With specific regard to drug use, McLafferty describes three areas where health geography can contribute to drug use research (2008). First, a geographic approach can be particularly beneficial to drug use research by exploring geographic inequalities. Second, this approach contributes by increasing our understanding about the relationships between place environments and health. Thirdly, the geographic approach aids by providing a method useful in analyzing disparities in health care access and location. Examining drug use in its place moves beyond individuals and examines the context surrounding this phenomenon. Several methods exist in order to perform this examination and some are described below.
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**Global Spatial Autocorrelation.** This is a statistical method used to determine what pattern exists globally across a region (i.e. random, uniform or clustered) (Jerrett, Gale, & Kontgis, 2010; Legendre, 1993; Moran, 1948). This technique has been used in public health research with respect to municipal bike accidents, obesity patterns, environmental health research, and in other topics (Chaney & Kim, 2014; Jerrett et al., 2010; Penney, Rainham, Dummer, & Kirk, 2013).

**Local Spatial Autocorrelation.** While global spatial autocorrelation examines patterns across the region, local spatial autocorrelation accounts for the relationship between place factors for individual units (e.g. zip code, neighborhood) with respect to its neighbors (Anselin, 1995). Although global spatial autocorrelation methods have existed for half a century, it was not until the early 1990s that local methods were developed for identifying clusters (McLafferty, 2008). The local method has been used in a variety of public health research studies ranging from park access and obesity to neighborhood homicides (Messner et al., 1999; Pouliou & Elliott, 2009; Talen & Anselin, 1998).

**Spatial Excess Risk.** Mapping excess risk (also known as spatial relative risk or standard mortality ratio) has been previously documented in the literature (Berke, 2005; Lawson, 2001). Spatial inequalities in health outcomes are due to variations determinants leading to clustering. Those nearer clusters would experience increase risk while those outside the cluster would experience less risk. Berke outlines a method for exploring spatial risk while controlling for background risk (2005). These methods are also discussed by Anselin and Merrill (2005; 2013).
Prior Studies Using Coalition for a Drug-free Greater Cincinnati Adapted PRIDE Student Drug Use Survey (CDFGC-SDUS)

Four primary studies have previously used the Cincinnati-based CDFGC-SDUS data. One study found that Hispanic youth are at higher risk of episodic heavy drinking compared to other ethnic groups. This study explored this issue categorically using odds-ratios and chi-squared analysis to determine these differences (King & Vidourek, 2010). Another study found that, among African-American youth, 30-day use was negatively related to academic performance, participating in school activities, attending church, and having parents/teachers talk about the dangers of alcohol and set/enforce rules regarding alcohol; while recent use was positively related to getting into trouble, skipping school, and having friends who use alcohol and other drugs. This study explored this issue categorically across the aggregated region using odds-ratios and chi-squared analysis (Vidourek & King, 2010). A third study documented the prevalence of 30-day use and frequency of heavy episodic drinking among African-American youth. Also, perceived harm and parent/peer disapproval of substance use was negatively associated with use (Vidourek & King, 2013). A fourth study described the prevalence and categorical differences of marijuana use (King, Vidourek, & Hoffman, 2012). Aside from prevalence, it found that low perceived harm, easy access and low parent/peer disapproval posed greatest risk of using marijuana. This research adds to that which has already been done by characterizing these inequalities by specific geographic location.

Method

This cross-sectional study used data collected from the 2012 Cincinnati CDFGC-SDUS. A total of 57,241 participants from the 5-county Cincinnati metropolitan region completed the CDFGC-SDUS. A total of 8,561 cases were removed for the following reasons: participants
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provided an invalid zip code (5,262 cases removed), participants lived outside the 5-county region (3,167 cases removed), or participants resided in very small zip codes which would cause problems with contiguity of spatial weights (132 cases removed). Ultimately, there were 48,680 usable cases for analysis. Zip code was the geographic variable used in this study. Prior research has justified using this as the geographic unit (Gruenewald et al., 2013; Johnson, Gruenewald & Remer, 2009; Smith, 2008). Aligning findings to specific communities can, in some cases, be problematic due to misalignment and should be interpreted with that consideration.

The Coalition for a Drug-free Greater Cincinnati (CDFGC) is a regional coalition whose mission is to prevent and reduce drug use among adolescents across the Cincinnati metropolitan region. CDFGC recruited school participation via mail, phone, email, and through local coalition partnerships. Student participation was voluntary. Survey administrators informed students about the purpose of the survey, the confidential nature of the survey, and the importance of providing honest answers. Each student in a participating school was given a survey to complete on the date of survey administration.

Instrumentation and Materials

Individual data were collected via the Coalition for a Drug-free Greater Cincinnati adapted PRIDE Student Drug Use Survey (CDFGC-SDUS). Originally developed in the late 1980’s, CDFGC began using the survey system in 2000. The whole of the instrument has remained unaltered since 2000, but a few questions have been added with respect to prescription drug use and suicide behavior. Edits were suggested and validated by the research committee within CDFGC. The instrument has been shown by previous research to be valid and reliable (Adams, 1994; Craig & Emshoff, 1987; Metze, 2000). The survey was made up of 13 sections covering the following topics: personal and family information, student information, prior drug
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use, effect of drug use, perceived harm, age of onset, location of use, time of use, non-medical use, ease of access, perceived disapproval of friends/family of using, safety behavior at school, and safe school locations. The variables used in this study were 30-day use, peer/parental approval, perceived safety, age of onset, and geography for tobacco, alcohol, marijuana and other illegal drugs. Questions used to collect these variables are presented in Supplementary Table 1.

As previously reported by Metze, reliability testing was performed with $n = 631$ students from three locales (2000). The survey was administered twice and a correlation coefficient was calculated between times. Correlation values were high (most greater than 0.90) for personal and family information section. Correlation values ranged from 0.513 to 0.867 for the student information section; most questions less than 0.70 had an exact agreement of greater than 0.80 indicating a weak but acceptable correlation over time. Questions with major disagreement in this section dealt with communication between student/teacher, peer, and parent. Correlation values were above 0.618 for tobacco, alcohol and marijuana and 0.500 for other drugs in the perceived harm of drug use; all exact agreement values were greater than 60%. It is hypothesized the weaker reliability for this section is due to the question asking students about a qualitative measurement (i.e. “How do you feel…”) compared to a quantitative measurement (i.e. “How many times…”)(Metze, 2000). Questions in the drug use frequency section demonstrated high test-retest correlation with the exception of inhalants, which had a high exact match. Questions about age of onset generally had high correlation values and all exact agreement between test times were greater than 80%.
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**Data Analysis**

**Software for data analysis.** Data analysis was performed using two software programs. Data management and spatial analysis was conducted using R statistical software (version 3.0.1) (R Core Team, 2013). Visualization of spatial data and management of shapefiles was performed using QGIS (version 2.0) geographic information system software (QGIS Development Team, 2013).

**Assessment of research questions.** Assessing if there is a regional global spatial autocorrelation (i.e. pattern) of drug use was determined using the Global Moran’s I statistic (Anselin, Syabri, & Kho, 2006; Anselin, 2005; Moran, 1948). There are some similarities to non-spatial bivariate correlation. First, Moran’s I is bounded by -1 and +1. Second, it compares how similar points (or areas in the case of zip codes) are to one another across a broad region (thus, the “global” Moran’s I). The interpretation of this statistic is as follows: values nearer to -1 indicate a uniform distribution (i.e. dispersion); values nearer to 0 indicate a random distribution; and values nearer to +1 indicate a clustered pattern.

Determining the local spatial autocorrelation was determined using the local indicators of spatial autocorrelation (LISA) method outlined by Anselin (1995). This measure shows the extent to which points that are close to given point or region (e.g. zip code) have similar values. Each geographic unit receives a measure of spatial autocorrelation and is compared to its neighbors. Results are usually broken down in to four categories: “high-high” meaning the individual unit possesses a high observation and its neighbors are also high (In practice this is a high standardized observation of a high standardized spatial lag (average of weighted neighbors) and a low p-value for the local Moran’s I test (being adjusted for by k number of neighbors)); “high-low” meaning the individual unit is high but its neighbors are low; “low-high” meaning
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the individual unit is low but its neighbors are high; “low-low” meaning the individual unit is low and its neighbors are also low; and “Non-significant.” These can be displayed geographically to identify hot and cold spots (Anselin, 2005).

Spatial excess risk was calculated by comparing observed values with expected values for each zip code in the region. As previously described, spatial excess risk for an area (also known as spatial relative risk or standard mortality ratio) is the ratio of the observed count and the expected count for that area. The expected count is the product of the overall regional rate and the population at risk within the zip code (Anselin, 2005; Merrill, 2013). The population at risk for each zip code was defined as any adolescent age 12-18 years old and counts were retrieved from U.S. Census for the same year the adolescent drug use data was collected (U.S. Census Bureau, 2011). Statistical significance was determined using 95% confidence intervals: intervals not containing one and where both limits were less than one were considered statistically significant “low risk”; intervals not containing one and where both limits were greater than one were considered statistically significant “high risk”.

Results

Participants were equally represented across grades and by sex. The majority of participants were White (78.8%) followed by African American (8.4%). This demographic breakdown is comparable to the regional rates for these race groups (U.S. Census Bureau, 2011). Table 1 presents the full demographic breakdown of participants. Descriptive quantile maps, where each category has an equal number of cases in each category are also available as Supplementary Figures 5-8.

Results for global spatial autocorrelation are presented in Table 2. There was a significant clustering pattern observed for several variables: perceived safety of marijuana ($I = 0.204, p <$
Variables that presented significant global spatial autocorrelation were examined at the local level using Local Indicators of Spatial Autocorrelation (LISA). Figure 1 shows local clustering of adolescent perceived safety of marijuana. Figures 2-4 show local clustering of peer approval of alcohol, marijuana, and other drugs. Figure 5 shows local clustering of age of onset for other drugs. A tabular form of Figures 2-4 is presented in Table 3 where communities are identified with respect to cluster types. Community types include rural, suburban and urban areas of the Cincinnati metropolitan region.

Results for spatial excess risk showed variation across the 5-county region. Top high-risk and low-risk communities are identified in Table 3. Supplemental Figures 1-4 depict these rates.

Discussion

This study examined spatial patterns of adolescent drug use across the Cincinnati metropolitan region. It sought to describe if a spatial pattern of drug use exists, and if it does what is the nature of that pattern. This study examined the excess risk of adolescent drug use by zip code relative to the 5-county region.

A statistically significant clustering pattern was identified for perceived safety of marijuana; peer approval for alcohol, marijuana, and other drugs; and age of onset for other drugs. Each of these was in turn examined at the local level using the LISA method. Age of onset for other drugs showed a weak clustering pattern. It was not significant at the usual $\alpha = 0.05$ level, but was significant at the $\alpha = 0.10$ level and practical significance warranted further investigation. A key finding is that there are clusters of peer approval for alcohol, marijuana and other drugs. This means there is variation across the region; some areas with high peer approval
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and some areas of low peer approval. This was not the case for tobacco though, where the perception of peer approval was random. Another key finding is that the age at which adolescents begin using other drugs varies geographically. These findings support prior research by providing further evidence that drug use and drug-related behavior varies across geography. For example, Brownstein, Green, Cassidy, and Butler describe clusters of opioid abuse at the state level (2010). Their findings are suggestive of communities in greatest need of intervention and public health assistance. Petronis and Anthony likewise found clusters of first-time cocaine users with in U.S. cities, which were related to socio-demographic factors (2003). Recognizing that spatial variation exists and identifying geographic areas of greatest need stands as a critical component of health promotion and education work.

Analysis used to characterize the clusters identified at the global level yielded evidence of geographic variation among these variables. These local clusters, along with the box plot maps (Supplementary Figures 5-8) demonstrate that drug use behavior and related perceptions occurs in urban, suburban, and rural settings. This is evidenced when looking at the top at risk communities for other drugs which include communities from NW Warren County (rural), NE Hamilton County (suburban), and Cincinnati city-center (urban) (See Table 3). It is interesting to note that adolescents in Warren County perceived using marijuana as safe, but they felt their peer would not approve of their use, nor that of alcohol or other drugs (see Table 3). Oppositely, adolescents in two different Cincinnati city-center communities felt that marijuana use was not safe and that their peers would approve of their use, along with alcohol and other drugs. Peer and parental approval of drug use has previously demonstrated as predictors of adolescent use (Beck & Treiman, 1996; Dishion & Skaggs, 2000; O’Connell et al., 2009). Warren County had several areas of significantly low risk for marijuana use, but the Cincinnati city-center communities both
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were high risk areas for marijuana use (See Supplementary Figure 3). A rural community in N Butler County also was a hot spot for high peer approval for marijuana and was a top at risk community for marijuana, alcohol, and tobacco use. This finding is supported by prior research showing the influence of peers on drug use, but adds to the literature by demonstrating a methodology to contextualize these findings (Dishion & Skaggs, 2000). A suburban community in NE Hamilton County had an unusually high level of peer approval for other drugs and was a high risk community for adolescent use of other drugs. NW Butler County was a low risk community for alcohol, marijuana, tobacco and other drug use among adolescents. This research suggests a relationship between community level risk and determinants of adolescent drug use. The SE Hamilton County area also had large cluster of low age of onset of other drugs while having pockets of high risk for adolescent other drug use. The relationship between earlier age of onset and greater risk for related problems has been documented in prior research (Chou & Pickering, 1992; O’Connell et al., 2009). Identifying communities with lower on-average age of onset can aid in efforts to prevent the outcomes of drug abuse.

This study has acknowledged inherent limitations. Data were collected using self-report surveying seventh through twelfth grade students at participating schools in 2012. Only cases that contained a valid zip code in the geographic region were used. The results of this study are generalizable to adolescents in the Cincinnati region. The specific results are not generalizable to other communities because of the unique geographic nature of this research. However, the methods and findings that spatial patterns do exist across a large metropolitan region are applicable other areas of research.

Future research should focus on describing differences between communities with high and low rates of use in this region. Understanding how communities differ from one another
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contributes to prevention and intervention efforts by identifying areas of need and strengths of low risk communities. This can be done by examining in-depth individual use behaviors and their contributing factors within each community, including where adolescent are using drugs. Another future step is to use this information to inform local community effort to inform local community health efforts.

This research has demonstrated that spatial clusters of drug use behavior and perceptions exist across a large metropolitan region. These clusters vary based on their geographic location and direction (i.e. high or low). Risk of adolescent use also differs by community compared to the larger geographic area. This methodology can be applied to other drug use scenarios to identify at-risk communities and allocate resources for prevention and intervention efforts.
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Tables

Table 1. Demographics.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Sex</th>
<th>Race</th>
<th>Race</th>
</tr>
</thead>
<tbody>
<tr>
<td>7th</td>
<td>16.4% Male</td>
<td>45.8% White</td>
<td>78.8%</td>
</tr>
<tr>
<td>8th</td>
<td>17.1% Female</td>
<td>48.5% African American</td>
<td>8.4%</td>
</tr>
<tr>
<td>9th</td>
<td>18.5% No response</td>
<td>5.7% Latino</td>
<td>2.1%</td>
</tr>
<tr>
<td>10th</td>
<td>19.1%</td>
<td></td>
<td>2.9%</td>
</tr>
<tr>
<td>11th</td>
<td>16.2%</td>
<td>Native American</td>
<td>0.7%</td>
</tr>
<tr>
<td>12th</td>
<td>12.8%</td>
<td>Multiple</td>
<td>4.2%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other</td>
<td>1.5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No response</td>
<td>1.6%</td>
</tr>
</tbody>
</table>

Table 2. Global Autocorrelation for drugs and variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Drug</th>
<th>$l$</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-day Use</td>
<td>Tobacco</td>
<td>-0.056</td>
<td>0.751</td>
</tr>
<tr>
<td></td>
<td>Alcohol</td>
<td>0.019</td>
<td>0.323</td>
</tr>
<tr>
<td></td>
<td>Marijuana</td>
<td>0.043</td>
<td>0.205</td>
</tr>
<tr>
<td></td>
<td>Other Drugs</td>
<td>0.004</td>
<td>0.404</td>
</tr>
<tr>
<td>Perceived Safety</td>
<td>Tobacco</td>
<td>-0.085</td>
<td>0.870</td>
</tr>
<tr>
<td></td>
<td>Alcohol</td>
<td>-0.009</td>
<td>0.486</td>
</tr>
<tr>
<td></td>
<td>Marijuana</td>
<td>0.204</td>
<td>$&lt;0.001$</td>
</tr>
<tr>
<td></td>
<td>Other Drugs</td>
<td>-0.050</td>
<td>0.727</td>
</tr>
<tr>
<td>Peer Approval</td>
<td>Tobacco</td>
<td>0.054</td>
<td>0.161</td>
</tr>
<tr>
<td></td>
<td>Alcohol</td>
<td>0.100</td>
<td>0.044</td>
</tr>
<tr>
<td></td>
<td>Marijuana</td>
<td>0.134</td>
<td>0.014</td>
</tr>
<tr>
<td></td>
<td>Other Drugs</td>
<td>0.145</td>
<td>0.009</td>
</tr>
<tr>
<td>Parent Approval</td>
<td>Tobacco</td>
<td>-0.061</td>
<td>0.779</td>
</tr>
<tr>
<td></td>
<td>Alcohol</td>
<td>-0.003</td>
<td>0.448</td>
</tr>
<tr>
<td></td>
<td>Marijuana</td>
<td>0.018</td>
<td>0.324</td>
</tr>
<tr>
<td></td>
<td>Other Drugs</td>
<td>-0.030</td>
<td>0.614</td>
</tr>
<tr>
<td>Avg. Age of Onset</td>
<td>Tobacco</td>
<td>0.067</td>
<td>0.116</td>
</tr>
<tr>
<td></td>
<td>Alcohol</td>
<td>0.056</td>
<td>0.155</td>
</tr>
<tr>
<td></td>
<td>Marijuana</td>
<td>0.042</td>
<td>0.208</td>
</tr>
<tr>
<td></td>
<td>Other Drugs</td>
<td>0.076</td>
<td>0.091</td>
</tr>
</tbody>
</table>
Table 3.

Local map clusters and areas of spatial relative risk identified.

<table>
<thead>
<tr>
<th>Map</th>
<th>(+)</th>
<th>(-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peer approval: other drugs</td>
<td>Cincinnati city-center, NE Hamilton Co.</td>
<td>W Hamilton Co., Warren Co.</td>
</tr>
</tbody>
</table>
Figures

Figure 1. Clustering of perceived safety of marijuana using Local Indicators of Spatial Autocorrelation (LISA).

Figure 2. Clustering of peer approval of alcohol using Local Indicators of Spatial Autocorrelation (LISA).
Figure 3. Clustering of peer approval of marijuana using Local Indicators of Spatial Autocorrelation (LISA).

Figure 4. Clustering of peer approval of other drugs using Local Indicators of Spatial Autocorrelation (LISA).
Figure 5. Clustering of age of onset of other drugs using Local Indicators of Spatial Autocorrelation (LISA).
Supplementary Table I

Selected variables for use from the PRIDE Student Drug Use data set.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Drugs</th>
<th>Tobacco</th>
<th>Alcohol</th>
<th>Marijuana</th>
<th>Other Drugs</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-day use</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Other illegal drugs</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Illicit drugs</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Illicit drug use</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Illicit drug use by age</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Illicit drug use by gender</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Illicit drug use by race</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Illicit drug use by socioeconomic status</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Illicit drug use by parental disapproval</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Illicit drug use by peer disapproval</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Illicit drug use by perceived harm</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Illicit drug use by age of onset</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Note: The full instrument is provided in the Appendix of this dissertation.
Spatial Patterns of Adolescent Drug Use

Supplementary Figure 1. Spatial Excess Risk Map of Tobacco Use.

Supplementary Figure 2. Spatial Excess Risk Map of Alcohol Use.
Supplementary Figure 3. Spatial Excess Risk Map of Marijuana Use.

Supplementary Figure 4. Spatial Excess Risk Map of Other Drug Use.
Spatial Patterns of Adolescent Drug Use

**Supplementary Figure 5.** Quantile Map of Tobacco Use.

**Supplementary Figure 6.** Quantile Map of Alcohol Use.
Spatial Patterns of Adolescent Drug Use

**Supplementary Figure 7.** Quantile Map of Marijuana Use.

**Supplementary Figure 8.** Quantile Map of Other Drug Use.
Abstract

This article provides a review of spatial analysis methods for use in health promotion and education research and practice. Spatial analysis seeks to describe or make inference about variable differences across a geographic area. This is important for understanding how health outcomes differ from place to place; and in terms of understanding some of the environmental underpinnings of health outcome data by placing it in context of geographic location. This article sought to (1) define spatial analysis methods, (2) describe how spatial methods differ from non-spatial methods, and (3) describe common spatial analysis methods for public health research and education. Four of the most commonly used spatial analysis techniques are described; along with the research questions they can help answer, and an example of their applied use. The techniques are: global spatial autocorrelation, cluster detection and identification, descriptive mapping, and spatial regression analysis. This article provides useful in informing health promotion and education researchers and practitioners seeking to examine research questions from a spatial perspective.

Keywords: GIS; Mapping; Spatial methods; Spatial analysis; Research methods; Context; Health education; Prevention research
Spatial Methods in HPE

**Background**

Epidemiological methods are an important part of assessing community health needs, informing planning and implementing of intervention/prevention efforts, and in evaluation research. The traditional epidemiologic triangle of disease (See Figure 1) describes the relationship between agent, environment and host. The interplay of these factors via space and time (and vectors if applicable) determines the development and spread of disease (Merrill, 2013). Prior research in health promotion and education has focused heavily on addressing the peripheral issues in the epidemiological triad of disease: host, agent, and environment; and few have focused on the spatial or spatio-temporal relationship of these factors. Examining the relationship of the spatial environment and health outcomes addresses the local social and cultural context of these observations (McLafferty, 2008). These spatial environments usually refer to environments that we live in and have meaning attached them (Kearns, 1993; McLafferty, 2008). Examples include neighborhoods, cities, etc. McLafferty describes three areas how this spatial approach to health research can be useful in community health: (1) Identifying health disparities across a geographic region, (2) Understanding the relationship between health and place, and (3) Examining disparities with respect to access, services, and treatment (2008). Incorporating a spatial element to research moves beyond individuals and examines the context surrounding this phenomenon.
Spatial Methods in HPE

This article is designed to discuss spatial epidemiological methods that are relevant to health promotion and education (HPE) work. This paper serves to inform and provide guidance for those seeking to utilize this methodology. Research using this approach can contextualize health issues by examining the relationship between health and place, and identify areas of need within a region. This article addresses the following research objectives: (1) Defining spatial methods, (2) Describe how spatial methods differ from non-spatial methods, and (3) Identifying spatial methods commonly used in public health research and the research questions they can help answer. The use of spatial epidemiological methods in health promotion and education is an emerging one. The primary aim of this article is to provide an overview of spatial methods and to present potential practical applications of this methodology to health education practice and research.

Spatial Methods

Any analysis, descriptive or inferential, that seeks to describe or account for variable differences across a geographic area is considered a spatial method. These differences across an area are known as spatial variation. Descriptive spatial methods generally seek to describe
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variables with respect to their location. This can take the shape of identifying geographic health inequalities, risk analysis, health outcome surveillance, analyzing access to health services, and understanding the relationship between health and place (Mclaafferty, 2008; Nykiforuk & Flaman, 2011). For example, using computer software to display where injection drug users are located with respect to syringe exchange locations would be a descriptive spatial analysis. Inferential spatial methods seek to predict, explain, or generalize findings across a broader geographic region. Identifying density of injection drug use clusters would be an example of this type of spatial method.

**Spatial vs. Non-spatial Methods**

In general, spatial epidemiological methods seek to explain variable dissimilarity across a geographic region; non-spatial methods do not take geographic location into account in their analysis. It is typical for there to be a corresponding spatial method for each non-spatial method (although not always the case). Regression analysis is often used to predict and explain outcome variables and, as a type of statistical analysis, has a few spatial counterparts, geographically weighted regression being one of them. Correlation coefficients, which describe the strength of relationship between two variables, also have a spatial equivalent called spatial autocorrelation. Like non-spatial correlation coefficients which have several ways to measure (e.g. Pearson, Spearman, etc.), there are several ways to measure spatial autocorrelation as well (e.g. Moran’s I, Getis-Ord G). Each of these spatial methods seeks to answer similar questions as their non-spatial counterpart with the key difference being their ability to explain, identify and account for spatial variation. The reason for this is that research questions are asked in context of geographical location.
Common Spatial Methods and Research Questions They Can Answer

Prior research has elicited common spatial methods used in health promotion and education research (See Manuscript 1). These methods include global spatial autocorrelation, cluster detection, descriptive mapping, and spatial regression.

Global Spatial Autocorrelation

Identifying the nature of global patterns (i.e. random, uniform or clustered) can be determined using global spatial autocorrelation analysis (Jerrett, Gale, & Kontgis, 2010; Legendre, 1993; Moran, 1948). As a result of this analysis we know the broad pattern of a variable, but we do not know the character of these patterns. Further analysis is warranted to characterize patterns and is discussed in the cluster detection and identification section below. Global spatial autocorrelation has been used in public health research to examine patterns of municipal bike accidents, obesity rates, substance abuse behavior, treatment and access to services among others (Chaney & Kim, 2014; Guerrero, Kao, & Perron, 2013; Penney, Rainham, Dummer, & Kirk, 2013). This analysis can be useful in health promotion and education by identifying if unusual patterns of health behavior exist across a region.

An illustration with safety of on-road motorists is used here. If one were interested in improving safety among this group it would be pertinent to identify places that are more or less safe across a broad region (e.g. city or county) in terms of collisions. One way to determine if this observed pattern contains a statistically significant pattern is using the test for global autocorrelation. In this example, one could identify if the rate of motor vehicle collisions across a region is uniform, random or clustered. This would provide evidence that inequalities exist with respect to motorist safety and would lead to analysis that characterizes these clusters.
Spatial Methods in HPE

Cluster Detection and Identification

Spatial association. Local Indicators of Spatial Autocorrelation (LISA) and Getis-Ord Local G are two commonly used methods for cluster detection (Anselin, 1995; Getis & Ord, 1992). While global spatial autocorrelation methods have existed for half a century, it was not until the early 1990’s that local methods were developed for identifying clusters (McLafferty, 2008). Global spatial autocorrelation examines patterns across the region, local spatial autocorrelation identifies where local clusters are located and characterized them.

Local spatial autocorrelation compares observed values in a region (e.g. zip code, neighborhood, etc.) with observed values in neighboring regions (e.g. neighboring zip codes, neighboring neighborhoods, etc.) (Anselin, 1995). Although these two measure types differ in their computation, they generally seek to characterize an area as being high or low in comparison to its neighboring areas. These high or low spots are sometime referred to as hot or cold spots. This method has been used in a variety of public health research studies ranging from park access and obesity to neighborhood homicides (Messner et al., 1999; Pouliou & Elliott, 2009; Talen & Anselin, 1998). This method is particularly useful to identify which communities have unusually high rates (or low rates) of a particular health variable in the context of its neighbors. This information can be directly used for targeting communities with HPE intervention and prevention efforts.
Spatial Methods in HPE

**Spatial scan analysis.** The spatial scan analysis uses a uniquely sized window (specified by the analyst) to move across a landscape and detect clusters (Kulldorff, 1997). It differs from local spatial autocorrelation because it calculates a maximum likelihood ratio of cases relative to the underlying population to identify areas that are clusters. Like local spatial autocorrelation, this method seeks to identify where clusters are located, but the method of identifying them is computationally different.

This method has been used to identify clusters of alcohol related mortality, HIV cases, and others (Hanson & Wieczorek, 2002; Hixon, Barczyk, Buckenmeyer, & Feldman, 2011). As with measures of spatial association, understanding where clusters of problematic health behavior are located would be important for informing health promotion work.

Here we continue the example provided earlier of motor vehicle safety in terms of cluster identification and detection. If the test for global spatial autocorrelation indicates there are clusters of motor vehicle accidents (i.e. $I > 0$ and $p < 0.05$), then one of the above methods can be implemented. Using these cluster detection methods proves useful for two reasons: (1) Identifying where areas of motor vehicle collision inequalities are located, and (2) Describing the nature of these inequalities (e.g. high or low rate pockets). Identifying where motor vehicle collisions are occurring at unusually high rates can warrant allocation of resources and examination of underlying causes of these high rates; areas with particularly low rates could provide insight on collision prevention.

**Descriptive Mapping**

Descriptive mapping is also known as Geographic Information Systems (GIS) mapping or data mapping. GIS are computer software applications that allow for creation of maps that display spatial data, as well as perform spatial analysis and management of spatial data. Data
Spatial Methods in HPE

mapping has always been dependent on computer technology. It was not until the late 1980s
when GIS became publicly available for use and although existing, it was limited by the
computing power available (Neteler & Mitasova, 2008). Currently there are several proprietary
and open-source options available. In general, descriptive mapping seeks to visually represent
data of a particular region. An example of a quantile map (one that uses an equal number of
cases in each category) of marijuana use among adolescents is provided as Figure 1. Similar to a
box plot, data were categorized as being lower outlier, lower quantile, etc. and displayed on the
map. This allows the reader to see where community values are with respect to each other. In
fact, Nykiforuk and Flaman described four ways mapping could be used in community health
research: (1) health outcome surveillance, (2) risk analysis, (3) access to health services and
planning, and (4) community profiling (2011). Descriptive mapping can be a very useful tool for
spatial analysis and dissemination purposes. Descriptive analysis can help portray health and
place; and descriptive mapping can be used for communicating findings to community members,
politicians and in leveraging funding.

Keeping the example of motor vehicle safety and collision, descriptive mapping can be a
particularly useful technique to communicate findings. Observing where collisions are occurring
and which areas have the highest/lowest collision rate can be insightful. One might see one
community with particularly high (or low) collision rate and notice a pattern or location within
that community where collisions tend to occur (e.g. a particular street or interchange). This
method can be particularly effective for disseminating and easily communicating information to
community decision makers. This technique can be combined with inferential spatial analysis
methods to provide statistical evidence for decision making.
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**Spatial Regression**

Non-spatial regression models (e.g. linear regression, logistic regression, etc.) do not account for the spatial relationship of observations to other observations or their geographic place. On the other hand, spatial regression models seek to account for this relationship. One common method, called geographically weighted regression, weights variables based on neighboring areas. Multi-level modeling is another technique that utilizes the hierarchical structure of observations within different areas or units. For example, individuals across a state may live in different zip codes and municipalities. Therefore, each individual belongs to a zip code and municipality. This type of modeling accounts for the variation between higher membership and examines the relationship of lower geography (e.g. zip code). This method has been used to examine neighborhood relationship of drug and alcohol activity with child maltreatment; drug crimes and violent crime; and a host of other public health issues (Freisthler, Needell, & Gruenewald, 2005; Gorman, Zhu, & Horel, 2005). The value of spatial regression modeling to health promotion and education is in identifying determinants, explaining relationship between variables, and developing methods for prediction while accounting for spatial relationship.

In terms of motor vehicle collisions, one could imagine wanting to know what neighborhood-level predictors influence collision rates. Because this research is geographically based (i.e. examining collisions across a region or within smaller sub-regions like zip codes) it is a fitting example to apply a spatial regression technique. The data is spatial in nature because of its geographic location and the connectivity of the road networks the passes through neighboring areas. Spatial regression analysis would account for the spatial relationship of the data while providing explanation for motor vehicle collisions.
Implications for Health Promotion and Education

Implications for Practice

Utilizing spatial analysis methods in health promotion research and education practice can provide a framework for identifying locales of greatest need, informing resource allocation, and geographically targeting intervention/prevention efforts. Identifying areas of health inequality serves to support community needs assessment and guide where health promotion and education work is needed most. This act can provide direction for allocating resources to areas of greatest need and prevent duplication of efforts. A major contribution of this methodology health promotion and education practice is in its utility for targeting specific geographies for intervention/prevention efforts.

A spatial analysis approach can be particularly adept at addressing the Seven Strategies of Community Change outlined by the Community Anti-Drug Coalitions of America (CADCA). This approach to addressing community health issues includes providing information, enhancing skills, providing support, enhancing access/reducing barriers, changing consequences, physical design considerations, and modifying/changing policies (CADCA, 2009). For example, descriptive mapping could be used to provide information to the community, populations at risk and key community leaders; it could also be used to identify restrictions in access (e.g. primary care); and could be instrumental in identifying issues with the physical environment (e.g. on-road bicycle safety) and in informing policy changes (e.g. speed limits). The other spatial analysis method discussed could likewise be used to address each area of community change and guide community change.
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Implications for Research

These methods are essential for understanding health outcomes in context of their social environment. This contextual understanding is critical for intervention/prevention efforts. Spatial analysis methods greatly add to contextualizing answers to research questions. This would occur first by identifying areas of health inequalities. Further, this methodology provides the means to characterize patterns across a region, including how an individual area relates to its neighboring areas. Future research in health promotion and education can address health issues in a multidisciplinary manner by utilizing spatial analysis methods.

Conclusion

This article sought to describe spatial analysis methods applicable to health promotion practice and research. Spatial methods were differentiated from non-spatial methods, and several of the most common methods were discussed in a summary manner. Analysis methods developed to examine variables in context of their geographic location naturally suite themselves to HPE because of their community-based nature. For example, spatial analysis methods can identify areas of inequality and be used as framework for future health promotion and education work. Chaney and Kim (2014) identified neighborhoods of Cincinnati that were at higher risk of bicycle/vehicle collisions. This assessment can be in turn used to inform local health policy makers and bicycle advocacy groups. Another example elucidates the spatial variation of adolescent drug use and behavior (See Manuscript 2). Results from this research identified communities where adolescents were at higher risk to use compared to other communities. Further research should seek to explain these differences by characterizing the different communities and providing insight into environmental prevention efforts. The utilization of spatial analysis methods provides a framework for understanding the underpinnings of observed
Spatial Methods in HPE

data by examining where it comes from. This understanding is increasingly important in public health prevention and intervention efforts.
Spatial Methods in HPE

References


Spatial Methods in HPE

*Learning Administration, 14*(4). Retrieved from


Figure 1. Descriptive Quantile Map of 30-day Use of Marijuana Among Adolescents in SE Ohio.
Conclusion

This dissertation used a spatial epidemiological approach to examine adolescent drug use in the Cincinnati area. It also reviewed this approach in the public health drug use literature and provided a methodological outline for spatial epidemiology in health promotion and education work.

Manuscript one showed that injection drugs and alcohol were the most common topics of research in spatial epidemiology of drug use. The results presented showed a variety of methods used to answer research questions, but the most common were spatial autocorrelation and descriptive mapping. Results from these research studies demonstrate geographic variability of use patterns, access to resources, and opportunity for future research. Manuscript two demonstrated there are spatial patterns of several variables. The clusters of these variables were then classified as being high or low when comparing itself with its neighbors. Specific geographical areas and communities are discussed within the context of results. Community excess risk was used to interpret the findings of clusters and was also presented. Manuscript three defines spatial analysis and outlines methods for cluster detection, spatial regression, and descriptive mapping. These methods are useful in HPE due to their community-based nature.
### Appendix

#### THE PRIDE QUESTIONNAIRE FOR GRADES 7-12

**sponsored by the Coalition for a Drug-Free Greater Cincinnati**

May not be used without permission of PRIDE Surveys.

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**I. PERSONAL AND FAMILY INFORMATION**

<table>
<thead>
<tr>
<th>1. Ethnic Origin:</th>
<th>2. Sex:</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>Male</td>
</tr>
<tr>
<td>African American</td>
<td>Female</td>
</tr>
<tr>
<td>Asian/Pacific Islander</td>
<td></td>
</tr>
<tr>
<td>Native American</td>
<td></td>
</tr>
<tr>
<td>Mixed Origin</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. Zip Code</th>
<th>4. Grade:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-9</td>
<td>7</td>
</tr>
<tr>
<td>10-12</td>
<td>8</td>
</tr>
<tr>
<td>13-15</td>
<td>9</td>
</tr>
<tr>
<td>16-18</td>
<td>10</td>
</tr>
<tr>
<td>19-21</td>
<td>11</td>
</tr>
<tr>
<td>22-24</td>
<td>12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5. Do you live with...</th>
<th>6. Do you have a job?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both parents</td>
<td>Yes, full-time</td>
</tr>
<tr>
<td>Mother only</td>
<td>Yes, part-time</td>
</tr>
<tr>
<td>Father only</td>
<td>No</td>
</tr>
<tr>
<td>Mother &amp; stepfather</td>
<td></td>
</tr>
<tr>
<td>Father &amp; stepmother</td>
<td></td>
</tr>
<tr>
<td>Extended family</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>7. Do your parents have a job?</th>
<th>8. What is the educational level of your:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Father</td>
<td>Mother</td>
</tr>
<tr>
<td>Yes, full-time</td>
<td></td>
</tr>
<tr>
<td>Yes, part-time</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

**II. STUDENT INFORMATION**

<table>
<thead>
<tr>
<th>1. Do you make good grades?</th>
<th>2. Do you get into trouble at school?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. Do you take part in school sports teams?</th>
<th>4. Grade:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>7</td>
</tr>
<tr>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5. Do you take part in community activities such as scouts, rec. teams, youth clubs, etc.?</th>
<th>6. Do you have a job?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes, full-time</td>
</tr>
<tr>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>7. Do your parents talk with you about the dangers of tobacco, alcohol and drug use?</th>
<th>8. How often do you use social media sites (Facebook, Twitter, YouTube, etc.)?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Everyday</td>
</tr>
<tr>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>9. Do your teachers talk with you about the dangers of tobacco, alcohol and drug use?</th>
<th>10. Do you break the rules about using alcohol and drugs?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>11. Do your parents set clear rules for you when you break the rules about using alcohol and drugs?</th>
<th>12. Do you break the rules about using alcohol and drugs?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes, full-time</td>
</tr>
<tr>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>13. Have you been in trouble with the police?</th>
<th>14. Do you take part in gang activities?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>15. Do your friends use tobacco (cigarettes, etc.)?</th>
<th>16. Do your friends use alcohol (beer, liquor, etc.)?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>17. Do your friends use marijuana (weed, chronic, dank, kush, etc.)?</th>
<th>18. Have you had 5 or more drinks (alcohol, beer, liquor, etc.)?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes, full-time</td>
</tr>
<tr>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>19. In the past 3 months, have you been at a party where alcohol was available?</th>
<th>20. In the past 3 months, have you been at a party where prescription drugs, not prescribed to you, were available?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes, full-time</td>
</tr>
<tr>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>21. In the past 3 months, have you been at a party where prescription drugs, not prescribed to you, were available?</th>
<th>22. Does school ask any students to take a drug test?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes, full-time</td>
</tr>
<tr>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>23. Have you bought or sold drugs AT school?</th>
<th>24. Have you bought or sold drugs NOT AT school?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes, full-time</td>
</tr>
<tr>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>25. Have you bought or sold drugs when NOT at school?</th>
<th>26. How often do you use social media sites (Facebook, Twitter, YouTube, etc.)?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Everyday</td>
</tr>
<tr>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>27. In the past 3 months, have you heard anti-drug messages?</th>
<th>28. In the past 3 months, have you heard anti-alcohol messages?</th>
</tr>
</thead>
<tbody>
<tr>
<td>TV</td>
<td>TV</td>
</tr>
<tr>
<td>Radio</td>
<td>Radio</td>
</tr>
<tr>
<td>Internet</td>
<td>Internet</td>
</tr>
<tr>
<td>Social media sites</td>
<td>Social media sites</td>
</tr>
<tr>
<td>Billboards</td>
<td>Billboards</td>
</tr>
<tr>
<td>Movie theaters</td>
<td>Movie theaters</td>
</tr>
<tr>
<td>Not heard/seen anti-drug messages</td>
<td>Not heard/seen anti-alcohol messages</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>29. Are you aware of an anti-drug organization or community group in your neighborhood?</th>
<th>30. How many days have you been absent from school this year?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>None</td>
</tr>
<tr>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>31. Alcohol?</th>
<th>32. Tobacco?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>33. Marijuana?</th>
<th>34. Have you been in trouble with the police?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

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### III. Within the Past Year How Often Have You...
1. Smoked cigarettes?
2. Used smokeless tobacco (chew, etc.)?
3. Smoked cigars?
4. Drank beer?
5. Drank coolers, hard lemonade, etc.?
6. Drank liquor (whiskey, vodka, rum, etc.)?
7. Smoked marijuana (weed, chronic, dank, kush, etc.)?
8. Used cocaine (crack, etc.)?
9. Used inhalants (glue, gas, etc.)?
10. Used hallucinogens (PCP, LSD, etc.)?
11. Used heroin?
12. Used steroids?
13. Used ecstasy (MDMA)?
14. Used meth (crystal, ice, crank, etc.)?

### VI. At What Age Did You First...
1. Smoke cigarettes?
2. Use smokeless tobacco (chew, etc.)?
3. Smoke cigars?
4. Drink beer?
5. Drink coolers, hard lemonade, etc.?
6. Drink liquor (whiskey, vodka, rum, etc.)?
7. Smoke marijuana (weed, chronic, dank, kush, etc.)?
8. Use cocaine (crack, etc.)?
9. Use inhalants (glue, gas, etc.)?
10. Use hallucinogens (PCP, LSD, etc.)?
11. Use heroin?
12. Use steroids?
13. Use ecstasy (MDMA)?
14. Use meth (crystal, ice, crank, etc.)?

### VIII. When Do You Usually...
(You may mark more than 1 response for each question)
1. Smoke cigarettes?
2. Use smokeless tobacco (chew, etc.)?
3. Smoke cigars?
4. Drink beer?
5. Drink coolers, hard lemonade, etc.?
6. Drink liquor (whiskey, vodka, rum, etc.)?
7. Smoke marijuana (weed, chronic, dank, kush, etc.)?
8. Use cocaine (crack, etc.)?
9. Use inhalants (glue, gas, etc.)?
10. Use hallucinogens (PCP, LSD, etc.)?
11. Use heroin?
12. Use steroids?
13. Use ecstasy (MDMA)?
14. Use meth (crystal, ice, crank, etc.)?

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### IX. NON-MEDICAL USE

**Uppers** = to give people more energy  
(such as Ritalin, Adderall, Concerta, etc.)

**Downers** = to calm people down  
(such as Valium, Xanax, Ativan, etc.)

**Pain Killers** = to relieve severe pain  
(such as OxyContin, Vicodin, Percocet, etc.)

#### 1. Within the past year, how often have you used a prescription drug such as (uppers, downers, pain killers, etc) not prescribed for you?
- Did not use
- Once/year
- 6 times/year
- Once/month
- Twice/month
- Once/week
- 3 times/week
- Every day

#### 2. Within the past year, how often have you used an over the counter drug such as (cold medicine, diet pills, sleep aids, stay awake pills, etc.) to get high?
- Did not use
- Once/year
- 6 times/year
- Once/month
- Twice/month
- Once/week
- 3 times/week
- Every day

#### 3. At what age did you first use a prescription drug such as (uppers, downers, pain killers, etc) not prescribed for you?
- Never used
- 11 or under
- 12
- 13
- 14
- 15
- 16
- 17 or older

#### 4. At what age did you first use an over the counter drug such as (cold medicine, diet pills, sleep aids, stay awake pills, etc.) to get high?
- Never used
- 11 or under
- 12
- 13
- 14
- 15
- 16
- 17 or older

#### 5. How wrong would your parents feel it would be for you to use a prescription drug such as (uppers, downers, pain killers, etc) not prescribed for you?
- Not wrong at all
- A little bit wrong
- Wrong
- Very Wrong

#### 6. How wrong would your parents feel it would be for you to use an over the counter drug such as (cold medicine, diet pills, sleep aids, stay awake pills, etc.) to get high?
- Not wrong at all
- A little bit wrong
- Wrong
- Very Wrong

#### 7. Do you feel that using a prescription drug such as (uppers, downers, pain killers, etc) not prescribed for you is harmful to your health?
- No harm
- Some harm
- Harmful
- Very harmful

#### 8. Do you feel that using an over the counter drug such as (cold medicine, diet pills, sleep aids, stay awake pills, etc.) to get high is harmful to your health?
- No harm
- Some harm
- Harmful
- Very harmful

#### 9. How easy is it to get prescription drugs such as (uppers, downers, pain killers, etc) not prescribed for you?
- Don't know/can't get
- Very difficult
- Fairly difficult
- Very easy

#### 10. How easy is it to get over the counter drugs such as (cold medicine, diet pills, sleep aids, stay awake pills, etc.)?
- Don't know/can't get
- Very difficult
- Fairly difficult
- Very easy

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**PLEASE DO NOT WRITE IN THIS AREA**

[SERIAL]

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1. In the classroom
2. In the cafeteria (lunchroom)
3. In the halls
4. In the bathroom
5. In the gym
6. On the school bus
7. At school events (ballgames, etc.)
8. On the playground
9. In the parking lot

X. HOW EASY IS IT TO GET...
1. Cigarettes, smokeless tobacco, cigars, etc.?  
2. Beer, wine, liquor and other alcohol products?  
3. Marijuana (weed, chronic, dank, kush, etc.)  
4. Other illicit drugs?

XI. IN MY SCHOOL, I FEEL SAFE...

1. Carried a handgun?  
2. Carried a knife, club or other weapon?  
3. Threatened a student with a handgun, knife or club?  
4. Threatened to hurt a student by hitting, slapping or kicking?  
5. Hurt a student by using a handgun, knife or club?  
6. Hurt a student by hitting, slapping or kicking?  
7. Been threatened with a handgun, knife or club by a student?  
8. Had a student threaten to hit, slap or kick you?  
9. Been afraid a student may hurt you?  
10. Been hurt by a student using a handgun, knife or club?  
11. Been hurt by a student who hit, slapped, or kicked you?  

XII. HOW WRONG WOULD YOUR PARENTS/FRIENDS FEEL IT WOULD BE FOR YOU TO...

1. Use tobacco (cigarettes, etc.)?  
2. Use alcohol (beer, wine, liquor, etc.)?  
3. Use marijuana (weed, chronic, dank, kush, etc.)  
4. Use other illicit drugs?

XIII. WHILE AT SCHOOL HAVE YOU...(Past Year)

11. From whom do you usually get prescription drugs that were not prescribed for you?  (Mark all that apply)
   - Do not use  
   - Friends  
   - Parents  
   - Siblings  
   - Store  
   - Internet  
   - Other

12. Where do you usually use prescription drugs that were not prescribed for you?  (Mark all that apply)
   - Do not use  
   - At home  
   - At school  
   - In a car  
   - Friend's house  
   - Parties  
   - Other

13. When do you usually use prescription drugs that were not prescribed for you?  (Mark all that apply)
   - Do not use  
   - Before School  
   - During School  
   - After School  
   - Week Nights  
   - Weekends

XIV. ADDITIONAL QUESTIONS

1. Do not use  
2. At home  
3. At school  
4. In a car  
5. Friend's house  
6. Parties  
7. Other

THANK YOU FOR YOUR PARTICIPATION
Appendix Figure 1: Complete PRIDE Student Drug Use Survey used to collected data in the 2011-2012 school year.