URBAN-RURAL INFLUENCES ON DRIVING BEHAVIORS AND DRIVING OUTCOMES AMONG MICHIGAN YOUNG ADULTS: AN INVESTIGATION OF ROADWAY CHARACTERISTICS, ALCOHOL ESTABLISHMENTS, AND SOCIAL INFLUENCES

by

Tenaya Marie Sunbury

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Doctoral Committee:

Associate Professor, Edith A. Parker, Co-Chair
Research Professor and Lecturer, Jean T. Shope, Co-Chair
Professor Ana V. Diez-Roux
Professor Trivellore E. Raghunathan
Research Associate Professor, C. Raymond Bingham

To Frances Ruiz Moran

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Su preciosa conchita bonita (siempre),

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Okay, I'm done, so you can stand up now. Don't worry, the rest of my dissertation isn't like the acknowledgement section[3]…or is it? _*When*_ you read the rest of my dissertation, you may want to sit down again (just a suggestion). Oh, I would get some coffee, too. If you have any questions, I'll be waiting for you in the parking lot.

[2] I knew I could get a Star Wars joke in, if I tried. Page 148 is for you, Tommy.
[3] I love footnotes!!!

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ABSTRACT

Objective: Motor vehicle crashes are a huge public health problem. Identifying area characteristics (or aspects of the physical and social environment) and how these area characteristics are associated with driving behaviors and driving outcomes may provide insights into possible prevention strategies. Methods: Quantitative methods were used to analyze survey data collected from Michigan young adults and state driver records. Area-level data were obtained from the Michigan Geographic Data Library road network, Michigan Liquor Control Commission, and U.S. Census Bureau. Area characteristics were conceptualized and operationalized for each study by creating a circular buffer (with a 12.1 mile radius) around each respondent's geocoded residence to estimate each individual's area exposure.

The first study examined whether roadway characteristics were associated with individual driving behaviors and the likelihood of a crash (casualty or non-casualty). Results: Roadway characteristics were not associated with driving behaviors for either men or women. There was no direct relationship between roadway characteristics and the likelihood of crash. For men, but not for women, the results suggested that the association between the likelihood of casualty crash involvement and high-risk driving was higher with rural roads than urban roads, *OR* = 1.42, 95% CI [1.08, 1.86].

The second study examined whether area characteristics (alcohol establishment density and proportion of rural population) were associated with drinking behaviors and alcohol-related crashes. Results: There was an inverse relationship between alcohol establishment density and drinking behaviors, which was stronger in women than in men. The results indicated that higher density of alcohol establishments decreased the likelihood of men being involved in an alcohol-related crash *OR* = 0.014 [95% CI: <0.001, 0.576].

The last study examined the potential role of social influences (i.e., social approval for drink/driving) in explaining the relationship between area characteristics and participant perceptions of drink/driving as dangerous. Results: For both men and women there was a positive relationship between alcohol establishment density and perceptions of drink/driving as dangerous. Social approval for drink/driving was a potential mediator for women, but not for men. Dissertation Conclusion: More research is needed to elucidate the relationship between drink/driving and alcohol establishment density among young adults.

CHAPTER 1

INTRODUCTION

Motor Vehicle Crashes as a Public Health Problem

In 2006, motor vehicle crashes (MVCs) in the United States resulted in 42,642 fatalities, an average of 117 people dying per day or 1 person every 12 minutes. According to the National Highway Transportation Safety Administration (NHTSA; 2008b), MVCs are the leading cause of death for persons age 2 through 34 years. Each fatality has a lifetime social cost of over $977,000 due to lost labor and household productivity (Blincoe et al., 2002). Further, for every death, there are an estimated 10 injuries requiring hospitalization and 178 minor injuries (Christoffel & Gallagher, 2006). MVCs are the largest cause of injuries to the brain and spinal cord and the second largest cause of hospitalizations and outpatient care (Peek-Asa, Zwerling, & Stallones, 2004). In light of these sobering statistics, motor vehicle crashes are clearly a public health problem that needs more attention.

Urban–Rural Areas and Motor Vehicle Crashes

Although the general population continue to see MVCs as random “accidents” or “acts of God” (Girasek, 2001), epidemiological evidence supports the conclusion that MVCs and their effects are not random, particularly the differences between urban and rural areas (Christoffel & Gallagher, 2006). Specifically, rural areas bear a disproportionate share of motor vehicle fatalities and injuries (S. P. Baker, Whitefield, &

O'Neill, 1987; Brodsky & Hakkert, 1983; Chen, Maio, Green, & Burney, 1995; Clark, 2003; Clark & Cushing, 2004; Kmet, Brasher, & Macarthur, 2003; Leff, Stallones, Keefe, Rosenblatt, & Reeds, 2003; Muelleman & Mueller, 1996; NHTSA, 2006, 2008b, 2008c; Tiesman, Zwerling, Peek-Asa, Sprince, & Cavanaugh, 2007; F. L. R. Williams, Lloyd, & Dunbar, 1991). According to NHTSA's Traffic Safety Facts, in 2006, 56% of all U.S. traffic fatalities occurred in rural areas (NHTSA, 2008c), and in Michigan, 61% of fatal crashes occurred in rural locations (NHTSA, 2008c). Although numerous studies have clearly documented that rural areas have higher MVC fatality and injury rates than urban areas, less is known about why this is the case. Specific urban–rural characteristics and the mechanisms by which these area characteristics influence traffic crashes are poorly understood (U.S. General Accounting Office [GAO], 2004).

Current Hypotheses to Explain Urban–Rural MVC Differences

Three hypotheses have been proposed to explain differences in urban–rural MVCs. One hypothesis focuses on differences in individual driving behaviors. Indeed, some research suggests that rural road users are less likely to wear seat belts (D. R. Baker, Clarke, & Brandt, 2000; Ryan, Barker, Wright, & Mclean, 1992; Zwerling, Peek-Asa, Whitten, Choi, Sprince, & Jones, 2005) or utilize child safety seats (Lundell, 2003) and are more likely to drive with higher blood alcohol concentration (BAC) levels than urban road users (Dunsire & Baldwin, 1999; Kelleher, Pope, Kirby, & Rickert, 1996; NHTSA, 2008a; Peek-Asa et al., 2004; Ryan et al., 1992). A second hypothesis evolving from ecological studies suggests that rural roads tend to be unsafe and often consist of narrow lanes with little crash reduction engineering, such as medians to separate oncoming traffic (GAO, 2004; Peek-Asa et al., 2004). Finally, the third hypothesis is that post-crash factors, such as delayed discovery times and inadequate emergency response, may be the greatest contributors to rural motor vehicle fatalities (Henrickson, Ostrom, & Eriksson, 1991). However, Maio, Green, Becker, Burney, and Compton (1992) found that in Michigan response time to motor vehicle crashes was not a significant predictor of fatality when crash severity and driver's age were included in statistical models.

Differences in Urban–Rural Area Characteristics

To investigate urban-rural differences in characteristics, one must first define *rural* and determine what unique characteristics exist in urban compared with rural areas that might influence health and in particular, MVCs. Although there is no one definition or agreed-upon characteristic, most researchers agree that *rural* is often defined as in contrast to urban and that urban and rural areas differ on many aspects of the physical and social environment that influence health (Hall, Kaufman, & Ricketts, 2006; Hart, Larson, & Lishner, 2005). These aspects of the physical and social environment, or area characteristics, are also not homogenous across the United States, such that rural living in Michigan may not be the same as in Texas.

This study will examine urban-rural area characteristics in relation to motor vehicle crashes. The urban-rural area characteristics that will be examined in this study include roadway characteristics, alcohol establishment density, and social influences. A roadway characteristic represents the degree to which rural road design is hazardous (e.g., absence of medians and shoulders; reduced visibility). The two roadway characteristics are: unsafe road conditions (Cubbin & Smith, 2002) (which will be measured by a proxy measure, concentrated poverty), and the proportion of collector and local rural roads. The density of alcohol establishments, which is greater in urban areas, measures access to commercially available alcohol. Finally, social influences will be represented by parent/peers approval for drink/driving (U.S. Census Bureau, 2000).

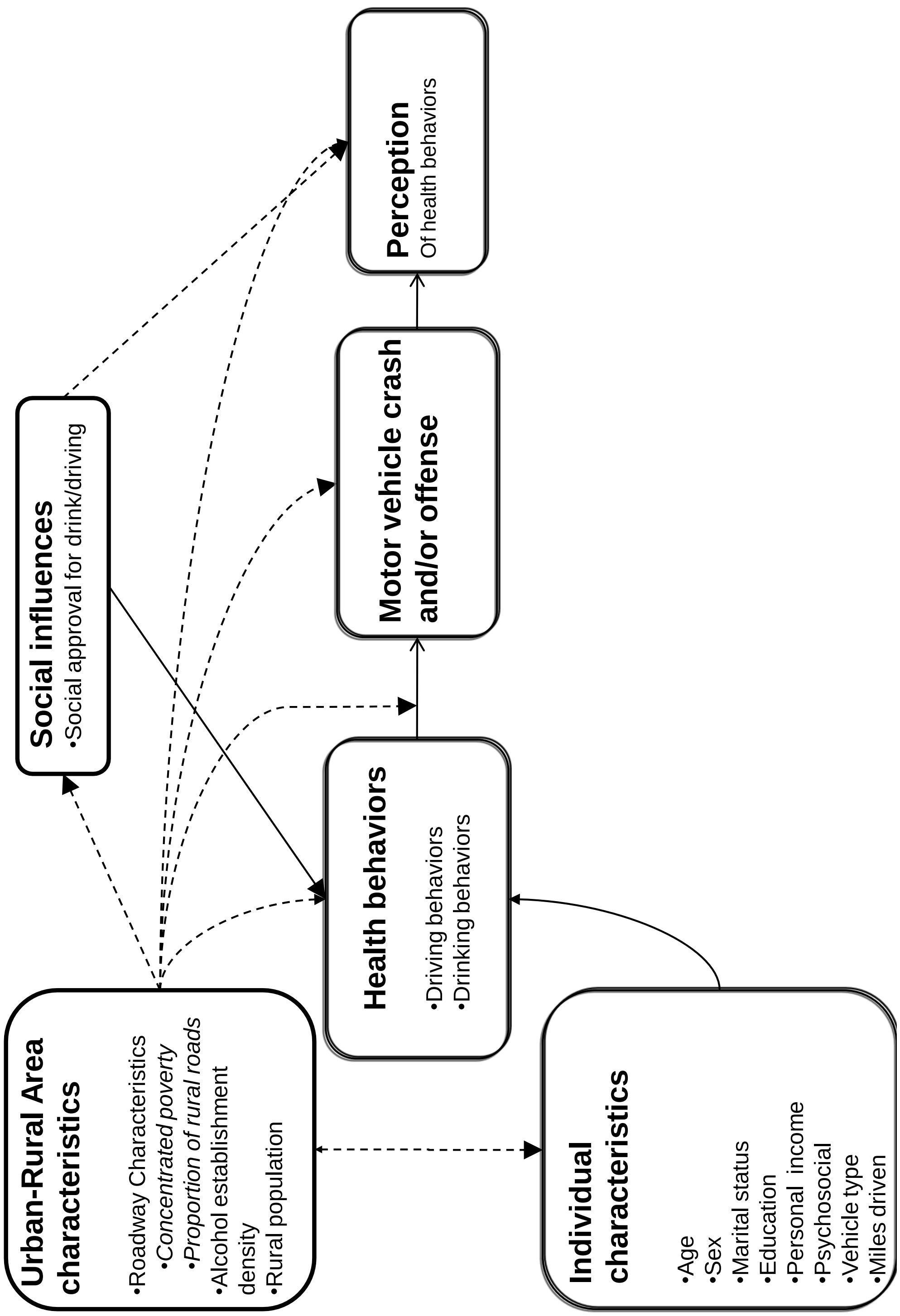
Conceptual Models

This dissertation seeks to explore specific area characteristics and possible mechanisms to explain the disparity between urban and rural MVCs. The conceptual model guiding these three papers was developed by integrating social ecological theory (McLeroy, Bibeau, Steckler, & Glanz, 1988; Stokols, 1996), fundamental determinants of health (Link & Phelan, 1995), and the Haddon Matrix (Haddon, 1972; Runyan, 2003). The social ecological theory posits that health behaviors are influenced by individual and area characteristics (e.g., organizational and community characteristics) however, this theory is limited because it does not explicate specific causal mechanisms. The fundamental determinants of health framework does include a causal mechanism by suggesting that social and economic influences are critical in determining health behaviors and, by implication, health outcomes. Hillemeier, Lynch, Harper, and Casper (2003), building on Link and Phelan (1995), state that not only are individual-level socioeconomic factors fundamental determinants of health, but socioeconomic area characteristics, such as access to health promoting resources, also shape individual health outcomes and social norms of health behavior. In other words, specific characteristics of the social and physical environment (Blankenship, Bray, & Merson, 2000; Chichester, Gregan, Anderson, & Kerr, 1998; LaVeist & Wallace, 2000) influence (i.e., encourage or inhibit) the availability of and access to health promoting resources.

Finally, the Haddon Matrix is a specific framework for investigating injury determinants. Haddon (1972) listed four causal factors for motor vehicle crashes: individual characteristics, vehicle characteristics, physical environmental characteristics, and sociocultural environment characteristics. For each of these factors, he suggested prevention strategies based on investigations of specific temporal phases: pre-crash, crash, and post-crash. Haddon suggested that prevention strategies be developed for pre-crash factors, the aim of which is to prevent the injury of an individual (Runyan, 2003).

By integrating these theoretical frameworks, Figure 1.1 shows a basic conceptual model used for this dissertation that outlines the proposed relationships among area characteristics, individual characteristics, health behaviors (e.g., driving behaviors and drinking behaviors), motor vehicle outcomes, and perceptions of health behaviors. This dissertation examined five relationships (or mechanisms) by which area characteristics may influence health. First, area characteristics may be associated with health behaviors (e.g., driving and drinking behaviors), defined as actions undertaken by individuals or groups that have health consequences (Glanz, Lewis, & Rimer, 2002), by influencing the availability and access to health promoting resources. The health behaviors examined in this dissertation included driving behaviors (**Chapter 2**) and drinking behaviors (**Chapters 3 & 4**) that influence the likelihood of motor vehicle crash or offense. Second, area characteristics may moderate the association of health behaviors and the likelihood of motor vehicle crashes (**Chapters 2 & 3**). In other words, the relationship between health behavior and motor vehicle crashes may depend on the area characteristics (e.g., how urban or rural an area is). Third, area characteristics may be directly associated with motor vehicle crashes or offenses by influencing the availability of and access to health promoting resources, such as inferior road design being associated with increasing crash severity. The motor vehicle crashes examined in this dissertation included casualty and non-casualty crashes (**Chapter 2**) and alcohol-related and non-alcohol-related crashes (**Chapter 3**). Fourth, the basic conceptual

Figure 1.1. Basic conceptual model outlining proposed relationships among urban–rural area characteristics, individual characteristics, health behaviors, motor vehicle outcomes, and perceptions of health behaviors. (*Solid lines represent consistent associations based on previous research and dashed lines represent associations under investigation.*



model proposes that area characteristics may influence an individual's perception of health behaviors. Specifically, the perception of drink/driving as dangerous (**Chapter 4**) is proposed to be influenced by drinking behaviors and drinking consequences (e.g., history of motor vehicle crash or offense) and may also be associated with area characteristics, such as alcohol establishment density or proportion of rural population. Finally, the fifth relationship proposes that an individual's perception of health behaviors may be influenced by parents and peers and that these social influences may also differ depending on whether someone lives in an urban or rural area (**Chapter 4**).

This research investigates the relationship between an individual's proximate area and health behaviors and outcomes associated with MVCs. Each chapter presents a conceptual model (see Figures 2.1, 3.1, and 4.1) for specific area characteristics and health behaviors under investigation. Each conceptual model also posits how health behaviors may be influenced by area characteristics (e.g., rural roads and density of alcohol establishment), while adjusting for individual characteristics. In previous research, individual characteristics have been found to be associated with driving behaviors (Bingham, Shope, Zakrajsek, & Raghunathan, 2008; Chipman, Macgregor, Smiley, & Leegosselin, 1993; Glassbrenner, Carra, & Nicholas, 2004; Kim, Nitz, Richardson, & Li, 1995; Li, Baker, Langlois, & Kellen, 1998; Ulfarsson & Mannering, 2004; K. Williams & Umberson, 2004). However, the conceptual model posits that individual characteristics have no direct relationship on motor vehicle crashes or offenses. Instead, motor vehicle crashes are indirectly associated with individual characteristics through driving behaviors.

Although this conceptual model does not attribute the majority of the contribution of crash risk solely to area characteristics, it suggests that if contextual contributions are neglected, a possible target of interventions may be overlooked. Neglecting contextual contributions also erroneously assumes that the population has equitable access to health-promoting area resources.

Dissertation Significance

The primary objective of this dissertation was to explore the relationship of area level characteristics to driving outcomes. The second objective was to examine the relationships among these area characteristic variables and specific health behaviors that are driving-related. The rate of MVCs continues to exact a toll on human life. Identifying area characteristics and how these area characteristics are associated with driving behaviors and driving outcomes may provide insight into possible prevention strategies.

This dissertation contributes to MVC research by first developing and utilizing conceptual models that identify specific characteristics that may be associated with MVCs in urban and rural areas. Second, this research identifies specific area characteristics (e.g., concentrated poverty, proportion of rural roads, alcohol establishment density, and rural population) that have been hypothesized to influence individual driving behaviors and driving outcomes (GAO, 2004). In doing so, this dissertation moves beyond area-level variables measured as *derived variables,* or aggregates of individual characteristics (e.g., median household income), to area-level variables measured as *integrated variables,* or variables that describe group exposures through means other than aggregating individual characteristics (e.g., existence of certain road types or density of alcohol establishments; Diez-Roux, 1998). Third, each study investigates relationships (e.g., direct, mediating, and/or moderating) proposed in the conceptual models (see Figures 2.1, 3.1, and 4.1) among area characteristics, individual characteristics, driving behaviors, and driving outcomes. Finally, this dissertation conceptualizes and operationalizes area characteristics for each study by creating a circular buffer, consisting of a 12.1-mile radius representing the average one-way vehicle trip length to and from work (Energy Information Administration, 2005), around each respondent's geocoded residence to estimate each individual's exposure to area characteristics.

Dissertation Organization

No study to date has simultaneously examined the independent contributions of both individual characteristics and area environmental characteristics on driving behaviors and motor vehicle crashes. By analyzing individual and area characteristics together, one can examine how each factor may separately influence driving behaviors and driving outcomes and also examine their combined effects. Thus, the purpose of this dissertation is to determine the extent to which urban–rural area characteristics and individual characteristics are associated with young adult driving behaviors, crash outcomes, and perceptions of risk.

This dissertation includes five chapters: an introductory chapter (**Chapter 1**) followed by three papers (Chapters 2–4), each of which focuses on specific urban–rural area characteristics and investigates whether these characteristics are associated with individual driving behaviors and motor vehicle crashes or perceptions of risk. The first empirical paper (**Chapter 2**) examines whether urban–rural roadway characteristics are associated with young adult driving behaviors and the likelihood of non-casualty and casualty crashes. In this chapter, roadway characteristics are represented by concentrated poverty and the proportion of rural collector and local roads. The second empirical paper (**Chapter 3**) explores whether area characteristics are associated with drinking behaviors and alcohol-related crashes. In this chapter, area characteristics are represented by alcohol establishment density and the proportion of rural population. The third empirical paper (**Chapter 4**) builds on Chapter 3 by considering whether area characteristics (i.e., alcohol establishment density and the proportion of rural population) are associated with perceptions of drink/driving as dangerous. **Chapter 5** concludes with a discussion and integration of key findings from each empirical paper, overall strengths and limitations, and implications for future research.

REFERENCES

Baker, D. R., Clarke, R., & Brandt, E. N. (2000). An analysis of factors associated with seat belt use: prevention opportunities for the medical community. *Journal of the Oklahoma State Medical Association, 93*(10), 496-500.

Baker, S. P., Whitfield, R. A., & O'Neill, B. (1987). Geographic variations in mortality from motor-vehicle crashes. *New England Journal of Medicine, 316*(22), 1384-1387.

Bingham, C. R., Shope, J. T., Zakrajsek, J., & Raghunathan, T. E. (2008). Problem driving behavior and psychosocial maturation in young adulthood. *Accident Analysis & Prevention, 40*(5), 1758-1764.

Blankenship, K. M., Bray, S. J., & Merson, M. H. (2000). Structural interventions in public health. *AIDS, 14*, S11-S21.

Blincoe, L. J., Seay, A. G., Zaloshnja, E., Miller, T. R., Romano, E. O., Luchter, S., & Spicer, R. S. (2002). *The economic impact of motor vehicle crashes 2000* (Report no. DOT HS-809-446). Washington, DC: U.S. Department of Transportation.

Brodsky, H., & Hakkert, A. S. (1983). Highway accident rates and rural travel densities. *Accident Analysis & Prevention, 15*(1), 73-84.

Chen, B., Maio, R. F., Green, P. E., & Burney, R. E. (1995). Geographic variation in preventable deaths from motor-vehicle crashes. *Journal of Trauma: Injury, Infection, and Critical Care, 38*(2), 228-232.

Chichester, B. M., Gregan, J. A., Anderson, D. P., & Kerr, J. M. (1998). Associations between road traffic accidents and socio-economic deprivation on Scotland's west coast. *Scottish Medical Journal, 43*(5), 135-138.

Chipman, M. L., Macgregor, C. G., Smiley, A. M., & Leegosselin, M. (1993). The role of exposure in comparisons of crash risk among different drivers and driving environments. *Accident Analysis & Prevention, 25*(2), 207-211.

Christoffel, T., & Gallagher, S. S. (2006). *Injury prevention and public health: practical knowledge, skills, and strategies* (2nd ed.). Gaithersburg, MD: Aspen.

Clark, D. E. (2003). Effect of population density on mortality after motor vehicle collisions. *Accident Analysis & Prevention, 35*(6), 965-971.

Clark, D. E., & Cushing, B. M. (2004). Rural and urban traffic fatalities, vehicle miles, and population density. *Accident Analysis & Prevention, 36*(6), 967-972.

Cubbin, C., & Smith, G. S. (2002). Socioeconomic inequalities in injury: Critical issues in design and analysis. *Annual Review of Public Health, 23*, 349-375.

Diez-Roux, A. V. (1998). Bringing context back into epidemiology: Variables and fallacies in multilevel analysis. *American Journal of Public Health, 88*(2), 216-222.

Dunsire, M., & Baldwin, S. (1999). Urban-rural comparisons of drink-driving behaviour among late teens: A preliminary investigation. *Alcohol and Alcoholism, 34*(1), 59-64.

Energy Information Administration. (2005). *Household vehicles energy use: latest data and trends* (DOE/EIA-0464). Washington, DC: U.S. Department of Energy. Retrieved November 11, 2007, from http://www.eia.doe.gov/emeu/rtecs/nhts_survey/2001/index.htmlFuller, R. (2005). Towards a general theory of driver behaviour. *Accident Analysis & Prevention, 37*(3), 461-472.

Girasek, D. C. (2001). Public beliefs about the preventability of unintentional injury deaths. *Accident Analysis & Prevention, 33*(4), 455-465.

Glanz, K., Lewis, F. M., and Rimer, B. K. (Eds.). (2002). *Health behavior and health education: Theory, research, and practice* (3rd ed.). San Francisco, CA: Jossey-Bass.

Glassbrenner, D., Carra, J. S., & Nichols, J. (2004). Recent estimates of safety belt use. *Journal of Safety Research, 35*(2), 237-244.

Haddon, W. (1972). A logical framework for categorizing highway safety phenomena and activity. *Journal of Trauma, 12*, 193-207.

Hall, S. A., Kaufman, J. S., & Ricketts, T. C. (2006). Defining urban and rural areas in US epidemiologic studies. *Journal of Urban Health-Bulletin of the New York Academy of Medicine, 83*(2), 162-175.

Hart, L. G., Larson, E. H., & Lishner, D. M. (2005). Rural definitions for health policy and research. *American Journal of Public Health, 95*(7), 1149-1155.

Henriksson, E., Ostrom, M., & Eriksson, A. (2001). Preventability of vehicle-related fatalities. *Accident Analysis & Prevention, 33*(4), 467-475.

Hillemeier, M. M., Lynch, J., Harper, S., & Casper, M. (2003). Measuring contextual characteristics for community health. *Health Services Research, 38*(6), 1645-1717.

Kelleher, K. J., Pope, S. K., Kirby, R. S., & Rickert, V. I. (1996). Alcohol availability and motor vehicle fatalities. *Journal of Adolescent Health, 19*(5), 325-330.

Kim, K., Nitz, L., Richardson, J., & Li, L. (1995). Personal and behavioral predictors of automobile crash and injury severity. *Accident Analysis & Prevention, 27*(4), 469-481.

Kmet, L., Brasher, P., & Macarthur, C. (2003). A small area study of motor vehicle crash fatalities in Alberta, Canada. *Accident Analysis & Prevention, 35*(2), 177-182.

LaVeist, T. A., & Wallace, J. M. (2000). Health risk and inequitable distribution of liquor stores in African American neighborhood. *Social Science & Medicine, 51*(4), 613-617.

Leff, M., Stallones, L., Keefe, T. J., Rosenblatt, R., & Reeds, M. (2003). Comparison of urban and rural non-fatal injury: The results of a statewide survey. *Injury Prevention, 9*(4), 332-337.

Li, G. H., Baker, S. P., Langlois, J. A., & Kelen, G. D. (1998). Are female drivers safer? An application of the decomposition method. *Epidemiology, 9*(4), 379-384.

Link, B. G., & Phelan, J. (1995). Social conditions as fundamental causes of disease. *Journal of Health & Social Behavior*, 80-94.

Lundell, J. (2003). Motor vehicle occupant safety in a rural state. *Texas Journal of Rural Health, 21(4),* 2-10.

Maio, R. F., Green, P. E., Becker, M. P., Burney, R. E., & Compton, C. (1992). Rural motor-vehicle crash mortality – the role of crash severity and medical resources. *Accident Analysis & Prevention, 24*(6), 631-642.

McLeroy, K. R., Bibeau, D., Steckler, A., & Glanz, K. (1988). An ecological perspective on health promotion programs. *Health Education Quarterly, 15*(4), 351-377.

Muelleman, R. L., & Mueller, K. (1996). Fatal motor vehicle crashes: Variations of crash characteristics within rural regions of different population densities. *Journal of Trauma: Injury, Infection, and Critical Care, 41*(2), 315-320.

National Highway Traffic Safety Administration, National Center for Statistics and Analysis. (2006). *Contrasting rural and urban fatal crashes 1994-2003* (DOT HS 809 896). Washington, DC: U.S. Department of Transportation. Retrieved October 20, 2006, from http://www-nrd.nhtsa.dot.gov/Pubs/809896.PDF

National Highway Traffic Safety Administration, National Center for Statistics and Analysis. (2008a). *Traffic safety facts 2006: Alcohol-impaired driving* (DOT HS 810 801). Washington, DC: U.S. Department of Transportation. Retrieved October 1, 2008, from http://www-nrd.nhtsa.dot.gov/Pubs/810801.PDF

National Highway Traffic Safety Administration, National Center for Statistics and Analysis. (2008b). *Traffic safety facts 2006: Overview* (DOT HS 810 809). Washington, DC: U.S. Department of Transportation. Retrieved October 1, 2008, from http://www-nrd.nhtsa.dot.gov/Pubs/810809.PDF

National Highway Traffic Safety Administration, National Center for Statistics and Analysis. (2008c). *Traffic safety facts 2006: Rural/urban comparison* (DOT HS 810 812). Washington, DC: U.S. Department of Transportation. Retrieved October 1, 2008, from http://www-nrd.nhtsa.dot.gov/Pubs/810812.PDF

Peek-Asa, C., Zwerling, C., & Stallones, L. (2004). Acute traumatic injuries in rural populations. *American Journal of Public Health, 94*(10), 1689-1693.

Runyan, C. W. (2003). Introduction: Back to the future – revisiting Haddon's conceptualization of injury epidemiology and prevention. *Epidemiologic Reviews, 25*, 60-64.

Ryan, G. A., Barker, J. M., Wright, J. N., & Mclean, A. J. (1992). Human factors in rural road crashes. *Australian Journal of Public Health, 16*(3), 269-276.

Stokols, D. (1992). Establishing and maintaining healthy environments - toward a social ecology of health promotion. *American Psychologist, 47*(1), 6-22.

Tiesman, H., Zwerling, C., Peek-Asa, C., Sprince, N., & Cavanaugh, J. E. (2007). Non-fatal injuries among urban and rural residents: The National Health Interview Survey, 1997-2001. *Injury Prevention, 13*(2), 115-119.

Ulfarsson, G. F., & Mannering, F. L. (2004). Differences in male and female injury severities in sports-utility vehicle, minivan, pickup and passenger car accidents. *Accident Analysis & Prevention, 36*(2), 135-147.

U.S. Census Bureau. (2000). *Census of Population and Housing: Summary tape file 3*[Data file]. Washington, DC: Author.

U.S. General Accounting Office. (2004, May). *Report to congressional committees, federal and state efforts to address rural road safety challenges* (GAO-04-663). Washington, DC: Author.

Williams, F. L. R., Lloyd, O. L., & Dunbar, J. A. (1991). Deaths from road traffic accidents in Scotland: 1979-1988. Does it matter where you live? *Public Health, 105*(4), 319-326.

Williams, K., & Umberson, D. (2004). Marital status, marital transitions, and health: A gendered life course perspective. *Journal of Health and Social Behavior, 45*(1), 81-98.

Zwerling, C., Peek-Asa, C., Whitten, P. S., Choi, S. W., Sprince, N. L., & Jones, M. P. (2005). Fatal motor vehicle crashes in rural and urban areas: Decomposing rates into contributing factors. *Injury Prevention, 11*(1), 24-28.

CHAPTER 2

THE ASSOCIATIONS AMONG URBAN-RURAL ROADWAY CHARACTERISTICS, DRIVING BEHAVIORS, INDIVIDUAL CHARACTERISTICS, AND DRIVING OUTCOMES IN MICHIGAN YOUNG ADULTS

INTRODUCTION

Rural roads are the most dangerous for drivers. Although urban areas experience a greater number of crashes per million miles travelled than rural areas, the motor vehicle injury rate in rural areas is higher than in urban areas for every 1,000 crashes (Zwerling et al., 2005). Moreover, the motor vehicle crash (MVC) fatality rate on rural roads is more than double the rate on urban roads for every 100 million miles traveled (National Highway Traffic Safety Administration [NHTSA], 2006, 2008b). Young drivers aged 16 to 24 living in rural areas may be especially at risk for a MVC fatality (Blatt & Furman, 1998). The literature examining urban and rural motor vehicle crash differences concentrates on four main factors: roadway characteristics, individual characteristics, driving behaviors, and emergency response quality, with the most commonly cited factor being roadway characteristics (U.S. General Accounting Office [GAO], 2003, 2004).

Roadway characteristics such as road conditions and design are known contributors to crashes (Chen et al., 2009; Haynes, Jones, Harvey, Jewell, & Lea, 2005; Treat, 1980). Some researchers suggest that rural roads are more dangerous due to inferior and outmoded road conditions such as poor road surfaces (Baker, Whitfield, O'Neill, 1987; Graham, 1993; Kmet, Brasher, & Macarthur, 2003). Other researchers posit that road design characteristics such as narrow lanes, lack of traffic control devices or signage (Kmet et al., 2003; Wylie & Kimball, 1997), little crash reduction engineering (Peek-Asa, Zwerling, & Stallones, 2004), limited sight distance (GAO, 2004), and the presence of more objects near the rural roads are responsible for the increased risk of severe crashes. In addition, rural road conditions and design (Wylie & Kimball, 1997) may increase the incidence of unsafe driving behaviors such as crossing the centerline (Garder, 2006) or failing to yield (Kim, Washington, & Oh, 2006). In other words, the presence of certain roadway characteristics may increase high-risk driving behaviors.

Roads can be characterized according to their location (urban or rural) and functional classification. An urban road is any road located in or near urban areas where the population is greater than or equal to 5,000 people, and a rural road is any road "located in or near areas where the population is less than 5,000" (GAO, 2004, p. 5). Functional classifications are designated by the U.S. Department of Transportation (USDOT, 1989) and include interstate, arterial roads, collector roads, and local roads. Interstate roads serve the mobility function of moving traffic for longer trips; arterial roads consist of interstates and state routes between cities; collector roads are connecting streets in large and small cities; and local roads provide access to property (e.g., residential streets). Of the different road types, collector roads (which connect streets in large and small cities) and local roads (which provide access to property) have more than twice the fatality rate of interstate roads per 100,000 motor vehicle miles traveled (Bureau of Transportation Statistics, 2002).

Road condition is classified according to a scale developed by the U.S. Department of Transportation that uses pavement roughness as the index (Bureau of Transportation, 2002). Although inferior road conditions are noted as a contributing factor in higher rural fatality rates, road condition data are currently not available for rural collector and local roads. However, inferior road conditions have also been hypothesized to explain past associations between concentrated poverty and MVC fatalities and injuries (Cubbin, LeClere, & Smith, 2000; Cubbin & Smith, 2002; Ferrando, Rodríguez-Sanz, Borrell, Martínez, & Plasència, 2005; Williams, Currie, Wright, Elton, & Beattie, 1997). In a recent review, Cubbin and Smith (2002) concluded that there was a positive relationship between concentrated poverty and nonfatal injuries. One potential reason for this association is that areas with high concentrations of poverty may experience poorer and unsafe qualities of the built environment (Bernard et al. 2007; Maantay, 2001; Scalar & Northridge, 2001). Thus, concentrated poverty may be a proxy for road condition; however, this proxy relationship has never been directly tested. Additionally, although poverty in the United States has been associated with rural areas (Jensen, McLaughlin, & Slack, 2003), there is no research suggesting that poverty in rural areas is associated with poorer road conditions in the U. S. or Michigan. Thus, use of concentrated poverty as a proxy for road condition should be examined.

Urban and rural differences in individual characteristics for those involved in MVCs have also been noted (Tiesman, Zwerling, Peek-Asa, Sprince, & Cavanaugh, 2007; Dunsire & Baldwin, 1999; Glassbrenner, Carra, & Nichols, 2004; Zwerling et al., 2005). For instance, urban and rural differences in age, sex, vehicle type (e.g., pickups, vans, and SUVs), and miles driven may be proxies for engaging in high-risk driving behaviors that increase the probability of a MVC, yet these two factors (i.e., individual characteristics and driving behaviors) have not been examined together in previous urban-rural MVC studies. In previous research, individual characteristics have been found to be associated with driving behaviors (Bingham, Shope, Zakrajsek, & Raghunathan, 2008; Chipman, Macgregor, Smiley, & Leegosselin, 1993; Glassbrenner, Carra, & Nicholas, 2004; Kim, Nitz, Richardson, & Li, 1995; Li, Baker, Langlois, & Kelen, 1998; Ulfarsson & Mannering, 2004; Williams & Umberson, 2004).

Differences in driving behaviors have also been implicated in explaining greater rural fatality rates. When compared to urban fatalities, a greater proportion of rural MVC fatalities involved speeding and not wearing a seat belt (GAO, 2004; NHTSA, 2008b; Ryan, Barker, Wright & McLean, 1992). Research on driving behaviors has shown that when drivers engage in high-risk driving (e.g., speeding), their risk (or probability) of being involved in a crash increases.

Some researchers argue that delayed discovery times and emergency response times and quality are to blame for differences in urban and rural motor vehicle fatalities (Esposito, 1995; Henriksson, Ostrom, & Eriksson, 1991; Kmet, et al., 2003; Muelleman & Mueller, 1996). Although this explanation may be the case for some states in the U. S., research on MVC fatalities in Michigan found that response time was not a significant predictor of fatality when crash severity and age were included in statistical models (Maio, Burney, Gregor, & Baranski, 1996; Maio, Green, Becker, Burney, & Compton, 1992).

The existing literature is limited in some significant ways. First, previous research on factors contributing to urban–rural differences in MVCs has investigated only one or two of the above factors in isolation using univariate and/or bivariate analyses, yet the effect of these factors cannot be fully understood except in the context of other factors. Second, research examining rural roads has exclusively focused on fatalities as an outcome as opposed to nonfatal injuries (van Beeck, 2004). Third, the dichotomous measures of urban–rural characteristics that are prevalent in the literature have been criticized for being simplistic and sometimes irrelevant to the phenomenon being examined (Goodall, Kafadar, & Tukey, 1998; Hall, Kaufman, & Ricketts, 2006; Hart, Larson, & Lishner, 2005). Fourth, most urban–rural MVC studies utilize national data (Tiesman, et al., 2007; Zwerling, et al., 2005); however, when state-level studies are conducted that important variation in smaller geographical areas could be overlooked (Chen, Maio, Green, & Burney, 1995; Maio et al., 1996).

This study addresses the limitations of the existing research by (a) utilizing multivariate models that include the relevant factors implicated in urban–rural differences in MVCs; (b) exploring the likelihood of both non-casualty and casualty crash involvement (i.e., crashes that result in an injury or fatality) as the primary outcome measures instead of only fatal crashes; (c) employing continuous measures of rurality and poverty instead of dichotomous measures to estimate more variation in exposure to roadway characteristics; and (d) utilizing individual-level data rather than aggregated national-level data to estimate exposure to roadway characteristics. Examining the relationships among roadway characteristics, driving behaviors, and crash outcomes while adjusting for individual characteristics may better identify the factors that could be modified by intervention so that MVC injuries and fatalities are reduced and future research is better prioritized. To this end, this paper specifically examines the relationships among urban–rural roadway characteristics, driving behaviors, and the likelihood of a crash or casualty crash among Michigan young adults.

CONCEPTUAL MODEL

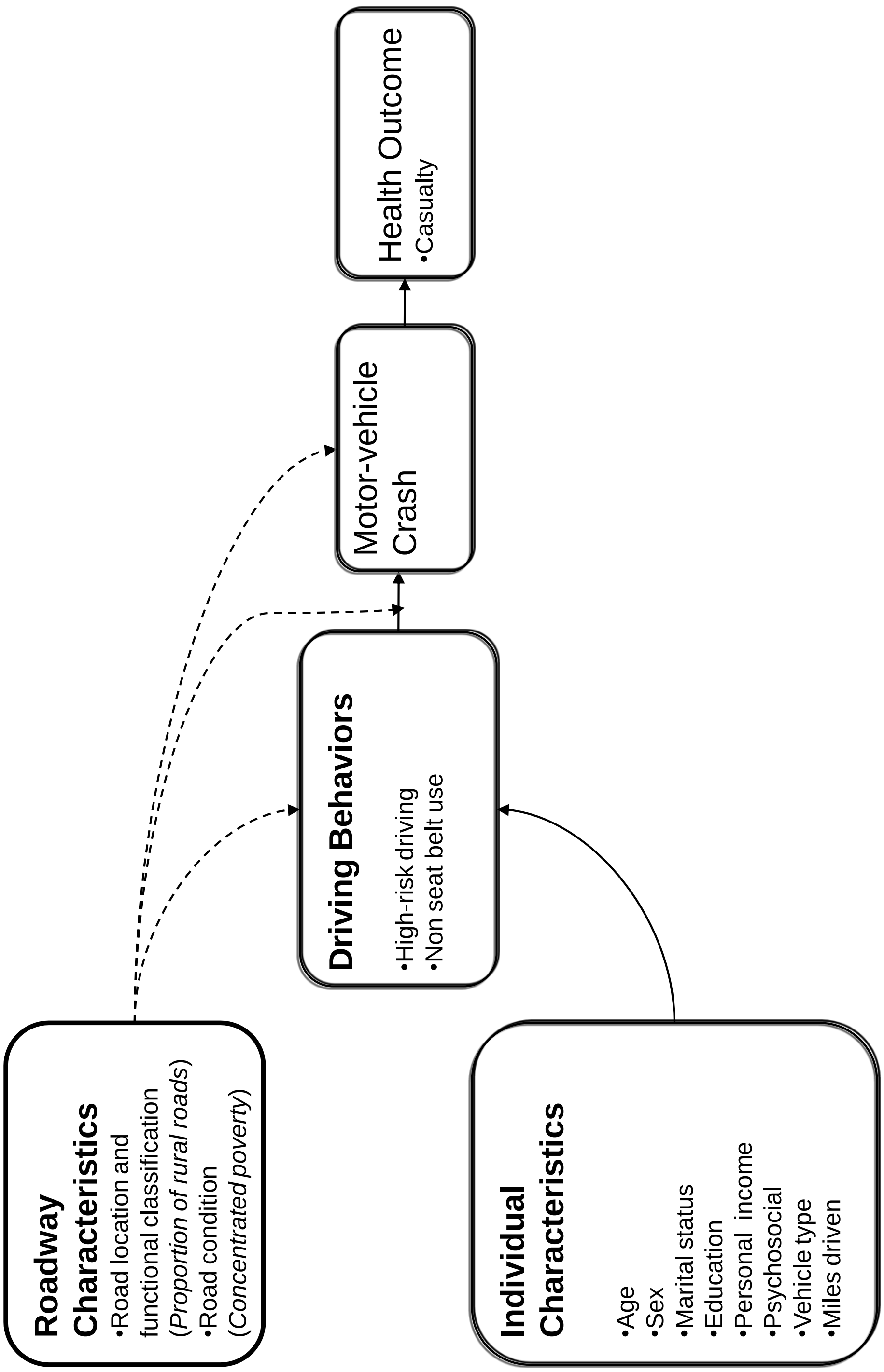
The proposed conceptual model (see Figure 2.1) posits that roadway characteristics and individual characteristics are associated with driving behaviors and therefore, the likelihood of a crash or casualty crash. Roadway characteristics include road location and functional classification and road condition. Given the lack of information on road condition, concentrated poverty will be used as a proxy for road condition in this study and is thus depicted in the model. Individual characteristics include demographic variables (e.g., age, sex, and personal income), psychosocial variables (e.g., physical/verbal hostility), vehicle type, and miles driven. The conceptual model posits that individual characteristics have no direct relationship with driving outcomes. Instead, the conceptual model posits that individual characteristics are indirectly associated with the probability of crash occurrence and crash severity through driving behaviors as a mediator.

This paper examines three possible ways roadway characteristics may be associated with driving behaviors and the likelihood of a crash or casualty crash. First, roadway characteristics are directly associated with driving behaviors. Second, roadway characteristics are directly associated with the likelihood of a crash even when adjusting for individual characteristics with driving behaviors as a mediator. Third, roadway characteristics may moderate the association between driving behaviors and the likelihood of crash and casualty crash. Relationships between different constructs are outlined in Figure 2.1, including a solid line for consistent associations based on previous research and dashed lines for associations under investigation (Earp & Ennett, 1991).

RESEARCH QUESTIONS

1. Are roadway characteristics associated with young adult driving behaviors, while adjusting for individual characteristics?
2. Are roadway characteristics and young adult driving behaviors associated with crashes and casualty crashes, while adjusting for individual characteristics?
3. Do roadway characteristics moderate the association between driving behaviors and crashes and casualty crashes, while adjusting for individual characteristics?

Figure 2.1. Conceptual model outlining three proposed relationships among roadway characteristics, driving behaviors, individual characteristics, and driving outcomes.



Solid lines represent consistent associations based on previous research and dashed lines represent associations under investigation.

METHODS

Sample and Survey

Data sources: Individual characteristics. Data used in these secondary analyses came from a telephone survey conducted as part of a longitudinal study entitled "Psychosocial Correlates of Adolescent Driving Behavior." Conducted at the University of Michigan Transportation Research Institute, the study followed up participants after a school-based substance use prevention evaluation (Shope, Copeland, Kamp, & Lang, 1998; Shope, Copeland, Maharg, & Dielman, 1996a; Shope, Copeland, Marcoux, & Kamp, 1996b; Shope, Dielman, Butchart, & Campanelli, 1992). The data used for this study were cross-sectional in nature and chosen for the current analyses because respondents were in their early 20's (*M* = 23.5 years of age), an age group characterized by the highest rates of risky driving (NHTSA, 2008a).

All respondents who had participated in previous school surveys were eligible for the young adult telephone interview if they held a Michigan driver's license or personal state identification. Addresses of eligible participants were obtained from the Michigan Department of State. Participants in the earlier school surveys were students attending southeast Michigan public schools and did not necessarily represent the statewide population. However, the young adult survey participants and individuals from the same Michigan birth cohorts have been shown to have comparable frequencies of driving offenses and crashes (Elliott, Waller, Raghunathan, Shope, & Little, 2000). Tracking and interviewing began in November 1997 and continued through January 2000. The response rate of the original eligible sample was 58.5% (using definition Response Rate 5 from the American Association for Public Opinion Research, 2000), and all participants provided informed consent. Survey completion took approximately 30 minutes, and respondents received $15 for their participation.

Outcome Measures

Association of Roadway characteristics with self-reported driving behaviors (Research Question 1 outcomes). Driving behavior during the previous 12 months was self-reported and represented by two measures, high-risk driving and seat belt use, which were assessed by 22 items.

High-risk driving was a 20-item measure developed by Donovan and colleagues with seven submeasures: moving traffic violations involving following, speeding, passing, lane usage, right-of-way, turns, and control signals; respondents were asked the number of times they engaged in each of the specific driving behaviors during the past year (Donovan, 1993). (Alphas shown are from the original testing of the scales by Donovan).

The two items measuring moving traffic violations involving following ($\alpha = 0.76$) asked respondents to report the number of times they "tail-gate[d] another car to get it to go faster or to pull over into a slower lane" and "follow[ed] another car so closely that you couldn't have stopped safely if the other car braked." Respondents who were missing responses for either of the items were assigned a missing value for the measure. Speeding violations ($\alpha = 0.77$) consisted of three items asking respondents to report the number of times they drove "10–19 miles over the posted speed limit," "at high speed through a residential neighborhood or school zone," and "20 miles per hour or more over the posted speed limit." Respondents who were missing responses for one or more of the items were assigned a missing value for the measure. Passing violations ($\alpha = 0.66$) consisted of three items asking respondents to report the number of times they passed "a car on a blind curve or when coming to the top of a hill," "a car in a no-passing zone," and "2 or 3 cars at a time on a two-lane road." Respondents who were missing responses for one or more of the items were assigned a missing value for the measure. Lane usage violations (α = 0.76) were measured by four items: "change lanes when it really wasn't safe to do so," "cut in front of another car at full speed so you could make a turn," "speed through slower traffic by switching quickly back and forth between lanes," and "drive so you were drifting in and out of your lane." Respondents who were missing responses for two or more of the items were assigned a missing value for the measure. Right-of-way violations (α = 0.62) consisted of two items asking respondents to report the number of times they "force[d] your way into traffic out of turn after stopping at a stop sign" and "pull[ed] out from the curb without waiting for a real break in traffic." Respondents who were missing responses for two or more of the items were assigned a missing value for the measure. Three items measured turn violations (α = 0.72) by asking respondents to report the number of times they made "a U-turn where a sign said not to," a "left or right turn where it wasn't allowed," and "turn[ed] right at a red light where a sign said not to." Respondents who were missing responses for one or more of the items were assigned a missing value for the measure. Lastly, three items measured control signal violations (α = 0.70) by asking respondents to report the number of times they drove "through an intersection just as the light changed from yellow to red," "through a stop sign without coming to a full stop," and "through a light that was already red." Respondents who were missing responses for one or more of the three items were assigned a missing value for the measure. Response frequencies for each of the seven submeasures ranged from zero to 999 times; these frequencies were collapsed into 14 ordinal categories (1-14) and averaged so that higher scores represented more high-risk driving.

Although seat belt use does not prevent traffic crashes, it lessens the likelihood of an injury or fatality when a crash does occur (Evans, 1990) and may be conceptualized as part of a latent construct of overall road safety and driving behaviors. Seat belt use was assessed by two items asking, “How often do you wear a seat belt when you’re drive on local trips?” and “How often do you wear a seat belt when you’re driving on long trips?” Response codes were 1 = *always or almost always*, 2 = *most of the time*, 3 = *sometimes*, 4 = *seldom*, and 5 = *never or almost never*. These items were reverse coded and averaged so that higher scores reflected greater seat belt use. Respondents who were missing responses for either of the items were assigned a missing value for the measure.

Roadway characteristics’ association with crashes (Research Questions 2 and 3 outcome). The Michigan Secretary of State provided annual driver license records for the study participants. Non-casualty and casualty crash data 3 years before and after the interview date were included in the analyses. Thus, approximately 6 years of data were provided, but crashes occurring when respondents were beginning drivers were omitted. Outcome variables of interest included whether or not a respondent was involved in a non-casualty or a casualty crash. A non-casualty crash was any crash involving at least one motor vehicle, which did not result in an injury or fatality, whereas a casualty crash was any crash involving at least one motor vehicle, which resulted in at least one injury or fatality among the passengers of any vehicle involved in the crash.

Predictor Measures: Roadway Characteristics

Road location and functional classification (*Proportion of rural roads).* The proportion of rural collector and local roads per respondent was calculated. Michigan road data files (i.e., shapefiles) were obtained from the Michigan Geographic Data Library, version 6b. The Michigan road shapefiles spatially represent the road network in Michigan in 2004. Each road file contains attributes that describe the road name and functional class. The Michigan census tract shapefile was overlaid with the road shapefile using a computer program called ArcView, version 9.1. To obtain the length of rural collector and local roads in each census tract, these roads were selected by specifying the road function class codes 07–09 (Tessmer & Burgess, 2006). Using the same method, the total length of roads in each census tract was calculated. The proportion of rural collector and local roads (or proportion of rural roads) per census tract was calculated by dividing the length of rural collector and local roads by total road length for each census tract. The square root transformation of the proportion of rural roads was used in multivariate regression analyses because it provided a better fit.[4]

Road condition (Concentrated poverty). As mentioned previously, concentrated poverty was used as the proxy for road condition for this study. To represent concentrated poverty, the proportion of individuals living in poverty was calculated for each census tract. Michigan census tract economic characteristics were obtained from the 2000 U.S. Census Bureau Long Form, Summary File 3a (U.S. Census Bureau, 2000). The proportion of individuals who lived in poverty in 1999 was obtained by dividing the number of individuals in each census tract whose ratio of income-to-poverty level was less than 1.00 by the total population for whom poverty status was determined.

Estimating respondents' exposure to roadway characteristics. To create individualized exposure to roadway characteristics, each survey respondent's residential address at the time of the telephone survey was geocoded in ArcView 9.1. Geocoding is a process in which physical addresses (e.g., residential) are assigned a latitude and

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[4]Proportion of rural roads exhibited positive skewness (2.30) and positive kurtosis (5.88). Square root transformation resulted in a relatively normal distribution (skewness 0.70 and kurtosis 0.27). The transformation was verified by plot examinations of residuals versus predicted values.

longitude.[5] To estimate an individual's exposure to the roadway characteristics, a circular buffer was created around each respondent with a radius of 12.1 miles because this is the average one-way vehicle trip length to and from work,[6] as determined by the 2001 National Household Travel Survey (Energy Information Administration, 2005). Because roadway characteristics have been generalized to the census tract level, the areal apportionment method[7] was used to allocate data from census geography to the 12.1-mile buffers to create an individualized exposure estimate for each survey respondent (Mohai & Saha, 2006; Saporito, Chavers, Nixon, & McQuiddy, 2007; Cummins, Diez-Roux, & Macintyre, 2007).

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[5]To generate a geocoded address, a survey respondent's residential address was inputted and translated into a point on a map with a score (from 0 = *no match* to 100 = *perfect match*) showing how successfully an address was matched to a reference street map. Of 5,464 respondent addresses, 5,026 (92%) were matched with scores from 80 to 100, 268 (5%) addresses were matched with a score less than 80 but greater than 0, and 170 (3%) addresses were considered unmatched. Addresses with a score less than 80 and unmatched geocoded records were manually cleaned or geocoded according to zip code centroid and indexed. For example, some unmatched geocoded records represented post office box addresses (n = 35), which were mostly found in rural areas. If these records had not been manually processed, a bias against rural areas could have been introduced. In these case, the software assigned a latitude and longitude point in the middle (or centroid) of the respondent's zip code (Krieger et al., 2002).

[6]Of the final sample, 3,898 (83.72%) of respondents reported currently working (includes military, temporary lay-off, or maternity leave) or looking for work.

[7]An ArcGIS version 9.2 tool called Spatial Overlay was used to extract census tract data from one layer and join it to the buffer layer. In other words, for one buffer (representing a survey respondent), there are data from multiple and partial census tracts. SAS version 9.1 and the areal apportionment method were used to calculate an individuals' exposure for each buffer. The areal apportionment method formula, $C = \frac{\sum_{i=1}^{n} (a_i / A_i)(p_i)(c_i)}{\sum_{i=1}^{n} (a_i / A_i) p_i}$, allocates data between census geography and the respondent's buffer, where an area's environmental characteristic (c_i) is weighted by population (p_i) and proportion of area (a_i/A_i) of the census tract captured by the buffer (Mohai & Saha, 2006). An individualized exposure estimate (C) was obtained by summing the allocated census tract data captured by each buffer.

Additional Covariates – Individual Characteristics

Information on individual characteristics (age, sex, education, personal income, marital status, psychosocial variables, vehicle type, and miles driven) was obtained during the telephone interview.

Demographic variables. Age was calculated by subtracting a respondent's date of birth from the date of interview. Education was determined by asking respondents to report the highest grade in school completed (categorized as 1 = *less than eighth grade*, 2 = *finished eighth grade*, 3 = *some high school*, 4 = *graduated high school*, 5 = *graduated technical or trade school*, 6 = *some college*, 7 = *graduated college*, 8 = *some graduate or professional school*, and 9 = *earned a postgraduate degree*). Personal income was coded 1 = *under $5,000*, 2 = *$5,000 to $14,999*, 3 = *$15,000 to $24,999*, 4 = *$25,000 to $34,999*, 5 = *$35,000 to $44,999*, 6 = *$45,000 to $54,999*, and 7 = ≥ *$55,000*. Marital status was reported as 1 = *currently married*, 2 = *separated*, 3 = *divorced*, 4 = *widowed*, or 5 = *never married*. Marital status was recoded to a dichotomous variable, *ever married*, which includes married, separated, divorced, or widowed, versus *never married*.

Psychosocial variables. Individual-level psychosocial variables were selected for their relevance to driving behaviors. Tolerance of deviance (TOD) was a 10-item measure asking respondents to rate the wrongness of specific behaviors: "to give a fake excuse for missing work, not showing up for a meeting, or cutting class," "to damage public or private property on purpose," "to start a fight and hit someone," "to give false information when filling out a job or loan application," "to shoplift something of value from a store," "to start an argument and insult the other person even though it isn't really called for," "to damage something of value because you are angry with the person it belongs to," "to write a check even though you know it might bounce," "to lie to people close to you to cover up something [you] did," and "to take things of value that do not belong to you" (Donovan, 1993; α = 0.81). Each TOD item was coded 1 = *very wrong*, 2 = *wrong*, 3 = *a little wrong*, or 4 = *not at all wrong*. An overall score was calculated by averaging the responses to all 10 items. A higher score indicated greater TOD. Respondents who were missing responses for three or more of the 10 items were assigned a missing value for the measure.

Risk-taking propensity was a four-item measure (Donovan, 1993; α = 0.77). Participants were asked to rate how well the following statements described them: "I'd do almost anything on a dare," "I enjoy the thrill I get when I take risks," "I like to live dangerously," and "I like to take chances even when the odds are against me." Responses for each item were coded 1 = *not at all like me*, 2 = *a little like me*, or 3 = *a lot like me*. An overall score was calculated by averaging responses to the four items, with a higher score indicating greater risk-taking propensity. Respondents who were missing responses for one or more of the four items were assigned a missing value for the measure.

Physical/verbal hostility (Donovan, 1993; α = 0.63) was a seven-item measure asking participants to rate how well the following statements described them: "I don't think there is ever a good reason for hitting anyone," "If people annoy me, I let them know exactly what I think of them," "I like to argue with other people just to get them annoyed," "If I have to use force to defend my rights, I will," "When I get angry at someone, I often say really nasty things," "When I really lose my temper, I've been known to hit or slap someone," and "If people push me around, I hit back." Responses to each item were coded 1 = *not at all like me*, 2 = *a little like me*, or 3 = *a lot like me*. After reverse coding one item ("I don't think there is ever a good reason for hitting anyone”), an overall score was calculated by averaging responses to the seven items such that higher scores indicated greater hostility. Respondents who were missing responses for one or more of the seven items were assigned a missing value for the measure.

Vehicle type and miles driven. To represent the exposure to crash risk that various types and levels of driving present, respondents’ vehicle type and miles driven were assessed. Vehicle type was a one-item measure asking, “What type of vehicle do you usually drive?” This item was coded 1 = *passenger car*, 2 = *van*, 3 = *pick-up truck*, 4 = *motorcycle*, 5 = *moped*, 6 = *sports utility vehicle*, and 7 = *other*. Motorcycles and mopeds were deleted, because there were too few participants who drove these vehicles to adequately examine the effects of these categories on the outcomes. The remaining vehicle types were coded into a dichotomous variable with *passenger car* as 1 and *all other vehicles* recoded as 0. Miles driven was a one-item measure that asked respondents, “About how many miles in total did you drive in the past 12 months? A missing response for either item was assigned a missing value for the measure.[8]

Statistical Analyses

Analyses for this paper were restricted to respondents with a 12.1-mile buffer that lay within the Michigan state boundary during the time of the survey and who had driven a motor vehicle on a public road within the past year. Of the 5,464 available respondents, 505 respondents were excluded because they did not live in Michigan during the time of the interview, and 41 respondents were excluded because they had not driven a motor vehicle on a public road in the year prior to the survey. Also excluded

[8] There were no missing items for miles driven. This item was used as an a priori criterion for study inclusion.

were 24 respondents who had buffers that overlapped with nearby states (e.g., 2 overlapped in Wisconsin, 15 overlapped with Ohio, and 7 overlapped with Indiana). Additionally, 237 respondents were excluded because they were missing information on one or more variable. The final sample size for all analyses was 4,657.

Prior to listwise deletion, diagnostic procedures were utilized to determine the missing data mechanism (Allison, 2002). A dummy coded matrix was created by assigning ones to missing measures and zeroes to non-missing measures. The dummy coded matrix was analyzed for patterns and correlations among measures. Additionally, using logistic regression, respondents were modeled (1 = *missing*, 0 = *not missing*) for each missing variable on predictor and outcome variables to test whether the missingness of the missing variable could be predicted by the observed measures. The missingness of each predictor (X) was not predicted by each observed outcome variable (Y); therefore, the results should be unbiased to missingness.

Because the outcomes may be spatial autocorrelated, there is concern that the linear regression assumption of independent observations could have been violated (Waller & Gotway, 2004). In response to this concern, spatial autocorrelation was empirically tested using GeoDa software, version 0.9.5-i5 (2004; Anselin, Syabri, & Kho, 2006). Spatial dependence statistics (Moran's I = 0.0108, $p = 0.001$) indicated weak, but statistically significant, dependence among model residuals, but linear spatial trend models were nonsignificant.[9] Therefore, spatial regression was not necessary, and

[9]Moran's I and spatial trend models are reported for high-risk driving. A linear trend model was tested. The sign of the X coordinate variable was positive, suggesting an increase from the West to East direction, but the variable was nonsignificant ($p = 0.74$). The Y coordinate variable was negative, suggesting a declining trend from the South to North direction, but this variable was also nonsignificant ($p = 0.12$).

regression models that assume spatial independence were estimated using SAS version 9.1.3.

Analyses were done to test each of the three relationships suggested by the conceptual model. All models were estimated separately by sex because there is evidence suggesting that men and women represent two different populations with distinct influences on driving behaviors and driving outcomes (Bingham, Elliott, & Shope, 2007; Bingham et al., 2008; Ulfarsson & Mannering, 2004). Analysis of variance was used to test for mean differences between urban and rural residents in continuous variables, and chi-square statistics were used to test differences in categorical variables.

The first relationship, between roadway characteristics and driving behaviors, was tested using each driving behavior (i.e., high-risk driving and seat belt use) as an outcome. Linear ordinary least squares regression was used to estimate associations of each driving behavior with roadway characteristics. Associations were examined before and after adjustment for age, education, personal income, marital status, psychosocial variables, vehicle type, and miles driven.

The second and third relationships proposed in the conceptual model (see Figure 2.1) were tested with multinomial regression models and examined the associations of casualty crash, crash (with no casualty), and no crash (as the referent group) with roadway characteristics. The second relationship between roadway characteristics and the likelihood of any crash and casualty crashes was tested in two ways: 1) the direct association was tested; 2) the association was tested with driving behaviors as a mediator. To examine whether driving behaviors (i.e., high-risk driving and seat belt use) mediated the relationship between roadway characteristics and driving outcomes, models were examined before and after adjustment for driving behaviors.

The third analysis examined the moderating influence of roadway characteristics on the association between driving behavior and the likelihood of any crash and a casualty crash. The moderating relationship was tested using an interaction term between roadway characteristics and each driving behavior (i.e., high-risk driving and seat belt use) with the likelihood of crash and casualty crash as an outcome (Aiken & West, 1991). Associations were examined before and after adjustment for age, education, personal income, marital status, psychosocial variables, vehicle type, and miles driven, and without including driving behavior as a mediator.

The models were tested in a hierarchal fashion, with conceptual domains entered sequentially. For example, final models included the domains of the roadway characteristics first, followed by demographic variables, psychosocial variables, driving exposure, and then driving behaviors. A measure of goodness-of-fit (either log-likelihood statistics or adjusted R^2) is reported for each specific model. To contrast and evaluate competing models, the difference between two log-likelihood statistics was compared.

RESULTS

Descriptive Statistics

Table 2.1 shows descriptive statistics for the sample (n = 4,657), as well as by road location (urban/rural areas) and road condition (measured by the proxy measure of high/low poverty). Mean participant age was 23.51 years, and 49% were male. The majority (73.27%) of participants had more than a high school education, and 16.79% made more than $35,000 in personal income within the past year. The majority of the sample (3,958 or 85.0%) lived in urban areas, and 699 (or 15.0%) respondents lived in rural areas.

Roadway Characteristics' Association With Driving Behaviors (Research Question 1)

High-risk driving. The results of analyses examining the first proposed relationship of whether roadway characteristics are associated with young adult driving behaviors (i.e., high-risk driving and seat belt use) are shown in Tables 2.2–2.5. For men (see Table 2.2), concentrated poverty and proportion of rural roads was negatively associated with high-risk driving (Model 3).[10] The association between concentrated poverty, proportion of rural roads, and high-risk driving was eliminated with the addition of education and personal income to the model (Model 4). Men's high-risk driving was positively associated with education, personal income, tolerance of deviance, risk-taking propensity, physical/verbal hostility, and driving more miles in the previous year (Model 6). The additional adjustment for psychosocial variables (i.e., tolerance of deviance, risk-taking propensity, and physical/verbal hostility) had a large impact on model fit (log-likelihood from -6172.20 to -5999.93).

For women (see Table 2.3), proportion of rural roads was also negatively associated with high-risk driving (Models 1 and 3). However, the additional adjustment for marital status, education, and personal income eliminated the statistically significant inverse association between the proportion of rural roads and high-risk driving (Model 4). Women's high-risk driving was positively associated with tolerance of deviance, risk-taking propensity, physical/verbal hostility, and driving more miles in the previous year (Model 6). The additional adjustment for psychosocial variables (i.e., tolerance of deviance, risk-taking propensity, and physical/verbal hostility) also had a large impact on model fit (log-likelihood from -6240.74 to -6055.97).

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[10]Results from partial plots show that variance explained for high-risk driving is enhanced when concentrated poverty and proportion of rural roads are entered simultaneously in the model.

Seat belt use. Roadway characteristics were not associated with seat belt use for either men or women (see Tables 2.4 and 2.5). For men (see Table 2.4), seat belt use was inversely associated with personal income, tolerance of deviance, risk-taking propensity, and physical/verbal hostility and positively associated with ever married, education, and driving a vehicle that was not a passenger car. For women (see Table 2.5), seat belt use was positively associated with education and inversely associated with tolerance of deviance, risk-taking propensity, and physical/verbal hostility.

Roadway Characteristics' Association With Crashes (Research Questions 2 and 3)

More than half the sample (*n* = 2,601 or 55.85%) had not been involved in a crash in the 6-year period studied (see Table 2.1). Less than a third (29.98%) of the sample was involved in a non-casualty crash, and 660 (or 14.17%) respondents were involved in a casualty crash. Statistical differences were found between men's and women's crash outcomes. Women were more likely to be crash-free than men (55.09% vs. 44.91%). More men than women experienced both non-casualty (53.94% vs. 46.06%) and casualty crashes (54.70% vs. 45.30%; results not shown).

Roadway characteristics were proposed to have a direct effect or moderating effect on the likelihood of a crash or casualty crash while adjusting for individual characteristics (see Tables 2.6 and 2.7). For men, there was no direct relationship between roadway characteristics and crash outcomes (results not shown), however, roadway characteristics in men appeared to have a moderating effect, in that the results for the third relationship analysis suggests that the association between the likelihood of casualty crash involvement and high-risk driving and seat belt use was higher with rural roads than urban roads, *OR* = 1.42, 95% CI [1.08, 1.86], and *OR* = 2.76, 95% CI [1.10, 6.96], respectively. Additionally, the likelihood of being involved in both casualty and non-casualty crashes (relative to no crashes) were significantly less for men with more education. Moreover, men with more tolerance of deviance were less likely to be involved in non-casualty crashes as compared to both casualty and no crash; however, men who drove more miles in the past year were more likely to be involved in casualty crashes.

For women, neither the proportion of rural roads nor concentrated poverty had a significant main effect on crash outcomes (see Table 2.7). Additionally, there was no evidence that roadway characteristics moderated the association between high-risk driving or seat belt use and the likelihood of a non-casualty or casualty crash (results not shown). For women, more seat belt use was associated with fewer non-casualty crashes but not casualty crashes. Moreover, women with more physical/verbal hostility were more likely to be involved in casualty crashes *OR* = 1.58, 95% CI [1.09, 2.30].

DISCUSSION

Although many studies have reported that rural areas bear a disproportionate share of motor vehicle injury and fatality rates (Baker et al., 1987; Clark, 2003; Clark & Cushing, 2004; Kmet et al., 2003; Muellerman & Mueller, 1996; NHTSA, 2006, 2008b; Tiesman et al., 2007), very few studies have examined the possible relationships among factors such as roadway characteristics, individual characteristics, driving behaviors, and the likelihood of a crash or casualty crash. This study addressed the limitations in previous research by examining multiple factors (e.g. roadway characteristics, individual characteristics, and driving behaviors) and their relationships to motor vehicle crashes.

The conceptual model posited three possible relationships among roadway characteristics, individual characteristics, and the likelihood of non-casualty or casualty crash. The first relationship proposed an association between roadway characteristics (measured as proportion of rural roads and road condition, which was measured by a proxy, concentrated poverty) and driving behaviors while adjusting for individual characteristics. The results of this study show that, for men, there was an inverse association between the proportion of rural collector and local roads and high-risk driving, such that men who resided near fewer rural collector and local roads reported the greatest high-risk driving. This inverse relationship is contrary to other research (GAO, 2004; NHTSA, 2008b; Ryan et al., 1992) and could be due to unmeasured confounders unique to Michigan (e.g., traffic volume/density). One way to detect these unmeasured confounders was by examining some of the high-risk driving behavior submeasures. Some submeasures depended on the presence of other traffic (e.g., following, passing) and traffic controls (e.g., signage, control signals), all or some of which may be absent on rural roadways (Elvik, 2004). In previous studies (Patil, Shope, Raghunathan, & Bingham, 2006), and for the current study, few differences were found when specific submeasures were examined (results not shown). Seat belt use was not associated with roadway characteristics for either men or women. This finding was also noted in the National Occupant Protection Use Survey (NHTSA, 2002), which found no difference between urban and rural seat belt use.

The next relationship proposed by the conceptual model was that roadway characteristics have a direct relationship with the likelihood of a crash even while adjusting for individual characteristics and driving behaviors. The data did not support this relationship between roadway characteristics and the likelihood of crash; however the data did support the role of individual driving behaviors and characteristics. This conclusion is supported by finding evidence of a moderation effect of roadway characteristics on the association between the likelihood of a casualty crash and high-risk driving (Kraemer, Stice, Kazdin, Offord, & Kupfer, 2001). For men, the proportion of rural roads moderated the association between the likelihood of a casualty crash and high-risk driving was found. In other words, a young man who engaged in high-risk driving and resided near more rural collector and local roads had greater odds of being involved in a casualty crash than a young man residing in a similar area who engaged in less high-risk driving. However, for women, there was no evidence of a moderating effect of roadway characteristics on the association between the likelihood of a casualty crash and driving behaviors. Instead, for women, individual characteristics and driving behaviors took precedence in predicting crash involvement.

Strengths and Limitations

The findings should be interpreted cautiously based on study design specifications and assumptions that limit the generalizability to other populations and geographic areas. First, the study sample has a more narrow age distribution than previous studies (Blatt & Furman, 1998; Ryan et al., 1992). This sample consisted of young adults in their early 20's. Even though drivers under the age of 25 years have the highest rate of involvement in fatal crashes of any group (NHTSA, 2008a), generalizability may be limited to other age groups.

Second, it would have been more precise to use roadway characteristics of crash locations instead of the roadway characteristics of the respondents' residential areas. However, crash data could not be used because physical addresses were not provided in the crash data; therefore, respondents' residences were used as a proxy for crash location. The rationale for this proxy is supported by Blatt and Furman (1998) who compared residence location to crash location and found that 75% of fatal crashes occurring in rural areas involved rural residents and 75% of the fatal crashes in urban areas involved urban residents.

Lastly, it was not feasible or the focus of this paper to measure specific road conditions for each respondent; therefore, the proportion of rural collector and local roads and concentrated poverty were used as proxies for inferior road design and conditions (Baker et al., 1987; Kmet et al., 2003; Peek-Asa et al., 2004; Ryan et al., 1992). Although concentrated poverty has often been utilized as a proxy for inferior conditions and has been associated with motor vehicle crashes (Cubbin & Smith, 2002; Ferrando, et al., 2005; Williams, et al., 1997), the results of this study found no such association. Moreover, these results found that there was an inverse relationship between concentrated poverty and the proportion of rural collector and local roads ($r = -0.35$), suggesting that concentrated poverty is an invalid proxy of rural road conditions in Michigan. The associations found in past research could exist because of confounding due to transportation mix (e.g., pedestrians and drivers) and land use mix (i.e., urban design), which may differ between low and high poverty areas. There are currently no measures that specifically quantify road conditions, traffic density, and the mix of transportation modes at both the local urban and rural level. Until rural road conditions are monitored to the same extent and standard as urban roads, better proxies will have to be found and used to represent these conditions.

With those limitations stated, it is also important to recognize that these study findings contribute to a very small body of previous research on urban–rural differences in driving outcomes. Whereas previous urban–rural research has been limited to ecological studies that examine bivariate associations based on aggregated national data (GAO, 2003), these findings utilize individual driver data to simultaneously examine the complex relationships among factors that may influence crashes and casualty crashes. Specific individual characteristics, such as marital status, education, and driving behaviors have not been included in previous analyses, yet were found to be protective or risk factors in this study.

Moreover, this is the first study to use individual data to estimate rural road exposure, using a 12.1-mile radius buffer around respondents' residences. Previous studies investigating urban–rural differences in MVC injuries or fatalities relied on geographic administrative boundaries (e.g., state, county) that may or may not be adequate or appropriate to estimate an individual driver's exposure to roadway characteristics (Baker et al., 1987; Clark, 2003; Clark & Cushing, 2004; Kmet et al., 2003; Muellerman & Mueller, 1996). The creation and application of this alternative approach adds to the methodological strength of these analyses and suggests other ways in which this methodology could be applied to injury research or to reexamine previous studies in which respondent addresses are known. For example, Blatt and Furman (1998) and LaScala, Gerber, and Gruenewald (2000) are two studies which could be reexamined because they have participant addresses, but defined exposure using an administrative unit within which a person resides (e.g., ZIP code). Another example in analyzing pedestrian injuries could apply radius buffers around residences corresponding to an average walking distance, instead of using census tracts to estimate exposure to roadway characteristics.

Table 2.1. *Individual and Roadway Characteristics for the Final Sample, Stratified by Proportion of Rural Roads and Concentrated Poverty (n = 4,567)*

	FULL SAMPLE (n = 4,657)		URBAN[a] (n = 3,958)		RURAL (n = 699)		HIGH POVERTY (n = 3,049)		LOW POVERTY (n = 1,608)	
			Proportion of rural roads ≤ 25%		Proportion of rural roads > 25%		Concentrated poverty > 12%		Concentrated poverty ≤ 12%	
	(Count & Column %) or *M*	*SD*	(Count & Column %) or *M*	*SD*	(Count & Column %) or *M*	*SD*	(Count & Column %) or *M*	*SD*	(Count & Column %) or *M*	*SD*
Demographic										
Age (years)	23.51	0.85	23.48*	0.84	23.65*	0.84	23.48*	0.86	23.56*	0.82
Marital status (ever married)	1,363 (29.27%)		1,078 (27.24%)*		285 (40.77%)*		800 (26.24%)*		563 (35.01%)*	
Sex (male)	2,282 (49.00%)		1,950 (49.27%)		332 (47.50%)		1,518 (49.79%)		764 (47.51%)	
Education[b]										
< High School	208 (4.47%)		164 (4.14%)*		44 (6.29%)*		123(4.03%)		85 (5.29%)	
High School	1,037 (22.27%)		835 (21.10%)*		202 (28.90%)*		678 (22.24%)		359 (22.33%)	
> High School	3,412 (73.27%)		2,959 (74.76%)*		453 (64.81%)*		2,248 (73.73%)		1164 (72.39%)	
Personal Income										
< $15,000	1,349 (28.97%)		1,127 (28.47%)		222 (31.76%)		927 (30.40%)*		422 (26.24%)*	
≥ $15,000 - < $35,000	2,526 (54.24%)		2,152 (54.37%)		374 (53.51%)		1,640 (53.79%)*		886 (55.10%)*	
≥ $35,000	782 (16.79%)		679 (17.16%)		103 (14.74%)		482 (15.81%)*		300 (18.66%)*	
Driving exposure										
Miles driven (past year)	18,043.05	18,867.49	18,082.12	18,050.01	17,821.77	22,967.88	18,091.81	18,675.56	17,950.58	19,231.69
Vehicle type (passenger car)	3,264 (70.45%)		2,808 (70.94%)		474 (67.81%)		2,132 (69.92%)		1,150 (71.52%)	
Psychosocial										
Tolerance of deviance	1.29	0.29	1.3*	0.30	1.27*	0.29	1.30	0.29	1.29	0.30
Risk-taking propensity	1.31	0.39	1.31	0.39	1.31	0.41	1.31	0.39	1.31	0.40
Physical/verbal hostility	1.61	0.38	1.61	0.38	1.61	0.37	1.61	0.38	1.61	0.38
Driving behaviors[c]										
High-risk driving	4.41	3.62	4.49*	3.62	3.94*	3.60	4.43	3.63	4.36	3.60
Seat belt use	4.55	1.01	4.55	1.02	4.56	0.96	4.54	1.01	4.56	1.01
Driving outcome[d]										
No crash	2,601	55.85%	2,217	56.01%	384	54.94%	1,718	56.35%	883	54.91%
No casualty crash	1,396	29.98%	1,173	29.64%	223	31.90%	893	29.29%	503	31.28%
Casualty crash	660	14.17%	568	14.35%	92	13.16%	438	14.37%	222	13.81%
Roadway characteristics										
Concentrated poverty	0.13	0.04	0.14	0.03	0.09	0.04	0.15	0.02	0.09	0.02
Proportion of rural roads	0.11	0.15	0.06	0.06	0.41	0.15	0.07	0.09	0.19	0.20

*$p < 0.05$ using F-tests for continuous variables and Chi-square tests for categorical variables.

[a]Concentrated poverty cut-off point was chosen based on state-wide median. Proportion of rural road cut-off point was chosen based on state-wide mean.

[b]Education and personal income were collapsed into three categories for the descriptive table only.

[c]Driving behaviors are dependent variables for the first proposed relationship; mediator and moderator variables for the second and third proposed relationships, respectively.

[d]Driving outcome is the dependent variable for the second and third proposed relationships.

Table 2.2. *Ordinary Linear Regression Models of High-Risk Driving With Roadway and Individual Characteristics for Men (n = 2,282)*

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
	B (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)
Roadway characteristics						
Proportion of rural roads	-0.560 (-0.383)		-0.889* (0.407)	-0.561 (0.404)	-0.582 (0.375)	-0.661 (0.374)
Concentrated poverty		-3.635 (-2.127)	-5.332** (0.262)	-3.328 (2.255)	-2.527 (2.093)	-2.825 (2.087)
Demographic						
Age				-0.066 (0.091)	-0.038 (0.084)	-0.027 (0.084)
Marital status (ever married)				-0.115 (0.187)	0.219 (0.175)	0.180 (0.175)
Education				0.340*** (0.058)	0.379*** (0.054)	0.405*** (0.054)
Personal income				0.273*** (0.056)	0.230*** (0.052)	0.182** (0.053)
Psychosocial						
Tolerance of deviance					1.735*** (0.232)	1.751*** (0.231)
Risk-taking propensity					1.918*** (0.173)	1.925*** (0.172)
Physical/verbal hostility					1.172*** (0.202)	1.139*** (0.201)
Driving exposure						
Vehicle type (passenger car)						-0.141 (0.147)
Miles driven						0.015*** (0.003)
Log-Likelihood	-6206.17	-6205.79	-6203.40	-6172.20	-5999.93	-5989.66

*p<0.05.***p*<0.01. ****p*<0.001.

Table 2.3. *Ordinary Linear Regression Models of High-Risk Driving With Roadway and Individual Characteristics for Women (n = 2,375)*

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
	B (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)
Roadway characteristics						
Proportion of rural roads	-0.951** (0.345)		-0.998** (0.369)	-0.449 (0.358)	-0.344 (0.331)	-0.409 (0.330)
Concentrated poverty		1.294 (1.978)	-0.756 (2.115)	-0.253 (2.041)	-0.191 (1.889)	-0.233 (1.880)
Demographic						
Age				-0.071 (0.084)	-0.051 (0.078)	-0.046 (0.078)
Marital status (ever married)				-0.741*** (0.148)	-0.383** (0.139)	-0.405** (0.139)
Education				0.479*** (0.054)	0.424*** (0.051)	0.418*** (0.051)
Personal income				0.371*** (0.057)	0.350*** (0.053)	0.303*** (0.053)
Psychosocial						
Tolerance of deviance					2.788*** (0.265)	2.792*** (0.264)
Risk-taking propensity					2.012*** (0.220)	1.949*** (0.219)
Physical/verbal hostility					1.260*** (0.194)	1.279*** (0.193)
Driving exposure						
Vehicle type (passenger car)						-0.167 (0.163)
Miles driven						0.019*** (0.004)
Log-Likelihood	-6334.87	-6338.47	-6338.81	-6240.74	-6055.97	-6043.85

*p<0.05. **p<0.01. ***p<0.001.

Table 2.4. *Ordinary Linear Regression Models of Seat Belt Use With Roadway and Individual Characteristics for Men (n = 2,282)*

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	B (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)
Roadway characteristics						
Proportion of rural roads	0.137 (0.118)		0.122 (0.126)	0.127 (0.124)	0.123 (0.121)	0.154 (0.121)
Concentrated poverty		-0.490 (0.657)	-0.257 (0.699)	-0.044 (0.028)	-0.143 (0.675)	-0.013 (0.674)
Demographic						
Age				-0.044 (0.028)	-0.046 (0.027)	-0.044 (0.027)
Marital status (ever married)				0.170** (0.057)	0.132* (0.057)	0.124* (0.057)
Education				0.172*** (0.018)	0.156*** (0.017)	0.150*** (0.018)
Personal income				-0.062** (0.017)	-0.054** (0.017)	-0.043* (0.017)
Psychosocial						
Tolerance of deviance					-0.177* (0.075)	-0.185* (0.075)
Risk-taking propensity					-0.224*** (0.056)	-0.222*** (0.056)
Physical/verbal hostility					-0.388*** (0.065)	-0.374*** (0.065)
Driving exposure						
Vehicle type (passenger car)						0.192*** (0.047)
Miles driven						0.0003 (0.001)
Log-Likelihood	-3524.55	-3524.95	-3524.49	-3466.54	-3417.22	-3409.02

*$p<0.05$. **$p<0.01$. ***$p<0.001$.

Table 2.5. *Ordinary Linear Regression Models of Seat Belt Use With Roadway and Individual Characteristics for Women (n = 2,375)*

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	B (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)
Roadway characteristics						
Proportion of rural roads	0.122 (0.083)		0.073 (0.089)	0.072 (0.089)	0.058 (0.087)	0.062 (0.087)
Concentrated poverty		-0.926* (0.471)	-0.776 (0.510)	-0.824 (0.505)	-0.820 (0.498)	-0.810 (0.498)
Demographic						
Age				-0.027 (0.021)	-0.028 (0.021)	-0.028 (0.021)
Marital status (ever married)				0.078* (0.037)	0.042 (0.037)	0.050 (0.037)
Education				0.098*** (0.013)	0.098*** (0.014)	0.097*** (0.014)
Personal income				-0.033* (0.014)	-0.031* (0.014)	-0.026 (0.014)
Psychosocial						
Tolerance of deviance					-0.238** (0.070)	-0.241** (0.070)
Risk-taking propensity					-0.170** (0.058)	-0.162** (0.058)
Physical/verbal hostility					-0.234*** (0.051)	-0.237*** (0.051)
Driving exposure						
Vehicle type (passenger car)						0.067 (0.043)
Miles driven						-0.002 (0.001)
Log-Likelihood	-2957.08	-2956.26	-2955.92	-2925.77	-2891.02	-2888.42

*$p<0.05$. **$p<0.01$. ***$p<0.001$.

Table 2.6. *Odds Ratios (and 95% Confidence Intervals) for Final Multinomial Logistic Models Predicting the Likelihood of Casualty Crash and Crash for Men (n = 2,282)*

	Crash, with Casualty		**Crash, without Casualty**	
	Odds ratio	95% Confidence interval	Odds ratio	95% Confidence interval
Roadway characteristics				
Proportion of rural roads	0.759	[0.293, 1.970]	1.171	[0.586, 2.340]
Concentrated poverty	5.658	[0.145, 220.166]	0.605	[0.038, 9.649]
Roadway characteristics by Driving behavior interactions				
Proportion of rural roads x High-risk driving	1.418*	[1.083, 1.856]	1.129	[0.926, 1.376]
Concentrated poverty x High-risk driving	1.001	[0.356, 2.800]	0.771	[0.357, 1.662]
Proportion of rural roads x Seat belt use	2.764*	[1.098, 6.955]	1.243	[0.636, 2.429]
Concentrated poverty x Seat belt use	0.710	[0.031, 16.428]	0.254	[0.020, 3.304]
Demographic				
Age	0.985	[0.854, 1.136]	1.031	[0.923, 1.151]
Marital status (ever married)	0.856	[0.632, 1.156]	0.920	[0.729, 1.159]
Education	0.858**	[0.780, 0.944]	0.908**	[0.843, 0.978]
Personal income	1.068	[0.976, 1.169]	1.021	[0.952, 1.096]
Psychosocial				
Tolerance of deviance	0.851	[0.568, 1.263]	0.683*	[0.497, 0.933]
Risk-taking propensity	0.993	[0.731, 1.341]	1.069	[0.846, 1.348]
Physical/verbal hostility	1.266	[0.896, 1.785]	1.067	[0.814, 1.397]
Driving Behavior				
High-risk driving	0.991	[0.817, 1.109]	1.038	[0.946, 1.185]
Seat belt use	0.906	[0.535, 1.330]	1.006	[0.807, 1.703]
Driving exposure				
Vehicle type (passenger car)	0.814	[0.633, 1.047]	0.862	[0.709, 1.047]
Miles driven	1.000**	[1.000, 1.000]	1.000	[1.000, 1.000]

Note: Reference category for the equation is 'No Crash'
*p<0.05. **p<0.01.

Table 2.7. *Odds Ratios (and 95% Confidence Intervals) for Final Multinomial Logistic Models Predicting the Likelihood of Casualty Crash and Crash for Women (n = 2,375)*

	Crash, with Casualty		**Crash, without Casualty**	
	Odds ratio	95% Confidence interval	Odds ratio	95% Confidence interval
Roadway characteristics				
Proportion of rural roads	1.190	[0.484, 2.929]	0.922	[0.470, 1.808]
Concentrated poverty	3.474	[0.079, 153.393]	0.108	[0.007, 1.756]
Demographic				
Age	1.044	[0.896, 1.217]	1.115	[0.993, 1.251]
Marital status (ever married)	0.625**	[0.469, 0.833]	0.805*	[0.654, 0.990]
Education	0.947	[0.854, 1.050]	0.965	[0.893, 1.043]
Personal income	1.003	[0.900, 1.117]	1.077	[0.996, 1.166]
Psychosocial				
Tolerance of deviance	0.753	[0.438, 1.294]	0.924	[0.619, 1.379]
Risk-taking propensity	1.039	[0.674, 1.600]	1.101	[0.794, 1.527]
Physical/verbal hostility	1.58*	[1.086, 2.300]	0.841	[0.627, 1.128]
Driving Behavior				
High-risk driving	0.991	[0.951, 1.033]	1.010	[0.979, 1.041]
Seat belt use	0.964	[0.823, 1.128]	0.831***	[0.745, 0.926]
Driving exposure				
Vehicle type (passenger car)	0.912	[0.663, 1.255]	1.036	[0.813, 1.321]
Miles driven	1.000*	[1.000, 1.000]	1.000*	[1.000, 1.000]

Note: Reference category for the equation is 'No Crash'
*p<0.05. **p<0.01. ***p<0.001.

REFERENCES

Aiken, L. S., & West, S.G. (1991). *Multiple regression: Testing and interpreting interactions*. Thousand Oaks, CA: Sage.

Allison, P. D. (2002). *Missing data*. Thousand Oaks, CA: Sage.

American Association for Public Opinion Research. (2000). *Standard definitions: Final dispositions of case codes and outcome rates for surveys*. Retrieved May 20, 2009, fromhttp://www.aapor.org/uploads/Standard_Definitions_04_08_Final.pdf

Anselin, L., Syabri, I., & Kho, Y. (2006). GeoDa: An introduction to spatial data analysis. *Geographical Analyses*, *38*(1), 5-22.

Baker, S. P., Whitfield, R. A., & O'Neill, B. (1987). Geographic variations in mortality from motor-vehicle crashes. *New England Journal of Medicine, 316*(22), 1384-1387.

Bernard, P., Charafeddine, R., Frohlich, K. L., Daniel, M., Kestens, Y., & Potvin, L. (2007). Health inequalities and place: A theoretical conception of neighbourhood. *Social Science & Medicine, 65*(9), 1839-1852.

Bingham, C. R., Elliott, M. R., & Shope, J. T. (2007). Social and behavioral characteristics of young adult drink/drivers adjusted for level of alcohol use. *Alcoholism: Clinical and Experimental Research, 31*(4), 655-664.

Bingham, C. R., Shope, J. T., Zakrajsek, J., & Raghunathan, T. E. (2008). Problem driving behavior and psychosocial maturation in young adulthood. *Accident Analysis & Prevention, 40*(5), 1758-1764.

Blatt, J., & Furman, S. M. (1998). Residence location of drivers involved in fatal crashes. *Accident Analysis & Prevention, 30*(6), 705-711.

Brodsky, H., & Hakkert, A. S. (1983). Highway accident rates and rural travel densities. *Accident Analysis & Prevention, 15*(1), 73-84.

Bureau of Transportation Statistics. (2002). *Michigan transportation profile*. Retrieved November 11, 2007, from http://www.bts.gov/publications/state_transportation_statistics/michigan/index.html

Chen, B., Maio, R. F., Green, P. E., & Burney, R. E. (1995). Geographic variation in preventable deaths from motor vehicle crashes. *Journal of Trauma: Injury, Infection, and Critical Care, 38*(2), 228-232.

Chen, H. Y., Ivers, R. Q., Martiniuk, A. L. C., Boufous, S., Senserrick, T., et al. (2009). Risk and type of crash among young drivers by rurality of residence: Findings from the DRIVE Study. *Accident Analysis & Prevention, 41*(4), 676-682.

Chipman, M. L., Macgregor, C. G., Smiley, A. M., & Leegosselin, M. (1993). The role of exposure in comparisons of crash risk among different drivers and driving environments. *Accident Analysis & Prevention, 25*(2), 207-211.

Clark, D. E. (2003). Effect of population density on mortality after motor vehicle collisions. *Accident Analysis & Prevention, 35*(6), 965-971.

Clark, D. E., & Cushing, B. M. (2004). Rural and urban traffic fatalities, vehicle miles, and population density. *Accident Analysis & Prevention, 36*(6), 967-972.

Cubbin, C., LeClere, F. B., & Smith, G. S. (2000). Socioeconomic status and injury mortality: Individual and neighborhood determinants. *Journal of Epidemiology and Community Health, 54*(7), 517-524.

Cubbin, C., & Smith, G. S. (2002). Socioeconomic inequalities in injury: Critical issues in design and analysis. *Annual Review of Public Health, 23*, 349-375.

Cummins, S., Curtis, S., Diez-Roux, A. V., & Macintyre, S. (2007). Understanding and representing ‘place’ in health research: A relational approach. *Social Science & Medicine, 65*(9), 1825-1838.

Donovan, J. E. (1993). Young adult drink-driving: Behavioral and psycho-social correlates. *Journal of Studies of Alcohol, 54*(5), 600-613.

Dunsire, M., & Baldwin, S. (1999). Urban-rural comparisons of drink-driving behaviour among late teens: A preliminary investigation. *Alcohol and Alcoholism, 34*(1), 59-64.

Earp, J. A., & Ennett, S. T. (1991). Conceptual models for health education research and practice. *Health Education Research, 6*(2), 163-171.

Elliott, M. R., Waller, P. F., Raghunathan, T. E., Shope, J. T., & Little, R. J. (2000). Persistence of violation and crash behavior over time. *Journal of Safety Research, 31*(4), 229-242.

Elvik, R. (2004). To what extent can theory account for the findings of road safety evaluation studies? *Accident Analysis & Prevention, 36*(5), 841-849.

Energy Information Administration. (2005). *Household vehicles energy use: Latest data and trends*.(DOE/EIA-0464). Washington, DC: U.S. Department of Energy. Retrieved November 11, 2007, fromhttp://www.eia.doe.gov/emeu/rtecs/nhts_survey/2001/index.html

Esposito, T. (1995). Analysis of preventable trauma and inappropriate trauma care in a rural state. *The Journal of Trauma, 39*(5), 955-962.

Evans, L. (1990). Restraint effectiveness, occupant ejection from cars and fatality reductions. *Accident Analysis & Prevention, 22*(2), 167-175.

Ferrando, J., Rodriguez-Sanz, M., Borrell, C., Martinez, V., & Plasencia, A. (2005). Individual and contextual effects in injury morbidity in Barcelona (Spain). *Accident Analysis & Prevention, 37*(1), 85-92.

Garder, P. (2006). Segment characteristics and severity of head-on crashes on two-lane rural highways in Maine. *Accident Analysis & Prevention, 38*(4), 652-661.

Goodall, C. R., Kafadar, K., & Tukey, J. W. (1998). Computing and using rural versus urban measures in statistical applications. *American Statistician, 52*(2), 101-111.

Glassbrenner, D., Carra, J. S., & Nichols, J. (2004). Recent estimates of safety belt use. *Journal of Safety Research, 35*(2), 237-244.

Graham, J. D. (1993). Injuries from traffic crashes: Meeting the challenge. *Annual Review of Public Health, 14*(1), 515-543.

Hall, S. A., Kaufman, J. S., & Ricketts, T. C. (2006). Defining urban and rural areas in U.S. epidemiologic studies. *Journal of Urban Health: Bulletin of the New York Academy of Medicine, 83*(2), 162-175.

Hart, L. G., Larson, E. H., & Lishner, D. M. (2005). Rural definitions for health policy and research. *American Journal of Public Health, 95*(7), 1149-1155.

Haynes, R., Jones, A., Harvey, I., Jewell, T., & Lea, D. (2005). Geographical distribution of road traffic deaths in England and Wales: Place of accident compared with place of residence. *Journal of Public Health, 27*(1), 107-111.

Henriksson, E., Ostrom, M., & Eriksson, A. (2001). Preventability of vehicle-related fatalities. *Accident Analysis and Prevention, 33*(4), 467-475.

Jensen, L. & McLaughlin, D. K., & Slack, T. (2003). Rural poverty: The persistent challenge. In D. L. Brown & L. E. Swanson (Eds.), *Challenges for rural America in the twenty-first century* (pp. 118-131). University Park, PA: The Pennsylvania State University.

Kim, K., Nitz, L., Richardson, J., & Li, L. (1995). Personal and behavioral predictors of automobile crash and injury severity. *Accident Analysis & Prevention, 27*(4), 469-481.

Kim, D. G., Washington, S., & Oh, J. (2006). Modeling crash types: New insights into the effects of covariates on crashes at rural intersections. *Journal of Transportation Engineering, 132*(4), 282-292.

Kmet, L., Brasher, P., & Macarthur, C. (2003). A small area study of motor vehicle crash fatalities in Alberta, Canada. *Accident Analysis & Prevention, 35*(2), 177-182.

Kraemer, H. C., Stice, E., Kazdin, A., Offord, D., & Kupfer, D. (2001). How do risk factors work together? Mediators, moderators, and independent, overlapping, and proxy risk factors. *American Journal of Psychiatry, 158*(6), 848-856.

Krieger, N., Chen, J. T., Waterman, P. D., Soobader, M. J., Subramanian, S. V., & Carson, R. (2002). Geocoding and monitoring of US socioeconomic inequalities in mortality and cancer incidence: Does the choice of area-based measure and geographic level matter? The Public Health Disparities Geocoding Project. *American Journal of Epidemiology, 156*(5), 471-482.

LaScala, E. A., Gerber, D., & Gruenewald, P. J. (2000). Demographic and environmental correlates of pedestrian injury collisions: A spatial analysis. *Accident Analysis & Prevention, 32*(5), 651-658.

Li, G. H., Baker, S. P., Langlois, J. A., & Kelen, G. D. (1998). Are female drivers safer? An application of the decomposition method. *Epidemiology, 9*(4), 379-384.

Maantay, J. (2001). Zoning, equity, and public health. *American Journal of Public Health, 91*(7), 1033-1041.

Maio, R. F., Burney, R. E., Gregor, M. A., & Baranski, M. G. (1996). A study of preventable trauma mortality in rural Michigan. *Journal of Trauma: Injury, Infection, and Critical Care, 41*(1), 83-90.

Maio, R. F., Green, P. E., Becker, M. P., Burney, R. E., & Compton, C. (1992). Rural motor-vehicle crash mortality: The role of crash severity and medical resources. *Accident Analysis & Prevention, 24*(6), 631-642.

Mohai, P., & Saha, R. (2006). Reassessing racial and socioeconomic disparities in environmental justice research. *Demography, 43*(2), 383.

Muelleman, R. L., & Mueller, K. (1996). Fatal motor vehicle crashes: Variations of crash characteristics within rural regions of different population densities. *Journal of Trauma: Injury, Infection, and Critical Care, 41*(2), 315-320.

National Highway Traffic Safety Administration, National Center for Statistics and Analysis. (2002). *National Occupant Protection Use Survey*. Washington, DC: U.S. Department of Transportation.

National Highway Traffic Safety Administration, National Center for Statistics and Analysis. (2006). *Contrasting rural and urban fatal crashes 1994-2003* (DOT HS 809 896). Washington, DC: U.S. Department of Transportation. Retrieved October 20, 2006, http://www-nrd.nhtsa.dot.gov/Pubs/809896.PDF

National Highway Traffic Safety Administration, National Center for Statistics and Analysis . (2008a). Traffic safety facts 2006: Overview (DOT HS 810 809). Washington, DC: US Department of Transportation. Retrieved October 2, 2008, from http://www-nrd.nhtsa.dot.gov/Pubs/810623.PDF

National Highway Traffic Safety Administration, National Center for Statistics and Analysis. (2008b). Traffic safety facts 2006: Rural/urban comparison (DOT HS 810 625). Washington, DC: U.S. Department of Transportation. Retrieved October 2, 2008, from http://www-nrd.nhtsa.dot.gov/Pubs/810625.PDF

Patil, S. M., Shope, J. T., Raghunathan, T. E., & Bingham, C. R. (2006). The role of personality characteristics in young adult driving. *Traffic Injury Prevention*, *7*(4), 328-334.

Peek-Asa, C., Zwerling, C., & Stallones, L. (2004). Acute traumatic injuries in rural populations. *American Journal of Public Health, 94*(10), 1689-1693.

Ryan, G. A., Barker, J. M., Wright, J. N., & Mclean, A. J. (1992). Human factors in rural road crashes. *Australian Journal of Public Health, 16*(3), 269-276.

Salminen, S. (2000). Traffic accidents during work and work commuting. *International Journal of Industrial Ergonomics, 26*(1), 75-85.

Saporito, S., Chavers, J. M., Nixon, L. C., & McQuiddy, M. R. (2007). From here to there: Methods of allocating data between census geography and socially meaningful areas. *Social Science Research, 36*(3), 897-920.

Scalar, E., & Northridge, M. E. (2001). Poverty, politics, and public health. *American Journal of Public Health, 91*(7), 1013-1015.

Shope, J. T., Copeland, L. A., Kamp, M. E., & Lang, S. W. (1998). Twelfth grade follow-up of the effectiveness of a middle school-based substance abuse prevention program. *Journal of Drug Education, 28*(3), 185-197.

Shope, J. T., Copeland, L. A., Maharg, R., & Dielman, T. E. (1996a). Effectiveness of a high school alcohol misuse prevention program. *Alcoholism: Clinical and Experimental Research, 20*(5), 791-798.

Shope, J. T., Copeland, L. A., Marcoux, B. C., & Kamp, M. E. (1996b). Effectiveness of a school-based substance abuse prevention program. *Journal of Drug Education, 26*(4), 323-337.

Shope, J. T., Dielman, T. E., Butchart, A. T., Campanelli, P. C. (1992). An elementary school-based alcohol misuse prevention program: Follow-up evaluation. *Journal of Studies of Alcohol, 53,* 106-120*.*

Sivak, M., Luoma, J., Flannagan, M. J., Bingham, C. R., Eby, D. W., Shope, J. T. (2007). Traffic safety in the U.S.: Re-examining major opportunities. *Journal of Safety Research, 38*(4), 337-355.

Tessmer, J.M.& Burgess, M. (2006). *FARS Analytic Reference Guide 1975 to 2006*. National Highway Traffic Safety Administration, National Center for Statistics and Analysis. Washington, DC: U.S. Department of Transportation.

Tiesman, H., Zwerling, C., Peek-Asa, C., Sprince, N., & Cavanaugh, J. E. (2007). Non-fatal injuries among urban and rural residents: The National Health Interview Survey, 1997-2001. *Injury Prevention, 13*(2), 115-119.

Treat, J. R. (1980). A study of precrash factors involved in traffic accidents. *Highway Safety Research Institute, 10-11*(6 & 1), 1-35.

Ulfarsson, G. F., & Mannering, F. L. (2004). Differences in male and female injury severities in sports-utility vehicle, minivan, pickup and passenger car accidents. *Accident Analysis & Prevention, 36*(2), 135-147.

U.S. Census Bureau. (2000). Census of Population and Housing: Summary tape file 3 [Data file]. Washington, DC: Author.

U.S. General Accounting Office. (2003, March). *Highway safety: Research continues on variety of factors that contribute to motor vehicle crashes* (GAO-03-436). Washington, DC: Author.

U.S. General Accounting Office. (2004, May). *Report to congressional committees, federal and state efforts to address rural road safety challenges* (GAO-04-663). Washington, DC: Author.

van Beeck, E. (2004). Priorities in injury epidemiology. *European Journal of Epidemiology, 19*(5), 401-403.

Waller, L. A., & Gotway, C.A. (2004). *Applied spatial statistics for public health data*. New York: John Wiley & Sons.

Williams, J. M., Currie, C. E., Wright, P., Elton, R. A., & Beattie, T. F. (1997). Socioeconomic status and adolescent injuries. *Social Science & Medicine, 44*(12), 1881-1891.

Williams, K., & Umberson, D. (2004). Marital status, marital transitions, and health: A gendered life course perspective. *Journal of Health and Social Behavior, 45*(1), 81-98.

Wylie, M. A., & Kimball, R. B. (1997). Rural motor vehicle crashes: Can we prevent them? *Journal of Emergency Nursing, 23*(6), 542-4.

Zwerling, C., Peek-Asa, C., Whitten, P. S., Choi, S. W., Sprince, N. L., & Jones, M. P. (2005). Fatal motor vehicle crashes in rural and urban areas: Decomposing rates into contributing factors. *Injury Prevention, 11*(1), 24-28.

CHAPTER 3

ALCOHOL ESTABLISHMENT DENSITY, DRINKING BEHAVIORS, INDIVIDUAL CHARACTERISTICS, AND ALCOHOL-RELATED CRASHES FOR MICHIGAN YOUNG ADULTS

INTRODUCTION

In 2006, almost a third (32% or 13,470) of all people killed in motor vehicle crashes in the United States were killed in crashes involving an alcohol-impaired driver, meaning that at least one driver in the crash had a blood alcohol concentration (BAC) of 0.08 g/dL (the legal limit in all U.S. states) or higher (National Highway Transportation Administration [NHTSA], 2008). The vast majority of these alcohol-related fatalities (82% or 11,044) involved drivers with a BAC of 0.08 g/dL or higher; among these drivers, those ages 21–24 years and 25–34 years have the highest percentages of alcohol-impaired fatal crash involvement (33% and 29%, respectively; NHTSA, 2008).

Not only do these young adult age groups have the highest percentages of alcohol-related fatalities, but they also represent the greatest number of drinking drivers on the road. Although there has been some decline in the number of drinking drivers overall, national roadside breath test surveys reveal that there were no significant declines among drivers with high-risk BACs (e.g., 0.05 g/dL and higher) or those with BACs of 0.10 or higher in the age group 21–34 years, the group that has repeatedly had the highest rates of problem drinking (e.g., binge drinking) and drink/driving (Voas, Wells, Lestina, Williams, & Greene, 1998). Thus, young adult drink/driving and alcohol-related motor vehicle crashes (MVCs) continue to be significant public health problems (Substance Abuse and Mental Health Services Administration [SAMHSA], 2005).

Relevant to drinking behaviors and drink/driving are alcohol establishments, which are defined as commercial businesses licensed by a governmental agency to sell or distribute alcohol and are one context in which alcohol is made available to drivers. Because alcohol establishments are more likely to be located in urban areas, thus increasing alcohol availability, one would expect more drinking and more alcohol-related MVCs in urban than rural areas. While most literature examining the association between alcohol establishments and MVCs has rarely been able to examine alcohol-related crashes specifically, prior studies have found a positive relationship between alcohol establishment density (concentration of alcohol establishments in a given geographic area) and MVCs at different administrative spatial units: state (Colón, 1982), county (Blose & Holder, 1987; Jewel & Brown, 1987), city (Scribner, Mackinnon, & Dwyer, 1994), and neighborhood (VanOers & Garretsen, 1993). These studies hypothesize that higher alcohol establishment density is associated with more opportunity for alcohol consumption, thus leading to greater likelihood of a crash. However, other studies have found the opposite relationship: fewer alcohol establishments associated with more crashes (Colón & Cutter, 1983; Meliker et al., 2004; Smart & Doherty, 1976). One explanation for this inverse relationship (Meliker et al., 2004) is that urban drivers who drink can avoid driving by accessing alternative modes of transportation (e.g., walking and/or public transportation) or may not have to drive as far to their destination.

There are several possible explanations for the contradictory findings in previous investigations of the association between alcohol establishment density and MVCs. First, previous studies relied on aggregate-level (or ecological) associations between alcohol establishments and alcohol-related outcomes, negating the influence of individual drinking behaviors, which may have led to errors in the interpretation of the findings (or an ecological fallacy) (Diez-Roux, 1998). Drinking behaviors and crash involvement are associated with individual characteristics such as age, sex, marital status, education, personal income, vehicle type, and miles driven. Additionally, psychosocial factors such as impulsivity, sensation-seeking, and behavioral undercontrol have been consistently positively associated with alcohol misuse and alcohol-related problems (Nolen-Hoeksema, 2004). Men usually exhibit higher ratings of impulsivity, sensation-seeking, and behavioral undercontrol than women; however, similar psychosocial factors have also been shown to predict women's driving behaviors and outcomes (Elliott, Shope, Raghunathan, & Waller, 2006).

Second, defining alcohol establishment exposure using an administrative spatial unit (e.g., county, zip code, or census tract) may not represent an individual driver's exposure to area characteristics, because his or her exposure may not correspond to the boundary lines of administrative units. Third, most of the studies were conducted primarily in urban areas. Thus, there has been a lack of attention to rural areas, which is unfortunate considering that there is literature reporting regional urban–rural differences in the prevalence of alcohol use and alcohol-related problems (Borders & Booth, 2007; Damkot, 1979; Dunsire & Baldwin, 1999; Jackson, Doescher, & Hart, 2006; Kmet, Brasher, & Macarthur, 2003). For instance, Borders and Booth (2007) analyzed the 2001–2002 National Epidemiologic Survey on Alcohol and Related Conditions (NESARC) and found that current drinkers in rural areas of the Midwest Census Region (which includes the state of Michigan) were more likely to have a current alcohol disorder and exceed recommended daily alcohol limits compared to other census regions, controlling for age, sex, race/ethnicity, marital status, and educational level (Chen, Durfour, & Yi, 2005). Also, Michigan-specific studies (Borgialli, Hill, Maio, Compton, & Gregor, 2000; Meliker et al., 2004) have found that more alcohol-related crashes occurred in areas of low population density. These studies primarily attribute their findings to either an urban–rural difference in alcohol establishment density and/or to individual drinking behaviors.

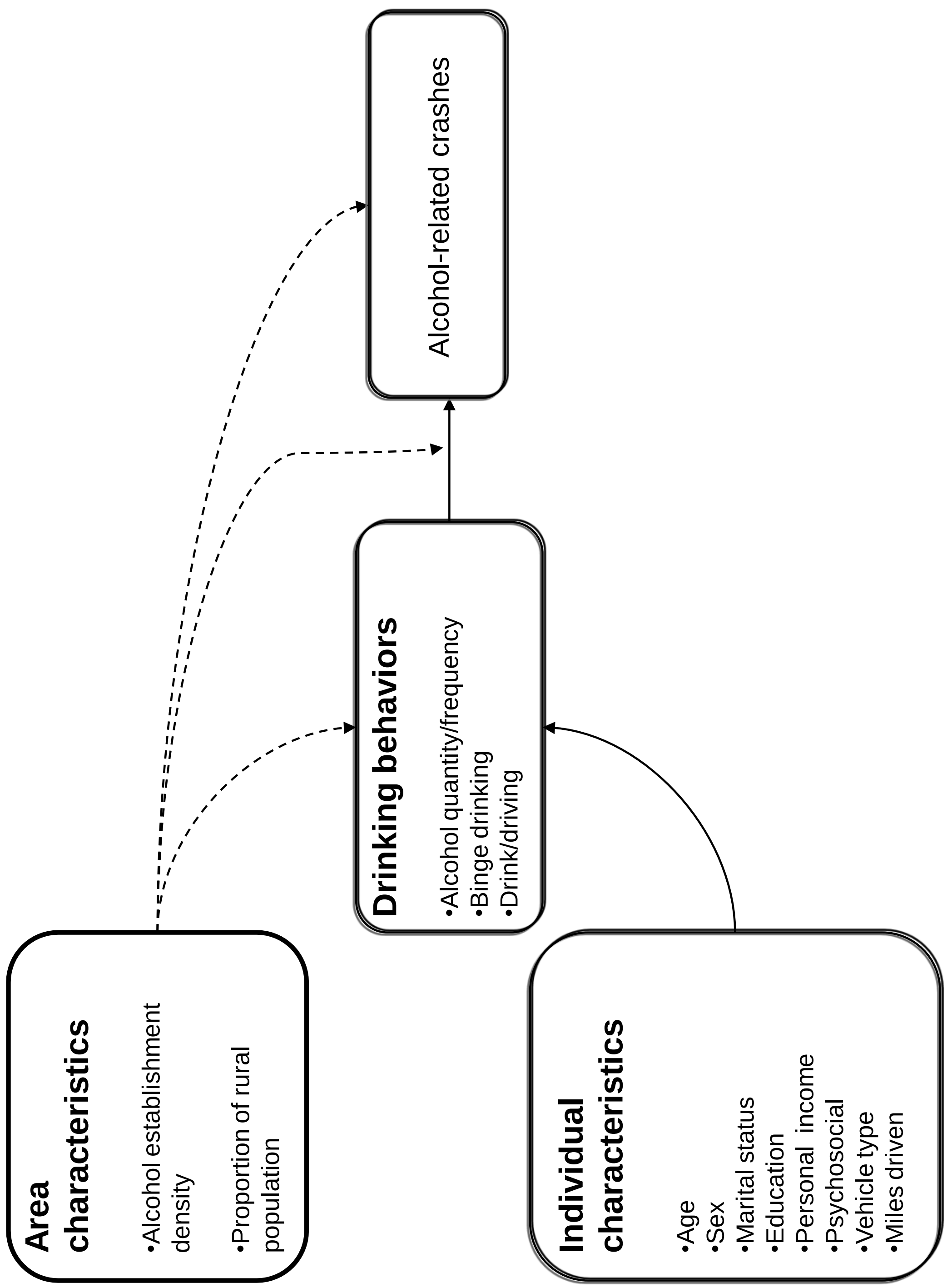
There is a paucity of research on the relationships among drinking behaviors, alcohol establishment density, and urban–rural differences; thus, this paper will specifically examine the relationships between area characteristics (e.g., alcohol establishment density and proportion of rural population) and drinking behaviors of Michigan young adults to determine if, how, and to what extent they are associated with alcohol-related MVCs. This research aims to address gaps in the literature by (a) examining individual-level data (rather than aggregated data) of young adults, who have the highest rates of drinking and drink/driving; (b) developing continuous and individualized estimates of exposure to alcohol establishments and of rurality to estimate the amount of variation in outcomes that might be accounted for by these area characteristics; and (c) examining some of the possible relationships among alcohol establishment density, drinking behaviors, and alcohol-related MVCs. An investigation into how alcohol establishments influence drinking behaviors and alcohol-related MVCs is imperative to the development of more appropriate and cost-effective prevention strategies.

CONCEPTUAL MODEL

The proposed conceptual model (see Figure 3.1) posits that area and individual characteristics may influence drinking behaviors and alcohol-related (when compared to non-alcohol-related) MVCs. Area characteristics include alcohol establishment density and proportion of rural population. Individual characteristics include demographic variables (e.g., age, sex, and personal income), psychosocial variables (e.g., physical/verbal hostility), as well as vehicle type and miles driven. In previous research, individual characteristics were associated with drinking behaviors (Elliott et al., 2006; SAMHSA, 2005; Voas et al., 1998); however, the conceptual model posits that individual characteristics have no direct relationship with alcohol-related MVCs. Instead, the conceptual model posits that individual characteristics are indirectly associated with alcohol-related crashes through drinking behavior as a mediator.

This paper investigates three possible ways area characteristics may be related to drinking behaviors and the likelihood of an alcohol-related crash, while adjusting for individual characteristics. First, area characteristics may be directly associated with drinking behaviors such as alcohol use, binge drinking, and drink/driving. Second, area characteristics may be directly associated with the likelihood of an alcohol-related crash above and beyond individual characteristics with drinking behaviors as a mediator. Third, the association between drinking behaviors and alcohol-related crashes may be moderated by area characteristics. Investigation of this last relationship will explore whether area characteristics moderates the association between drinking behaviors and alcohol-related crashes. Moreover, in order to shed light on the direction and strength of these associations, alcohol-related crashes will be compared to crashes that are not alcohol-related. If non-alcohol-related crashes are also found to be associated with area characteristics, then area characteristics do not distinguish between these two crash types. On the other hand, if a relationship between alcohol-related crashes (but not non-alcohol-related crashes) and area characteristics is found, then this may demonstrate a role area characteristics have in alcohol-related crash occurrence. Additionally, individual characteristics will be used to adjust statistical models to clarify the direction and strength of the relationships between area characteristics and the likelihood of an alcohol-related crash. The direction and associations between different construct

Figure 3.1. Conceptual model outlining three proposed relationships among area characteristics, drinking behaviors, individual characteristics, and alcohol-related crashes. (*Solid lines represent consistent associations based on previous research and dashed lines represent associations under investigation.)*



relationships are outlined in Figure 3.1. Solid lines represent consistent associations based on previous research; dashed lines represent associations under investigation (Earp & Ennett, 1991).

RESEARCH QUESTIONS

1. Are alcohol establishment density and proportion of rural population associated with alcohol use, binge drinking, and drink/driving, while adjusting for individual characteristics?
2. Are alcohol establishment density and proportion of rural population associated with alcohol-related crashes, while adjusting for individual characteristics?
3. Do alcohol establishments and proportion of rural population moderate the association between drinking behaviors and alcohol-related crashes, while adjusting for individual characteristics?

METHODS

Sample and Survey

Data sources: Individual characteristics. The study population is from a project entitled "Psychosocial Correlates of Adolescent Driving Behavior" conducted by the University of Michigan Transportation Research Institute and funded by the National Institute for Alcohol Abuse and Alcoholism (NIAAA R01 AA09026). The data used for this secondary analysis are part of a longitudinal study that began in 1984, when respondents were elementary school students enrolled in two large school-based substance use intervention studies (Shope, Copeland, Kamp, & Lang, 1998; Shope, Copeland, Maharg, & Dielman, 1996a; Shope, Copeland, Marcoux, & Kamp, 1996b; Shope, Dielman, Butchart, & Campanelli, 1992).

All respondents who had participated in previous school surveys were eligible for a telephone survey in young adulthood if they held a Michigan driver's license or had personal state identification. Addresses of eligible participants were obtained from the Michigan Department of State. Participants in the school surveys were students attending southeast Michigan public schools and did not necessarily represent the statewide population. However, the young adult survey participants and individuals from the same Michigan birth cohorts have been shown to have comparable frequencies of driving offenses and crashes (Elliott, Waller, Raghunathan, Shope, & Little, 2000). The eligible sample was partitioned into two cohorts based on the participants' high school graduation years.

The telephone survey was conducted over 4 years; these cross-sectional data were chosen for the current analysis because respondents were in their early 20's (N = 5,464; M = 23.5 years of age), an age group characterized by the highest rates of drinking and drink/driving (NHTSA, 2008). Tracking and interviewing began in November 1997 and continued through January 2000. The response rate of the original eligible sample was 58.5% (using definition Response Rate 5 [RR5] from the American Association for Public Opinion Research, 2000). Trained telephone survey interviewers administered the survey and collected the data. They usually contacted participants between the hours of 6:30 p.m. and 8:00 p.m. on weekdays. Survey completion took approximately 30 minutes, and respondents received $15 for their participation.

Outcome Measures

Association of area characteristics with drinking behaviors (Research Question 1). No single measure is capable of representing the variation in individual drinking behavior. Therefore, drinking behavior in this study was measured by three variables.

Respondents' quantity/frequency (Q/F) of alcohol consumption was the product of two survey items; quantity and frequency of alcohol consumption. Quantity of alcohol consumption was obtained by asking how many drinks containing alcohol respondents had on a typical drinking day, with responses coded 1 = *1 to 2 drinks*, 2 = *3 or 4 drinks*, 3 = *5 or 6 drinks*, 4 = *7 to 9 drinks*, and 5 = *10 or more drinks*. Frequency of alcohol consumption was obtained by asking how often respondents had a drink containing alcohol, with responses coded 1 = *never*, 2 = *once a month or less*, 3 = *2 to 4 times a month*, 4 = *2 to 3 times a week*, and 5 = *4 or more times a week*. A missing value on either item resulted in a missing value for the measure (Bingham, Shope, & Tang, 2005).

Binge drinking was sex-specific, with respondents reporting how many times within the past 12 months they had five (if male) or four (if female) or more drinks (of beer, wine, or liquor, etc.) when they were drinking. This item was developed for this study but was modeled after other binge drinking items commonly used in alcohol research (Wechsler & Nelson, 2001).[11] Responses were recorded as frequencies (range = 0–300).

Drink/driving was comprised of five items that assessed how many times in the last 12 months the respondent drove "within an hour of having 1 or 2 beers or other alcoholic beverages," "within an hour of having 3 or more beers or other alcoholic

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[11]For example, the National Institute on Alcohol Abuse and Alcoholism (NIAAA; 2004) defines binge drinking as "a pattern of drinking alcohol that brings BAC to 0.08 g/dL or above. For the typical adult, this pattern corresponds to consuming 5 or more drinks (male), or 4 or more drinks (female), in about 2 hours."

beverages," "while [they] felt high or light-headed from drinking," "when [they] knew drinking had affected [their] coordination," and "while driving a car" (Donovan, 1993; α = 0.94). The responses for each item were collapsed into 14 ordinal categories (range = 0–13), and a scale score was calculated by averaging across items, so that a higher score represented more frequent drink/driving behavior. Respondents who were missing responses for two or more of the five items were assigned a missing value for the measure.

Association of area characteristics with alcohol-related crashes (Research Questions 2 and 3). The Michigan Secretary of State provided annual drivers' license records for the study participants. Crash data 3 years before and after the interview date were used in the analyses. Outcome variables of interest included whether or not a respondent was involved in an alcohol-related crash, a single-vehicle nighttime crash, or a non-alcohol-related crash. Single-vehicle nighttime crashes, defined as crashes that only involve one vehicle and occur between 12:00 a.m. and 4:00 a.m., often involve alcohol and are used as a proxy for alcohol-involved crashes[12] (Heeren, Smith, Morelock, & Hingson, 1985). If a respondent was involved in an alcohol-related crash or a single-vehicle nighttime crash, the crash was considered to be alcohol-related and coded as 2; a crash that was not alcohol-related or a single-vehicle nighttime crash was coded as 1; a respondent with no record of a crash with the Michigan Secretary of State was given a code of zero.

[12]There were 79 respondents (20 women and 59 men) with at least one crash designated as "alcohol-related and 67 respondents (15 women and 52 men) with at least one crash designated as single-vehicle nighttime.

Predictor Measures: Area Characteristics

Alcohol establishment density. A file of 16,013 licensed alcohol establishments in Michigan was obtained in November 2006 from the Michigan Liquor Control Commission (MLCC) website and geocoded using a computer program called ArcView 9.1.[13] This file listed each business licensed to sell alcohol (e.g., grocery or convenience store, restaurant), a federally issued tax identification number, business address (i.e., street, city, and ZIP code), additional bars on the premises, other permits held by the establishment, license type and number, the last year the license was active, county, and local governmental unit.

Although there is no single way to measure density, operationalization should depend on the alcohol-related research question under investigation. Alcohol establishment density is often quantified as the number of establishments per capita or per unit area, which is appropriate for general research questions on alcohol use and misuse. However, when driving-related behavior is the outcome of interest, alcohol establishment density measures need to be more sophisticated to capture the co-occurrence of alcohol availability and alcohol-related crashes (Gruenewald, 2007; Gruenewald, Johnson, & Treno, 2002). For the purposes of this research, alcohol establishment density was measured by the number of alcohol establishments per mile of road, which captures how alcohol is accessed by drivers using the road network. Roadway miles were measured using Michigan road data files (i.e., shapefiles) obtained

[13]Geocoding is a process in which physical addresses are assigned a latitude and longitude. To generate a geocoded address, each business address was inputted and translated into a point on a map with a score (from 0 = *no match* to 100 = *perfect match*) showing how successfully addresses matched to a reference street map. Of 16,013 business addresses, 14,485 (90%) were matched with scores from 70 to 100; 423 (3%) addresses were matched with a score less than 70 but greater than 0; and 1,105 (7%) addresses were considered unmatched. Unmatched addresses were manually cleaned, or geocoded according to zip code centroid, and indexed.

from the 2004 Michigan Geographic Data Library version 6b. The density of alcohol establishments per mile of road was aggregated to the census tract level. Alcohol establishment density was dichotomized as high/low by a cut-off point chosen based on the Michigan state-wide mean.

Proportion of rural population. The U.S. Census Bureau defines rural in relation to urban. Urban consists of "core census block groups or blocks that have a population density of at least 1,000 people per square mile and surrounding census blocks that have an overall density of at least 500 people per square mile" (U.S. Census Bureau, 2002). Rural population consists of the population that is not classified as urban. Because census block groups and blocks are smaller than census tracts, portions of a census tract can have a rural population. Rural population for this study was defined as the proportion of a census tract population that was rural divided by the total census tract population. The square root transformation of the proportion of rural population was used in multivariate regression analyses because it provided a better fit.[14] Proportion of rural population was dichotomized as high/low based on a cut-off point chosen based on the Michigan state-wide median.

Estimating respondents' exposure to area characteristics. To create a measure of individualized exposure to area characteristics, each survey respondent's residential

[14]Proportion of rural population exhibited positive skewness (2.15) and positive kurtosis (5.69). Square root transformation resulted in a relatively normal distribution (skewness = 0.49; kurtosis = 0.27). The transformation was verified by plot examinations of residuals versus predicted values.

address at the time of the telephone survey was geocoded using ArcView 9.1.[15] To estimate an individual's exposure to area characteristics, a circular buffer was created around each respondent's address with a radius of 12.1 miles because this is the average one-way vehicle trip length to and from work, as determined by the 2001 National Household Travel Survey (Energy Information Administration, 2005). Because area characteristics have been generalized to the census tract level, the areal apportionment method was used to allocate data between census geography and the 12.1-mile buffers to create an individualized exposure estimate for each survey respondent (Cummins, Diez-Roux, & Macintyre, 2007; Mohai & Saha, 2006; Saporito, Chavers, Nixon, & McQuiddy, 2007).

An ArcGIS version 9.2 tool called Spatial Overlay was used to extract census tract data from one layer and join it to the buffer layer. In other words, for any one respondent's buffer, there are data from multiple and partial census tracts. SAS version 9.1 and the areal apportionment method were used to calculate an individual's exposure within each buffer. The areal apportionment method formula,

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[15]Each survey respondent's residential address was geocoded using the same procedure as for the alcohol establishments. Of 5,464 respondent addresses, 5,026 (92%) were matched with scores from 80 to 100; 268 (5%) addresses were matched with scores less than 80 but greater than 0; and 170 (3%) addresses were considered unmatched. Addresses with a score less than 80 were manually cleaned as described previously. For example, some unmatched geocoded records represented post office box addresses (n = 35), which were mostly found in rural areas. If these records had not been manually processed, a bias against rural areas could have been introduced. In these cases, the software assigned a latitude and longitude point in the middle (or centroid) of the respondent's zip code (Krieger et al., 2002).

$$C = \frac{\sum_{i=1}^{n} (a_i / A_i)(p_i)(c_i)}{\sum_{i=1}^{n} (a_i / A_i) p_i}$$

, allocates data between census geography and the respondent's buffer, where an area's environmental characteristic (c_i) is weighted by population (p_i) and proportion of area (a_i/A_i) of the census tract captured by the buffer (Mohai & Saha, 2006). An individualized exposure estimate (C) was obtained by summing the allocated census tract data captured by each buffer.

Additional Covariates

Demographic variables. Information on individual covariates (age, sex, education, personal income, marital status, psychosocial variables, vehicle type, and miles driven) was obtained during the telephone interview. Age was calculated by subtracting a respondent's date of birth from the date of the interview. Education was determined by asking respondents to report the highest grade in school completed (categorized as 1 = *less than eighth grade*, 2 = *finished eighth grade*, 3 = *some high school*, 4 = *graduated high school*, 5 = *graduated technical or trade school*, 6 = *some college*, 7 = *graduated college*, 8 = *some graduate or professional school*, and 9 = *earned a postgraduate degree*). Personal income was coded 1 = *under $5,000*, 2 = *$5,000 to $14,999*, 3 = *$15,000 to $24,999*, 4 = *$25,000 to $34,999*, 5 = *$35,000 to $44,999*, 6 = *$45,000 to $54,999*, and 7 ≥ *$55,000*. Marital status was reported as 1 = *currently married*, 2 = *separated*, 3 = *divorced*, 4 = *widowed*, or 5 = *never married*. Marital status was recoded to a dichotomous variable: *ever married* (married, separated, divorced, or widowed) versus *never married*.

Psychosocial variables. Tolerance of deviance (TOD) was a 10-item measure asking respondents to rate the wrongness of specific behaviors: “to give a fake excuse for missing work, not showing up for a meeting, or cutting class,” “to damage public or private property on purpose,” “to start a fight and hit someone,” “to give false information when filling out a job or loan application,” “to shoplift something of value from a store,” “to start an argument and insult the other person even though it isn’t really called for,” “to damage something of value because [you were] angry with the person it belongs to,” “to write a check even though [you knew] it might bounce,” “to lie to people close to [you] to cover up something [you] did,” and “to take things of value that do not belong to [you]” (Donovan, 1993; α = 0.81). Each TOD item was coded 1 = *very wrong*, 2 = *wrong*, 3 = *a little wrong*, or 4 = *not at all wrong*. An overall score was calculated by averaging the responses to all 10 items. A higher score indicated greater TOD. Missing responses for three or more of the 10 items were assigned a missing value for the measure.

Risk-taking propensity was a four-item measure (Donovan, 1993; α = 0.77). Participants were asked to rate how well the following statements described them: “I’d do almost anything on a dare,” “I enjoy the thrill I get when I take risks,” “I like to live dangerously,” and “I like to take chances even when the odds are against me.” Responses for each item were coded 1 = *not at all like me*, 2 = *a little like me*, or 3 = *a lot like me*. An overall score was calculated by averaging responses to the four items, with a higher score indicating greater risk-taking propensity. Respondents missing one or more of the four items were assigned a missing value for the measure.

Physical/verbal hostility (Donovan, 1993; α = 0.63) was a seven-item measure asking participants to rate how well the following statements described them: “I don’t think there is ever a good reason for hitting anyone,” “If people annoy me, I let them know exactly what I think of them,” “I like to argue with other people just to get them annoyed," "If I have to use force to defend my rights, I will," "When I get angry at someone, I often say really nasty things," "When I really lose my temper, I've been known to hit or slap someone," and "If people push me around, I hit back." Responses to each item were coded 1 = *not at all like me*, 2 = *a little like me*, or 3 = *a lot like me*. After reverse coding one item ("I don't think there is ever a good reason for hitting anyone"), an overall score was calculated by averaging responses to the seven items such that higher scores indicated greater hostility. Respondents missing responses to one or more of the seven items were assigned a missing value for the measure.

Vehicle type and miles driven. To represent the exposure to crash risk that various types and levels of driving present, respondents' vehicle types and miles driven were assessed. Vehicle type was a one-item measure asking "What type of vehicle do you usually drive?" This item was coded 1 = *passenger car*, 2 = *van*, 3 = *pick-up truck*, 4 = *motorcycle*, 5 = *moped*, 6 = *sports utility vehicle*, and 7 = *other*. Motorcycles and mopeds were deleted, because there were too few participants who drove these vehicles to adequately examine the effects of the categories on the outcome. The remaining vehicle types were coded into a dichotomous variable with *passenger car* as 1 and *all other vehicles* recoded as 0. Miles driven was a one-item measure that asked respondents "About how many miles in total did you drive in the past 12 months?" A missing response for either item was assigned a missing value for the measure.[16]

[16]There were no missing items for miles driven. This item was used as an a priori criterion for study inclusion.

Statistical Analyses

Analyses for this paper were restricted to respondents with a 12.1-mile address buffer that lay within the Michigan state boundary during the time of the survey and who had driven a motor vehicle on a public road and drunk alcohol within the past year. Final sample size for all analyses was 3,912.[17]

Respondents with missing data (*n* = 196) for any measure were excluded from all analyses. Prior to listwise deletion, diagnostic procedures were utilized to determine the missing data mechanism (Allison, 2002). A dummy coded matrix was created by assigning a 1 to missing measures or a 0 to non-missing measures. The dummy coded matrix was analyzed for patterns and Spearman correlations among measures.[18] Additionally, using logistic regression, respondents were modeled (1 = *missing*, 0 = *not missing*) for each missing variable on predictor and outcome variables to test whether the missingness of the missing variable could be predicted by the observed measures. The missingness of each predictor (*X*) was not predicted by each observed outcome variable (*Y*); therefore, results should be unbiased to missingness. Finally, respondents included in the analysis had similar demographic characteristics to respondents who

[17]Five-hundred and five respondents were excluded from the original sample (*N* = 5,464) because they did not live in Michigan during the time of the interview. Also excluded were 24 respondents who had buffers that overlapped with nearby states (e.g., 2 overlapped with Wisconsin, 15 overlapped with Ohio, and 7 overlapped with Indiana). Additionally, 41 respondents were excluded because they had not driven a motor vehicle on a public road in the year prior to the survey interview, and 786 respondents were excluded because they did not drink alcohol in the previous year. Finally, 196 respondents were excluded because they had missing data on one or more measures.

[18]After a priori exclusion criteria, most measures had less than 1% of respondents with missing data. Personal income had the greatest number of respondents missing (*n* = 65, 1.58%), followed by drink/driving (*n* = 56, 1.36%). There were no significant associations with any of the outcome variables (i.e., alcohol quantity/frequency, binge drinking, drink/driving, crash). Missingness for drink/driving was predicted by being male ($p = 0.009$) and having less education ($p = 0.048$). Missingness for binge drinking was predicted by alcohol quantity/frequency ($p = 0.001$). There were no missing values for alcohol quantity/frequency and crash.

were excluded, except that excluded respondents had lower education and income, had more physical/verbal hostility, and reported less drink/driving.

Because the outcomes may be spatially autocorrelated, there is concern that the linear regression assumption of independent observation could have been violated (Waller & Gotway, 2004). In response to this concern, spatial autocorrelation was empirically tested for each sex and outcome using GeoDa software, version 0.9.5-i5 (2004; Anselin, Syabri, & Kho, 2006). Spatial dependence statistics indicated weak, but statistically significant, dependence among model residuals, but linear spatial trend models were nonsignificant.[19] Therefore, spatial regression was not necessary, and regression models that assume spatial independence were estimated using SAS version 9.1.3.

Analyses were done to test each of the three relationships suggested by the conceptual model. All models were estimated separately for men and women because there is a body of research reporting sex differences in influences on drinking behaviors and alcohol-related outcomes (Bingham, Elliott, & Shope, 2007; Bingham, Shope, Zakrajsek, & Raghunathan, 2008; Chou et al., 2006; Jones & Lacey, 2001; Quinlan et al., 2005; Voas, Wells, Lestina, Williams, Greene, 1998; NHTSA, 2008;). Analysis of variance (ANOVA) was used to examine mean differences for continuous variables for high and low alcohol establishment density areas and urban and rural areas, whereas chi-square statistics were used to test differences for categorical variables.

[19]For women: alcohol quantity/frequency (Moran's I = 0.0001, p = 0.359), binge drinking (Moran's I = 0.0069, p = 0.006), drink/driving (Moran's I = 0.0013, p = 0.199), alcohol-related crash (Moran's I = 0.0001, p = 0.349). For men: alcohol quantity/frequency (Moran's I = 0.0067, p = 0.018), binge drinking (Moran's I = 0.0055, p = 0.033), drink/driving (Moran's I = 0.0014, p = 0.259), alcohol-related crash (Moran's I = 0.0071, p = 0.011). Each Global Moran's I coefficient was obtained using a row-standardized Arc distance weight of 12.1 miles for men and women.

The first relationship (i.e., first research question) between area characteristics and drinking behaviors was tested using each drinking behavior (i.e., alcohol use, binge drinking, and drink/driving) as an outcome. Negative binomial regression models were used to estimate associations of each drinking behavior with area characteristics. Associations were examined before and after adjustment for age, education, personal income, marital status, psychosocial variables, vehicle type, and miles driven.[20]

The second and third relationships (i.e., second research question) proposed in the conceptual model (see Figure 3.1) were tested with multinomial regression models and examined the associations of alcohol-related crash, non-alcohol-related crash, and no crash (as the referent category) with area characteristics. The second relationship analysis examined the direct association between area characteristics and the likelihood of an alcohol-related crash with drinking behaviors as mediators. To examine whether drinking behaviors mediated the relationship between area characteristics and driving outcomes, models were examined before and after adjustments for drinking behaviors.

The third analysis examined the moderating influence of area characteristics on the association between drinking behaviors and the likelihood of an alcohol-related crash. The moderating relationship was tested using an interaction term between each area characteristic and each drinking behavior, while adjusting for individual characteristics, with the likelihood of a crash and an alcohol-related crash as an outcome (Aiken & West, 1991).

The models were tested in a hierarchal fashion, with conceptual domains entered sequentially. For example, final models included the domains of area characteristics

[20]Driving exposure is associated with driving outcomes (i.e., crash). Although driving exposure may not be associated with drinking behaviors, it was utilized in all models to inform the proposed relationships in the conceptual model.

first, followed by demographics, psychosocial variables, driving exposure, and finally drinking behaviors. A measure of goodness-of-fit (log-likelihood statistic) is reported for each specific model. To contrast and evaluate competing models, log-likelihood statistics were compared.

RESULTS

Descriptive Statistics

The overall aim of this paper was to examine whether alcohol establishment density is associated with drinking behaviors and alcohol-related crashes among Michigan young adults. Table 3.1 shows descriptive statistics for the overall sample (n = 3,912), as well as by urban/rural area and high/low alcohol establishment density. Mean participant age was 23.48 years; 49.77% were male; 96.11% had a high school education or more; and 17.28% earned more than $35,000 in personal income within the past year. The respondents were approximately evenly split among low versus high alcohol establishment density areas: 2,099 (53.7%) and 1,813 (46.3%), respectively. Alcohol establishment density was negatively correlated with the proportion of rural population (Spearman's rank correlation coefficient [r] = -.69; bivariate results not shown).[21] On average, there were two alcohol outlets per 10 miles of roadway within the participants' radii (M = 0.20).

Association of Area Characteristics with Drinking Behaviors (Research Question 1)

Tables 3.2–3.7 show the results of analyses examining the first proposed relationship of area characteristics (i.e., alcohol establishment density and proportion of

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[21]Regression diagnostics (variance inflation factor [VIF]) did not indicate multicollinearity in the multivariate models.

rural population) with drinking behaviors. Among men, alcohol establishment density and proportion of rural population were negatively associated with alcohol quantity/frequency (see Table 3.2). Although the additional adjustment for psychosocial variables (i.e., tolerance of deviance, risk-taking propensity, and physical/verbal hostility) had a large impact on model fit (Model 5; Log-likelihood from 6477.78 to 6571.17), the association between area characteristics and alcohol quantity/frequency was not weakened (Model 6).

Results were similar among women, with negative associations for both alcohol establishment density and proportion of rural population with alcohol quantity/frequency (see Table 3.3). The addition of psychosocial factors did not substantially alter the associations for either of the area characteristics with alcohol quantity/frequency; however, they did improve the model fit substantially (Model 5; Log-likelihood from 795.88 to 861.22).

Binge drinking among men was negatively associated with alcohol establishment density (Model 2; see Table 3.4). This association was strengthened with the addition of demographic variables (Model 4) but eliminated when psychosocial variables were added (Model 5). In contrast, among women, the negative association between both area characteristics and binge drinking was not reduced with adjustments for demographic or psychosocial factors (see Table 3.5; Models 4 and 5).

Finally, among men, the negative association between drink/driving and alcohol establishment density was eliminated in the final model with the adjustment for driving exposure (see Table 3.6; Model 6). Among women, alcohol establishment density but not the proportion of rural population was negatively associated with drink/driving and remained after adjustment for the other variables (see Table 3.7; Model 6).

Association of Area Characteristics with Alcohol-Related Crashes (Research Questions 2 and 3)

More than half the sample (*n* = 2,183 or 55.80%) had not been involved in a crash in the 6-year period examined (see Table 3.1). More than a third of the sample had been involved in a crash in which no alcohol was involved (*n* = 1,605 or 41.03%), and 124 (or 3.17%) had been involved in at least one alcohol-related crash. Statistical differences were found between men's and women's alcohol-related crashes. More men than women were involved in both non-alcohol-related crashes (44.43% vs. 37.66%) and alcohol-related crashes (4.67% vs. 1.68%; results not shown).

The second and third relationships proposed that area characteristics have a direct or moderating effect on the likelihood of an alcohol-related crash. Results for multinomial regression models were tested separately for men and women (see Tables 3.8–3.9). Among men, there was a significant direct negative relationship between alcohol establishment density and alcohol-related crashes (see Table 3.8). For men, the likelihood of being in an alcohol-related crash was higher in rural areas than in urban areas, *OR* = 2.93, 95% CI [1.08, 7.97], although this association was eliminated with the addition of alcohol establishment density. Additional adjustments for alcohol quantity/frequency, binge drinking, and drink/driving increased model fit and reduced the association between area characteristics and the likelihood of an alcohol-related crash. Higher alcohol establishment density was associated with a lower likelihood of being involved in an alcohol-related crash, *OR* = 0.014, 95% CI [<0.001, 0.576]. For men, the results of the analysis of the moderating influence of area characteristics on the association between drinking behaviors and the likelihood of an alcohol-related crash showed that the association between drinking behaviors and alcohol-related crashes was not moderated by area characteristics.

Results were less clear among women (see Table 3.9). There was no direct relationship between area characteristics and alcohol-related crashes (see Table 3.9). However, women who reported greater alcohol use and more drink/driving were associated with a greater likelihood of being involved in alcohol-related crashes, *OR* = 1.36, 95% CI [1.15, 1.60], and *OR* = 1.23, 95% CI [1.05, 1.45], respectively. The results of the analysis of the moderating influence of area characteristics on the association between drinking behaviors and the likelihood of an alcohol-related crash suggest that the association between drink/driving and an alcohol-related crash was higher in rural areas than in urban areas, *OR* = 4.07, 95% CI [1.15, 14.37]. Additionally, the likelihood of an alcohol-related crash was greater for women who reported more drink/driving and who lived in lower alcohol establishment density areas than higher density areas, *OR* = 46.42, 95% CI [4.02, 536.18].

DISCUSSION

The only previous study to assess the relationship between alcohol establishments, population density, and alcohol-related crashes (Meliker et al., 2004) in Michigan found that the number of alcohol-related crashes was greater in low population density areas. However, that study was confined to Washtenaw and Livingston counties (located in southeast Michigan), which some would argue do not represent the fullest variation to be found in Michigan rural areas. The results of this research expand upon those findings by examining larger and more diverse areas in Michigan, thus increasing the variation found in urban and rural areas. More importantly, this study goes beyond prior work by including individual level drinking behaviors and conducting separate analyses by sex.

The results of this cross-sectional study of Michigan young adults support the conceptual model, in that area characteristics, as measured by alcohol establishment density and rural population, are associated with some drinking behaviors (for men and women) and alcohol-related MVCs (for men). Additionally, this was the first study to show that relationships between area characteristics and drinking behaviors, as well as alcohol-related crashes, were different for men and women.

The first relationship proposed by the conceptual model was an association between area characteristics and drinking behaviors. For both men and women, higher density of alcohol establishments was related to lower alcohol consumption (quantity/frequency), binge drinking, and drink/driving. Associations were in the same negative direction for both sexes; however, they were slightly stronger in women than in men for binge drinking and drink/driving. For men, drink/driving appears less related to alcohol establishment density and more related to individual characteristics such as tolerance of deviance, risk-taking propensity, and physical/verbal hostility. This inverse relationship between area characteristics and drinking behaviors is supported by a population-based survey (Borders & Booth, 2007) that found that current drinkers in rural areas of the Midwest Census Region (which includes the state of Michigan) were more likely than other census regions to have a current alcohol disorder and exceed recommended daily alcohol limits.

Although psychosocial factors (i.e., tolerance of deviance, risk-taking, and physical/verbal hostility) were positively associated with alcohol quantity/frequency, binge drinking, and drink/driving, and contributed to explaining much of their variation, they did little to predict a respondent's involvement in alcohol-related crashes. Similarly, Patil, Shope, Raghunathan, and Bingham (2006) found few associations between psychosocial factors and counts of serious crashes (defined as alcohol-related, single-vehicle, or at-fault).

The next relationship proposed by the conceptual model was that area characteristics would have a direct relationship with the likelihood of an alcohol-related crash even when adjusting for individual characteristics and with drinking behaviors as mediators. Although previous literature has documented sex differences in alcohol use and the rate of alcohol-related crashes, this study was the first to find sex differences in the relationship between area characteristics and alcohol-related crashes, suggesting that exposure to these area characteristics has a different impact on men than women. The results indicated that the odds of men being involved in an alcohol-related crash were greater in areas of lower alcohol establishment density. Moreover, the association of alcohol establishment density with alcohol-related crashes was reduced after adjusting for drinking behaviors (i.e., alcohol quantity/frequency, binge drinking, and drink/driving), corroborating the conceptual model's suggestion that these variables, not surprisingly, are risk factors for increased alcohol-related crashes. Among women, however, a direct relationship between area characteristics and alcohol-related crashes was not supported. These findings are consistent with two previous Michigan-based studies, one that found a greater proportion of alcohol-related crashes in areas of low population density (Meliker et al., 2004), and another that found an association between alcohol-related MVC fatalities and rural crash location (Borgialli et al., 2000). However, unlike the previous two studies, one of the important contributions of this study is the inclusion and examination of drinking behavior as a risk factor for alcohol-related crashes.

Lastly, a moderating relationship between area characteristics and drinking behaviors on the likelihood of an alcohol-related crash was examined. In other words, there may be an association between area characteristics and the likelihood of an alcohol-related crash depending on respondents' drinking behavior. For women who reported more drink/driving behavior, the likelihood of being involved in an alcohol-related crash was greater in areas of lower alcohol establishment density and greater rurality. It is reasonable to hypothesize that people drink/driving in rural areas have to drive further than people drink/driving in urban areas, and the longer driving distance may be an additional risk factor for a crash. However, the small number of women involved in alcohol-related crashes (n = 33) generated large and unstable odds ratios and confidence intervals; therefore, these results should be interpreted cautiously.[22]

The results of this research also indicate that people who reside near fewer alcohol establishments (e.g., rural areas) are at greater risk of alcohol misuse and alcohol-related crashes. This study also contributes to past research by showing that the reason for this inverse association between alcohol establishments and alcohol-related crashes (Colón & Cutter, 1983; Meliker et al., 2004; Smart & Docherty, 1976) may be greater alcohol use and misuse. However, it remains unclear why there is more alcohol use and misuse in areas with fewer alcohol establishments (Borders & Booth, 2007). Perhaps there are social influences (or what could be termed a "drinking culture") in rural Michigan areas that make drink/driving seem more acceptable (or less dangerous). Future research on this hypothesized relationship should examine whether there are urban–rural differences in the perceptions of drink/driving as dangerous and whether social influences affect perceptions of drink/driving.

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[22]There was sufficient variation to estimate a statistically significant positive association for women involved in alcohol-related crashes and alcohol establishment density. However, a majority of these women lived near a greater number of alcohol establishments, and in order to improve the prediction of alcohol-related crashes (i.e., reduce standard errors), it would have been necessary to include in the analysis more women who lived near fewer alcohol establishments.

Studies conducted outside the U. S. have also identified urban–rural differences in drink/driving. For example, research on random breath testing in Western Australia (Dunsire & Baldwin, 1999) found that more drink/driving offenses occurred in rural areas, and rural drivers were more likely to drink/drive (Beel & Stockwell, 1995). It is unfortunate that these findings cannot be compared to the United States' National Roadside Survey, which excludes counties with populations less than 20,000 (Voas et al., 1998). These differences in urban–rural alcohol use clearly suggest that including rural areas and areas with fewer alcohol establishments in drink/driving research is needed and may capture the heterogeneity in regional social, cultural, and policy-level factors (Borders & Booth, 2007; Romley, Cohen, Ringel, & Sturm, 2007). Lower alcohol establishment density may reflect other neighborhood characteristics, norms, or attitudes (such as drinking culture) of rural areas that could not be captured in these analyses. For example, the findings for this study may be the result of rural social isolation, lifestyles, or occupation, which may fundamentally influence alcohol use and driving exposure for this population.

Strengths and Limitations

The generalizability of these findings is limited because the Michigan alcohol establishment density and rurality in this study may not adequately reflect other geographic areas (Meliker et al., 2004; Borders & Booth, 2007). Additionally, individuals in their early 20's may not reflect the alcohol establishment exposure of other age groups (Voas et al., 1998). Another limitation of this study is the lack of knowledge about where alcohol was consumed prior to an alcohol-related crash. To better evaluate the relationship between alcohol establishments and alcohol-related MVCs, future studies should include the location of alcohol consumption. This study was not able to capture whether pre-crash drinking occurred in a licensed or an unlicensed alcohol establishment (e.g., own residence, friend's house, beach, a park, or a party), which might also contribute to young adult drinking and driving (Lang & Stockwell, 1991). Another possible limitation is that respondents' residences were used as a proxy for crash location; however, most crashes do occur near people's residences (Blatt & Furman, 1998).

Additionally, a potential limitation comes from possible differences in time between the exposure to alcohol establishment density and to the survey data collection. The MLCC data were obtained in November 2006. Survey information was collected in late 1997 but not completed until early 2000. Because the MLCC processes over 30,100 licenses every year, there is some concern that the misalignment of the survey period (1997–2000) with a more recent MLCC file (November 2006) could introduce some systematic bias.[23] To estimate the magnitude for systematic bias, an additional MLCC dataset was obtained in November 2007 and compared to the November 2006 data. The November 2007 file listed 15,996 alcohol establishments, 11,891 (or 74.34%) of which matched establishments from November 2006. Because a vast majority of the same alcohol establishments continued to be licensed a year later, it was assumed that the systematic bias was not a substantial problem.

With those limitations stated, these study findings nonetheless contribute to a very small body of previous research on alcohol establishment density, drinking behaviors, and alcohol-related crashes. Whereas previous alcohol establishment

[23]The MLCC was contacted twice by telephone to determine how often these files were updated on the website and whether there was an archive of the data that corresponded to the alcohol-related crash period of approximately 1994–2003. It was found that MLCC data were updated every week, but past data files were not archived. However, after reviewing other available sources of licensed alcohol establishments (e.g., Reference USA and D&B the Million Dollar Database), the advantages of using MLCC data were its completeness and usability.

research has been limited to ecological studies that examined associations based on aggregated data, these findings utilized individual drinking behavior and crash data.

Furthermore, whereas previous studies used conveniently available geographic boundaries (e.g., counties, zip codes, census tracts) without purposefully considering whether the boundaries represented realistic travel patterns for individuals, this study conceptualized exposure to an area at the individual driver level, and therefore has the potential to be more substantively meaningful. Because individuals do not travel only within the boundaries of their zip codes or census tracts, such boundaries do not adequately represent an individual's exposure to alcohol availability. In fact, Brady and Weitzman (2007) obtained different drinking prevalences using different geographic boundaries. The operationalization of an individualized exposure approach adds to the methodological strength of these analyses and could be used to examine different radii (e.g., walking distances), and thus different alcohol establishment exposures, in relation to drinking behaviors.

Finally, a major strength of this study is in utilizing a density measure of alcohol establishments per mile of road, which captured how alcohol was accessed by drivers. However, this measure could be further refined by examining whether alcohol establishment characteristics, such as license types and number of additional permits (e.g., entertainment), enhance the effect of density on individual drinking behaviors and alcohol-related crashes. For example, licenses that are "on-premise" require patrons to consume their alcohol purchase at the business (e.g., restaurants and bars). "Off-premise" licenses, on the other hand, require patrons to consume their alcohol purchase away from the business (e.g., supermarkets and liquor stores). Gruenewald, Johnson, and Treno (2002) found that the density of on-premise alcohol establishments was positively associated with a drivers' reports of drink/driving, whereas off-premise alcohol establishments were negatively associated with the number of such events. Previous studies (Gruenewald & Ponicki, 1995; Treno, Grube, & Martin, 2003) have also found differences in the associations (e.g., size and direction) of various alcohol establishment characteristics and drink/driving events. Moreover, alcohol establishments with additional permits have been suggested to increase alcohol use and misuse, but this establishment characteristic has not been studied extensively (Gruenewald, Remer, & Lipton, 2002). One study by Gruenewald, Johnson, and Treno (2002) posits that an alcohol establishment with an entertainment permit has the potential to expose patrons to an increased opportunity for alcohol consumption. In an effort to improve understanding of the influence of area characteristics on health, future research could examine specific alcohol establishment characteristics to determine whether different license types and/or additional permits are associated with drinking behaviors and alcohol-related crashes.

Table 3.1. *Individual and Area Characteristics for the Final Sample, Stratified by Proportion of Rural Population and Alcohol Establishment Density (n = 3,912)*

	FULL SAMPLE (*n* = 3,912)		**URBAN**[a] (*n* = 3,217)		**RURAL** (*n* = 695)		**HIGH ALCOHOL DENSITY** (*n* = 1,813)		**LOW ALCOHOL DENSITY** (*n* = 2,099)	
			Proportion of rural pop. ≤ 25%		Proportion of rural pop. > 25%		Alcohol density > 16.25		Alcohol density ≤ 16.25	
	(Count & Column %) or *M*	*SD*	(Count & Column %) or *M*	*SD*	(Count & Column %) or *M*	*SD*	(Count & Column %) or *M*	*SD*	(Count & Column %) or *M*	*SD*
Demographic										
Age (years)	23.48	0.84	**23.45**	**0.82**	**23.60**	**0.82**	23.49	0.79	23.47	0.86
Marital status (ever married)	1,034 (26.43%)		**781 (24.28%)**		**253 (36.40%)**		**433 (41.88%)**		**601 (58.12%)**	
Sex (male)	1,947(49.77%)		1,588 (49.36%)		359 (51.65%)		**855 (47.16%)**		**1,092 (52.02%)**	
Education[b]										
< High School	152 (3.89%)		**115 (3.57%)**		**37 (5.32%)**		**76 (4.19%)**		**76 (3.62%)**	
High School	874 (22.34%)		**682 (21.20%)**		**192 (27.63%)**		**365 (20.13%)**		**509 (24.25%)**	
> High School	2,886 (73.77%)		**2,420 (75.23%)**		**466 (67.05%)**		**1,372 (75.68%)**		**1,514 (72.13%)**	
Personal Income[b]										
< $15,000	1,076 (27.51%)		878 (27.29%)		198 (28.49%)		**455 (25.10%)**		**621 (29.59%)**	
≥ $15,000 - < $35,000	2,160 (55.21%)		1,779 (55.30%)		381 (54.82%)		**1,022 (56.37%)**		**1,138 (54.22%)**	
≥ $35,000	676 (17.28%)		560 (17.41%)		116 (16.69%)		**336 (18.53%)**		**340 (16.20%)**	
Driving exposure										
Miles driven (past year)	18,398.69	18,938.96	18,306.46	18,095.07	18,825.60	22,658.80	**17,386.67**	**18,255.01**	**19,272.82**	**19,553.97**
Vehicle type (passenger car)	2,749 (70.27%)		**2,301 (71.53%)**		**448 (64.46%)**		**1,317 (47.91%)**		**1,432 (52.09%)**	
Psychosocial										
Tolerance of deviance	1.31	0.30	1.31	0.30	1.30	0.30	1.32	0.30	1.30	0.29
Risk-taking propensity	1.33	0.40	1.32	0.40	1.35	0.42	1.31	0.38	1.34	0.42
Physical/verbal hostility	1.63	0.38	1.62	0.38	1.65	0.38	1.62	0.38	1.63	0.39
Drinking behaviors[c]										
Alcohol quantity/frequency	4.01	3.10	4.04	3.09	3.88	3.17	**3.81**	**2.85**	**4.19**	**3.30**
Binge drinking	15.29	33.16	15.21	31.81	15.65	38.83	**13.51**	**28.81**	**16.82**	**36.43**
Drinking and driving	1.57	2.32	1.59	2.29	1.49	2.43	**1.40**	**2.11**	**1.72**	**2.47**
Driving outcome[d]										
No crash	2,183	55.80%	1,805	56.11%	378	54.39%	1,039	57.31%	1,144	52.40%
Crash (non-alcohol related)	1,605	41.03%	1,318	40.97%	287	41.29%	726	40.04%	879	41.88%
Alcohol-related crash	124	3.17%	94	2.92%	30	4.32%	48	2.65%	76	3.62%
Area characteristics										
Alcohol establishment density[e]	0.20	0.09	0.22	0.08	0.10	0.05	0.29	0.05	0.12	0.04
Proportion of rural population	0.15	0.17	0.08	0.07	0.44	0.17	0.05	0.08	0.23	0.18

BOLD values are statistically significant at $p \le 0.05$ using F-tests for continuous variables and Chi-square tests for categorical variables.
[a]Proportion of rural population cut-off point was chosen based on state-wide median. Alcohol establishment density cut-off point was chosen based on state-wide mean.
[b]Education and personal income were collapsed into three categories for the descriptive table only.
[c]Drinking behaviors are dependent variables for the first proposed relationship; mediator and moderator variables for the second and third proposed relationships, respectively.
[d]Driving outcomes are the dependent variables for the second and third proposed relationships.
[e]Alcohol establishment density is expressed as the number of alcohol establishments per mile of road.

Table 3.2. *Negative Binomial Regression Models of Alcohol Quantity/Frequency With Area Characteristics and Individual Characteristics for Men (n = 1,947)*

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
	B (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)
Area characteristics						
Proportion of rural population	-0.010		-0.264**	-0.228*	-0.232*	-0.229*
	(0.076)		(0.100)	(0.099)	(0.095)	(0.094)
Alcohol establishment density[a]		-0.486**	-0.883***	-0.926***	-0.949***	-0.907***
		-0.174	(0.230)	(0.226)	(0.216)	(0.216)
Demographic						
Age				-0.011	-0.008	-0.010
				(0.019)	(0.018)	(0.018)
Marital status (ever married)				-0.348***	-0.319***	-0.316***
				(0.040)	(0.039)	(0.039)
Education				-0.057***	-0.042**	-0.040**
				(0.012)	(0.011)	(0.011)
Personal income				0.021	0.016	0.011
				(0.011)	(0.011)	(0.010)
Psychosocial						
Tolerance of deviance					0.195***	0.200***
					(0.046)	(0.046)
Risk-taking propensity					0.155***	0.155***
					(0.034)	(0.034)
Physical/verbal hostility					0.346***	0.338***
					(0.041)	(0.041)
Driving exposure						
Vehicle type (passenger car)						-0.082**
						(0.030)
Miles driven						0.0002
						(0.007)
Log-Likelihood	6426.36	6434.27	6433.72	6477.78	6571.17	6574.92

**p* < .05. ***p* < .01. ****p* < .001.

[a]Density is expressed as the number of alcohol establishments per mile of road.

Table 3.3. *Negative Binomial Regression Models of Alcohol Quantity/Frequency With Area Characteristics and Individual Characteristics for Women (n = 1,965)*

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
	B (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)
Area characteristics						
Proportion of rural population	-0.066		-0.237*	-0.188	-0.191*	-0.189*
	(0.074)		(0.099)	(0.097)	(0.095)	(0.095)
Alcohol establishment density[a]		-0.238	-0.595**	-0.675**	-0.647**	-0.635**
		(0.169)	(0.225)	(0.222)	(0.217)	(0.217)
Demographic						
Age				-0.050**	-0.050**	-0.050**
				(0.019)	(0.019)	(0.019)
Marital status (ever married)				-0.308***	-0.260***	-0.267***
				(0.035)	(0.035)	(0.035)
Education				-0.024*	-0.030*	-0.029*
				(0.012)	(0.012)	(0.012)
Personal income				0.034**	0.031*	0.028*
				(0.013)	(0.012)	(0.013)
Psychosocial						
Tolerance of deviance					0.263***	0.269***
					(0.058)	(0.058)
Risk-taking propensity					0.320***	0.312***
					(0.045)	(0.046)
Physical/verbal hostility					0.154**	0.157**
					(0.044)	(0.043)
Driving exposure						
Vehicle type (passenger car)						-0.091*
						(0.038)
Miles driven						0.004
						(0.001)
Log-Likelihood	745.32	745.93	748.82	795.88	861.22	864.12

*$p < .05$. **$p < .01$. ***$p < .001$.

[a]Density is expressed as the number of alcohol establishments per mile of road.

Table 3.4. *Negative Binomial Regression Models of Binge Drinking With Area Characteristics and Individual Characteristics for Men (n = 1,947)*

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	B (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)
Area characteristics						
Proportion of rural population	0.235		-0.075	-0.121	-0.152	-0.137
	(0.180)		(0.247)	(0.246)	(0.236)	(0.235)
Alcohol establishment density[a]		-0.883*	-0.997	-1.140*	-0.974	-0.869
		(0.398)	(0.545)	(0.553)	(0.518)	(0.516)
Demographic						
Age				0.026	-0.003	-0.004
				(0.042)	(0.042)	(0.042)
Marital status (ever married)				-0.616***	-0.595***	-0.602***
				(0.089)	(0.087)	(0.087)
Education				-0.086**	-0.059*	-0.055*
				(0.027)	(0.027)	(0.027)
Personal income				0.008	-0.005	-0.020
				(0.026)	(0.025)	(0.026)
Psychosocial						
Tolerance of deviance					0.580***	0.588***
					(0.111)	(0.111)
Risk-taking propensity					0.422***	0.429***
					(0.080)	(0.081)
Physical/verbal hostility					0.620***	0.579***
					(0.097)	(0.098)
Driving exposure						
Vehicle type (passenger car)						-0.195**
						(0.070)
Miles driven						0.002
						(0.002)
Log-Likelihood	116502.45	116504.03	116504.08	116527.52	116614.70	116619.14

$*p < .05$. $**p < .01$. $***p < .001$.

[a]Density is expressed as the number of alcohol establishments per mile of road.

Table 3.5. *Negative Binomial Regression Models of Binge Drinking With Area Characteristics and Individual Characteristics for Women (n = 1,965)*

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
	B (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)
Area characteristics						
Proportion of rural population	-0.086		-0.487	-0.481	-0.587*	-0.587*
	(0.191)		(0.252)	(0.248)	(0.239)	(0.240)
Alcohol establishment density[a]		-0.672	-1.421*	-1.716**	-1.757**	-1.734**
		(0.454)	(0.588)	(0.597)	(0.566)	(0.563)
Demographic						
Age				-0.126**	-0.122**	-0.123**
				(0.046)	(0.046)	(0.046)
Marital status (ever married)				-0.717***	-0.613***	-0.622***
				(0.087)	(0.084)	(0.084)
Education				-0.004	-0.034	-0.037
				(0.033)	(0.032)	(0.032)
Personal income				0.068*	0.064*	0.055
				(0.031)	(0.030)	(0.031)
Psychosocial						
Tolerance of deviance					0.736***	0.751***
					(0.163)	(0.164)
Risk-taking propensity					0.918***	0.890***
					(0.124)	(0.125)
Physical/verbal hostility					0.408**	0.419**
					(0.113)	(0.114)
Driving exposure						
Vehicle type (passenger car)						-0.109
						(0.097)
Miles driven						0.004
						(0.003)
Log-Likelihood	47195.42	47196.42	47198.25	47239.78	47311.00	47312.62

**p* < .05. ***p* < .01. ****p* < .001.

[a]Density is expressed as the number of alcohol establishments per mile of road.

Table 3.6. *Negative Binomial Regression Models of Drink/Driving With Area Characteristics and Individual Characteristics for Men (n = 1,947)*

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	B (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)
Area characteristics						
Proportion of rural population	0.226		0.014	0.084	0.113	0.111
	(0.147)		(0.192)	(0.189)	(0.179)	(0.179)
Alcohol establishment density[a]		-0.749*	-0.729	-0.902*	-0.879*	-0.774
		(0.325)	(0.426)	(0.423)	(0.400)	(0.400)
Demographic						
Age				-0.001	-0.011	-0.011
				(0.036)	(0.034)	(0.034)
Marital status (ever married)				-0.597***	-0.526***	-0.536***
				(0.076)	(0.074)	(0.074)
Education				-0.027	-0.002	0.003
				(0.023)	(0.022)	(0.022)
Personal income				0.068**	0.068**	0.049*
				(0.021)	(0.020)	(0.021)
Psychosocial						
Tolerance of deviance					0.716***	0.729***
					(0.088)	(0.088)
Risk-taking propensity					0.291***	0.294***
					(0.064)	(0.064)
Physical/verbal hostility					0.424***	0.402***
					(0.078)	(0.078)
Driving exposure						
Vehicle type (passenger car)						-0.112*
						(0.057)
Miles driven						-0.004*
						(0.002)
Log-Likelihood	-141.39	-139.94	-139.94	-107.99	-9.47	-4.69

$*p < .05$. $**p < .01$. $***p < .001$.

[a]Density is expressed as the number of alcohol establishments per mile of road.

Table 3.7. *Negative Binomial Regression Models of Drink/Driving With Area Characteristics and Individual Characteristics for Women (n = 1,965)*

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
	B (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)
Area characteristics						
Proportion of rural population	-0.019		-0.304	-0.156	-0.188	-0.181
	-0.175		(0.231)	(0.228)	(0.220)	(0.220)
Alcohol establishment density[a]		-0.556	-1.022	-1.331*	-1.190*	-1.146*
		-0.412	(0.542)	(0.534)	(0.512)	(0.512)
Demographic						
Age				-0.067	-0.050	-0.043
				(0.046)	(0.045)	(0.045)
Marital status (ever married)				-0.887***	-0.759***	-0.765***
				(0.086)	(0.084)	(0.085)
Education				-0.006	-0.027	-0.032
				(0.029)	(0.029)	(0.029)
Personal income				0.091**	0.086**	0.072*
				(0.030)	(0.030)	(0.030)
Psychosocial						
Tolerance of deviance					0.975***	0.967***
					(0.137)	(0.137)
Risk-taking propensity					0.721***	0.713***
					(0.105)	(0.106)
Physical/verbal hostility					0.301**	0.305**
					(0.103)	(0.104)
Driving exposure						
Vehicle type (passenger car)						0.019
						(0.092)
Miles driven						0.006*
						(0.003)
Log-Likelihood	-1327.53	-1326.63	-1325.76	-1267.04	-1179.92	-1177.21

**p* < .05. ***p* < .01. ****p* < .001.

[a]Density is expressed as the number of alcohol establishments per mile of road.

Table 3.8. *Change in Area Characteristics Odds Ratios (and 95% Confidence Intervals) for Multinomial Logistic Models Predicting the Likelihood of Alcohol-Related Crash and Crash (Not Alcohol-Related) for Men (n = 1,947)*

		-2 Log Likelihood	Proportion of rural population				Alcohol establishment density[a]			
			Crash (alcohol-related)		Crash (not alcohol-related)		Crash (alcohol-related)		Crash (not alcohol-related)	
			Odds ratio	95% Confidence interval	Odds ratio	95% Confidence interval	Odds ratio	95% Confidence interval	Odds ratio	95% Confidence interval
Model 1	Proportion of rural population	3294.66	2.931*	[1.078, 7.972]	0.927	[0.594, 1.446]				
Model 2	Alcohol establishment density	3287.79					0.014***	[0.001, 0.169]	0.731	[0.269, 1.989]
Model 3	Area characteristics together	3286.86	0.802	[0.200, 3.224]	0.752	[0.420, 1.347]	0.01**	[<0.001, 0.300]	0.483	[0.130, 1.798]
Model 4	Age, marital status, education, personal income	3253.40	0.889	[0.215, 3.681]	0.775	[0.431, 1.393]	0.009**	[<0.001, 0.294]	0.533	[0.142, 2.003]
Model 5	Age, marital status, education, personal income, psychosocial driving exposure	3231.45	0.762	[0.179, 3.251]	0.782	[0.434, 1.409]	0.010*	[<0.001, 0.375]	0.639	[0.169, 2.419]
Model 6	Age, marital status, education, personal income, psychosocial driving exposure, drinking behaviors	3209.84	0.821	[0.187, 3.599]	0.767	[0.425, 1.384]	0.014*	[<0.001, 0.576]	0.596	[0.156, 2.272]

Note: Reference category for the equation is 'No Crash'
$^*p < .05$. $^{**}p < .01$. $^{***}p < .001$.
[a]Density is expressed as the number of alcohol establishments per mile of road.

Table 3.9. *Odds Ratios (and 95% Confidence Intervals) for Final Multinomial Logistic Model Predicting the Likelihood of Alcohol-Related Crash and Crash (Not Alcohol-Related) for Women (n = 1,965)*

	Crash (alcohol-related)		Crash (not alcohol-related)	
	Odds ratio	95% Confidence interval	Odds ratio	95% Confidence interval
Area characteristics				
Proportion of rural population	1.040	[0.044, 14.541]	1.246	[0.616, 2.504]
Alcohol establishment density[a]	15.695	[0.096, >999.999]	0.698	[0.193, 2.504]
Demographic				
Age	1.352	[0.866, 2.088]	1.067	[0.951, 1.198]
Marital status (ever married)	1.247	[0.509, 2.855]	0.791*	[0.639, 0.978]
Education	0.987	[0.741, 1.332]	0.962	[0.892, 1.038]
Personal income	1.140	[0.847, 1.523]	1.045	[0.966, 1.130]
Psychosocial				
Tolerance of deviance	0.631	[0.136, 2.482]	0.829	[0.561, 1.221]
Risk-taking propensity	1.150	[0.686, 1.890]	1.103	[0.879, 1.384]
Physical/verbal hostility	1.021	[0.361, 2.736]	1.019	[0.770, 1.349]
Drinking behaviors				
Alcohol quantity/frequency	1.356***	[1.147, 1.600]	0.999	[0.944, 1.056]
Binge drinking	0.982*	[0.959, 0.999]	1.002	[0.997, 1.007]
Drink/driving	1.234*	[1.045, 1.449]	1.002	[0.937, 1.070]
Driving exposure				
Vehicle type (passenger car)	1.084	[0.452, 3.041]	1.041	[0.817, 1.330]
Miles driven	1.000	[1.000, 1.000]	1.000	[1.000, 1.000]

Note: Reference category for the equation is 'No Crash'
**p* < .05. ***p* < .01. ****p* < .001.
[a]Density is expressed as the number of alcohol establishments per mile of road.

REFERENCES

Aiken, L. S., & West, S. G. (1991). *Multiple regression: Testing and interpreting interactions*. Thousand Oaks, CA: Sage.

Alexander, S. M. (2003). Stylish hard bodies: Branded masculinity in men's health magazine. *Sociological Perspectives, 46*(4), 535-554.

Allison, P. D. (2002). *Missing data*. Thousand Oaks, CA: Sage.

American Association for Public Opinion Research. (2000). *Standard definitions: Final dispositions of case codes and outcome rates for surveys*. Retrieved May 10, 2007, from http://www.aapor.org/pdfs/standarddefs_4.pdf.

Anselin, L., Syabri, I., & Kho, Y. (2006). GeoDa: An introduction to spatial data analysis. *Geographical Analyses*, 38(1), 5-22.

Beel, A. & Stockwell, T. (1995). *The impact of Western Australia's 0.05 legislation on drivers' attitudes, perceptions, and behaviors*. Bentley, Western Australia: Curtin University of Technology.

Bingham, C. R., Elliott, M. R., & Shope, J. T. (2007). Social and behavioral characteristics of young adult drink/drivers adjusted for level of alcohol use. *Alcoholism: Clinical and Experimental Research, 31*(4), 655-664.

Bingham, C. R., Shope, J. T., & Tang, X. (2005). Drinking behavior from high school to young adulthood: Differences by college education. *Alcoholism: Clinical and Experimental Research, 29*(12), 2170-2180.

Bingham, C. R., Shope, J. T., Zakrajsek, J., & Raghunathan, T.E. (2008). Problem driving behavior and psychosocial maturation in young adulthood. *Accident Analysis & Prevention, 40*(5), 1758-1764.

Blatt, J., & Furman, S. M. (1998). Residence location of drivers involved in fatal crashes. *Accident Analysis & Prevention, 30*(6), 705-711.

Blose, J. O., & Holder, H. D. (1987). Liquor-by-the-drink and alcohol-related traffic crashes: A natural experiment using time-series analysis. *Journal of Studies on Alcohol, 48*(1), 52-60.

Borders, T. F., & Booth, B. M. (2007). Rural, suburban, and urban variations in alcohol consumption in the United States: Findings from the national epidemiologic survey on alcohol and related conditions. *Journal of Rural Health, 23*(4), 314-321.

Borgialli, D. A., Hill, E. M., Maio, R. F., Compton, C. P., & Gregor, M. A. (2000). Effects of alcohol on the geographic variation of driver fatalities in motor vehicle crashes. *Academic Emergency Medicine, 7*(1), 7-13.

Brady, J. E., & Weitzman, B. C. (2007). Inconsistencies in place definition: How different operational place definitions affect estimates of adolescent smoking and drinking risk. *Health & Place, 13*(2), 562-568.

Chen, C. M., Durfour, M. C., & Yi, H. Y. (2005). Alcohol consumption among young adults ages 18-24 in the United States: Results from the 2001-2002 NESARC survey. *Alcohol Research & Health, 28*(4), 269-280.

Chou, S. P., Dawson, D. A., Stinson, F. S., Huang, B. J., Pickering, R. P., Zhou, Y., & Grant, B. F. (2006). The prevalence of drinking and driving in the United States, 2001-2002: Results from the national epidemiological survey on alcohol and related conditions. *Drug and Alcohol Dependence, 83*(2), 137-146.

Colón, I. (1982). The influence of state monopoly of alcohol distribution and the frequency of package stores on single motor vehicle fatalities. *American Journal of Drug Abuse* (9), 325-331.

Colón, I., & Cutter, H.S. (1983). The relationship of beer consumption and state alcohol and motor vehicle policies to fatal accidents. *Journal of Safety Research, 14*(2), 83-89.

Cummins, S., Curtis, S., Diez-Roux, A. V., & Macintyre, S. (2007). Understanding and representing 'place' in health research: A relational approach. *Social Science & Medicine, 65*(9), 1825-1838.

Damkot, D. K. (1979). Alcohol and the rural driver. *Currents in Alcoholism, 6*, 319-325.

Diez-Roux, A. V. (1998). Bringing context back into epidemiology: Variables and fallacies in multilevel analysis. *American Journal of Public Health, 88*(2), 216-222.

Donovan, J. E. (1993). Young adult drink-driving: Behavioral and psycho-social correlates. *Journal Studies of Alcohol, 54*(5), 600-613.

Dunsire, M., & Baldwin, S. (1999). Urban-rural comparisons of drink-driving behaviour among late teens: A preliminary investigation. *Alcohol and Alcoholism, 34*(1), 59-64.

Earp, J. A., & Ennett, S. T. (1991). Conceptual models for health education research and practice. *Health Education Research, 6*(2), 163-171.

Elliott, M. R., Shope, J. T., Raghunathan, T. E., & Waller, P. F. (2006). Gender differences among young drivers in the association between high-risk driving and substance use. *Journal of Studies on Alcohol, 67*(2), 252-260.

Elliott, M. R., Waller, P. F., Raghunathan, T. E., Shope, J. T., & Little, R. J. A. (2000). Persistence of violation and crash behavior over time. *Journal of Safety Research, 31*(4), 229-242.

Energy Information Administration. (2005). *Household vehicles energy use: Latest data and trends* (DOE/EIA-0464). Washington, DC: U.S. Department of Energy. Retrieved November 11, 2007, fromhttp://www.eia.doe.gov/emeu/rtecs/nhts_survey/2001/index.html

Featherstone, M. (2004). Automobilities: An introduction. *Theory Culture & Society, 21*(4-5), 1- 24.

Gruenewald, P. J. (2007). The spatial ecology of alcohol problems: Niche theory and assortative drinking. *Addiction (Abingdon, England), 102*(6), 870.

Gruenewald, P. J., Johnson, F. W., & Treno, A. J. (2002). Outlets, drinking and driving: A multilevel analysis of availability. *Journal of Studies on Alcohol, 63*(4), 460-468.

Gruenewald, P. J., & Ponicki, W. R. (1995). The relationship of the retail availability of alcohol and alcohol sales to alcohol-related traffic crashes. *Accident Analysis & Prevention, 27*(2), 249-259.

Gruenewald, P. J., Remer, L., & Lipton, R. (2002). Evaluating the alcohol environment: Community geography and alcohol problems. *Alcohol Research & Health, 26*(1), 42-48.

Heeren, T., Smith, R. A., Morelock, S., & Hingson, R. W. (1985). Surrogate measures of alcohol involvement in fatal crashes: Are conventional indicators adequate? *Journal of Safety Research, 16*(3), 127-134.

Jackson, J. E., Doescher, M. P., & Hart, L. G. (2006). Problem drinking: Rural and urban trends in America, 1995. *Preventive Medicine, 43*(2), 122-124.

Jewell, R. T., & Brown, R. W. (1995). Alcohol availability and alcohol-related motor-vehicle accidents. *Applied Economics, 27*(8), 759-765.

Jones, R. K., & Lacey, J. H. (2001). *Alcohol and highway safety 2001: A review of the state of knowledge* (NHTSA DOT HS-809-383). Washington, DC: U.S. Department of Transportation.

Kmet, L., Brasher, P., & Macarthur, C. (2003). A small area study of motor vehicle crash fatalities in Alberta, Canada. *Accident Analysis & Prevention, 35*(2), 177-182.

Krieger, N., Chen, J. T., Waterman, P. D., Soobader, M. J., Subramanian, S. V., & Carson, R. (2002). Geocoding and monitoring of US socioeconomic inequalities in mortality and cancer incidence: Does the choice of area-based measure and geographic level matter? The Public Health Disparities Geocoding Project. *American Journal of Epidemiology, 156*(5), 471-482.

Lang, E., & Stockwell, T. (1991). Drinking locations of drunk-drivers: A comparative analysis of accident and nonaccident cases. *Accident Analysis & Prevention, 23*(6), 573-584.

Meliker, J. R., Maio, R. F., Zimmerman, M. A., Kim, H. M., Smith, S. C., & Wilson, M. L. (2004). Spatial analysis of alcohol-related motor vehicle crash injuries in southeastern Michigan. *Accident Analysis & Prevention, 36*(6), 1129-1135.

Michigan November 2006 licensed alcohol establishments. (2006). Lansing, MI: Michigan Liquor Control Commission. Retrieved November 11, 2006, from http://www.michigan.gov/cis/0,1607,7-154-10570_12905---,00.html

Mohai, P., & Saha, R. (2006). Reassessing racial and socioeconomic disparities in environmental justice research. *Demography, 43*(2), 383.

National Highway Traffic Safety Administration, National Center for Statistics and Analysis. (2008). *Traffic safety facts 2006: Alcohol-impaired driving* (DOT HS 810 801). Washington, DC: U.S. Department of Transportation. Retrieved October 2, 2008, from http://www-nrd.nhtsa.dot.gov/Pubs/810801.PDF

National Institute on Alcohol Abuse and Alcoholism. (2004, Winter). NIAAA Council approves definition of binge drinking. *NIAAA Newsletter, 3*, 3.

Nolen-Hoeksema, S. (2004). Gender differences in risk factors and consequences for alcohol use and problems. *Clinical Psychology Review, 24*(8), 981-1010.

Patil, S. M., Shope, J. T., Raghunathan, T. E., & Bingham, C. R. (2006). The role of personality characteristics in young adult driving. *Traffic Injury Prevention*, 7(4), 328-334.

Quinlan, K. P., Brewer, R. D., Siegel, P., Sleet, D. A., Mokdad, A. H., et al. (2005). Alcohol-impaired driving among U.S. adults, 1993-2002. *American Journal of Preventive Medicine, 28*(4), 346-350.

Romley, J. A., Cohen, D., Ringel, J., & Sturm, R. (2007). Alcohol and environmental justice: The density of liquor stores and bars in urban neighborhoods in the United States. *Journal of Studies on Alcohol, 68*(1), 48-55.

Saporito, S., Chavers, J. M., Nixon, L. C., & McQuiddy, M. R. (2007). From here to there: Methods of allocating data between census geography and socially meaningful areas. *Social Science Research, 36*(3), 897-920.

Scribner, R. A., Mackinnon, D. P., & Dwyer, J. H. (1994). Alcohol outlet density and motor-vehicle crashes in Los Angeles county cities. *Journal of Studies on Alcohol, 55*(4), 447-453.

Shope, J. T., Copeland, L. A., Kamp, M. E., & Lang, S. W. (1998). Twelfth grade follow-up of the effectiveness of a middle school-based substance abuse prevention program. *Journal of Drug Education, 28*(3), 185-197.

Shope, J. T., Copeland, L. A., Maharg, R., & Dielman, T. E. (1996). Effectiveness of a high school alcohol misuse prevention program. *Alcoholism: Clinical and Experimental Research, 20*(5), 791-798.

Shope, J. T., Copeland, L. A., Marcoux, B. C., & Kamp, M. E. (1996). Effectiveness of a school-based substance abuse prevention program. *Journal of Drug Education, 26*(4), 323-337.

Shope, J. T., Dielman, T. E., Butchart, A. T., & Campanelli, P. C. (1992). An elementary school-based alcohol misuse prevention program: Follow-up evaluation. *Journal Studies of Alcohol, 53,* 106-120.

Smart, R. G., & Docherty, D. (1976). Effects of introduction of on-premise drinking on alcohol-related accidents and impaired driving. *Journal of Studies on Alcohol*, 37(5), 683-686.

Substance Abuse and Mental Health Services Administration. (2005). *Driving under the influence among adult drivers*. Washington, DC: Office of Applied Studies. Retrieved October 15, 2008, from http://www.oas.samhsa.gov/2k5/DUI/DUI.pdf

Treno, A. J., Grube, J. W., & Martin, S. E. (2003). Alcohol availability as a predictor of youth drinking and driving: A hierarchical analysis of survey and archival data. *Alcoholism: Clinical and Experimental Research, 27*(5), 835-840.

U.S. Census Bureau (2002). Urban and rural classification. Retrieved May 9, 2006, from http://www.census.gov/geo/www/ua/ua_2k.html

VanOers, J. A. M., & Garretsen, H. F. L. (1993). The geographic relationship between alcohol use, bars, liquor shops and traffic injuries in Rotterdam. *Journal of Studies on Alcohol, 54*(6), 739-744.

Voas, R. B., Wells, J., Lestina, D., Williams, A., & Greene, M. (1998). Drinking and driving in the United States: The 1996 National Roadside Survey. *Accident Analysis & Prevention, 30*(2), 267-275.

Waller, L. A., & Gotway, C. A. (2004). *Applied spatial statistics for public health data*. New York: John Wiley & Sons.

Wechsler, H., & Nelson, T. F. (2001). Binge drinking and the American college student: What's five drinks? *Psychology of Addictive Behaviors, 15*(4), 287-291.

CHAPTER 4

DRIVERS' PERCEPTION OF DRINK/DRIVING AS DANGEROUS: SOCIAL INFLUENCES AND AREA CHARACTERISTICS

INTRODUCTION

A drink/driver is someone who drinks prior to or while driving a motor vehicle (Jones & Lacey, 2001), but what influences a person to drink/drive? According to some literature, the decision to drink/drive may be influenced by the driver's perceived risk of engaging in the behavior. There are several predictors of perceived risk of drink/driving, such as a person's history of excessive alcohol use and alcohol-related problems as well as their social influences, defined as the interpersonal influences of friends and family (Bingham, Elliott, & Shope, 2007; Jones & Lacey, 2001).

Drink/driving behavior is a public health problem because it poses a threat to human life and property. In 1982, approximately 50% of drivers involved in a motor vehicle fatality had a blood alcohol concentration (BAC) of 0.10 g/dL or higher (Jones & Lacey, 2001). By 1998, this proportion had dropped to 39% (Jones & Lacey, 2001). Although this apparent downward trend was promising, recent reports show that the declining alcohol-related fatality rates may have flattened out (Jones & Lacey, 2001; National Highway Traffic Safety Administration [NHTSA], 2008a). Meanwhile, alcohol-related crashes continue to constitute an enormous economic cost to the United States ($50.9 billion in 2000), accounting for 22% of all traffic costs (Blincoe et al., 2002). To understand how to reduce the impact of drink/driving and to improve upon the historic reductions, there is a need to identify factors associated with drink/driving.

One potential line of inquiry lies in a small body of research that found that drink/drivers have a lower perceived risk regarding the consequences of drink/driving than drivers who do not drink/drive (Albery & Guppy, 1995; Bingham, Elliott, & Shope, 2007; Guppy, 1993; Yu & Williford, 1993). For example, Albery and Guppy (1995) showed that drivers reporting previous drink/driving behavior also reported approximately three times lower perceived risk of apprehension due to alcohol impairment and approximately seven times lower perceived risk of involvement in an alcohol-related crash.

A driver's perceived risk of drink/driving may be positively associated with such factors as a history of excessive alcohol use, previous episodes of drink/driving, and social influences that are accepting of drink/driving and negatively associated with a history of crashes. Drivers with an alcohol problem are more likely to drink/drive and do so at higher BACs than drivers without an alcohol problem (Jones & Lacey, 2001). Additionally, research has suggested that drivers' social influences (e.g., family and friends) are also predictors of their drink/driving behavior (Bingham, Elliott, & Shope, 2007; Gulliver & Begg, 2004; Leadbeater, Foran, & Grove-White, 2008; Rice, Carr-Hill, Dixon, & Sutton, 1998). Young adults who perceived that their friends supported drink/driving were more likely to drink/drive, controlling for other factors including individual alcohol use (Bingham, Elliott, & Shope, 2007). Finally, men with a history of any crash (i.e., alcohol- or non-alcohol-related) at age 18 years were less likely to be involved in drink/driving behavior at 21 years (Gulliver & Begg, 2004).

Many of the demographic factors associated with risk perception are also associated with drinking behaviors. These factors include age, sex, marital status, education, personal income, and psychosocial factors. Predictors of more excessive drinking behaviors include younger age, being male, being unmarried, having less than a high school education, and earning less income (Jones & Lacey, 2001; Karlamangla, Zhou, Reuben, Greendale, & Moore, 2006). Research has identified the opposite factors as associated with greater perceived risk, for example, older age, being female, being married, and having more education (Dionne, Fluet, & Desjardins, 2007; Zador, 1991; Zador, Krawchuk, & Voas, 2000).

Recently, there has been a growing interest in the subject of social influences on driving behaviors. In general, the statistical strength and direction of the influences of social factors depends on the driving behavior being studied as well as the specific social factor involved. For example, parents' driving behavior has been found to be associated with children's driving behavior (Ben-Ari, Mikulincer, & Gillath, 2005); specifically, a teen whose parent had a history of traffic offenses was more likely to also have a traffic offense. Social influences on a driver's perceived risk of drink/driving could also include knowing someone who has been breath tested (Leadbeater, Foran, & Grove-White, 2008) or riding with an alcohol-impaired adult (Gulliver & Begg, 2004). Gulliver and Begg (2004) found that New Zealand adolescents were more likely to have lower perceived risk of drink/driving after riding with an impaired adult. This study examines specific driving behaviors (i.e., drink/driving) and the social approval of parents and peers of drink/driving behaviors.

Another promising line of research explores the relationship between area characteristics and a driver's perceptions of drink/driving as dangerous. Some studies have suggested that areas with less population density or fewer alcohol establishments have more alcohol use (see Chapter 3), alcohol-related crashes (Meliker et al., 2004), and alcohol-related motor vehicle fatalities than urban areas (Maio, Burney, Gregor, & Baranski, 1996; Maio, Green, Becker, Burney, & Compton, 1992; NHTSA, 2008b). Few studies have examined the possible influence of both the area characteristics and the social approval of parents and peers of drink/driving behaviors on the perceptions of drink/driving as dangerous. Thus, this research examines the relationships among the social (i.e., social approval for drink/driving) and area (i.e., rural population and alcohol establishment density) characteristics and drivers' perceptions of drink/driving as dangerous, while adjusting for individual characteristics.

CONCEPTUAL MODEL

The conceptual model (see Figure 4.1) posits how area, social, and individual characteristics may influence an individual's perception of drink/driving as dangerous. Perception of drink/driving as dangerous is defined in this paper as an individual's assessment of the probability of negative drink/driving outcomes due to a particular choice or behavior (Slovic, 2000). These individual perceptions are influenced by many factors, such as drinking behaviors (i.e., excessive alcohol use, prior drink/driving), any prior alcohol-related offenses and crashes, social influences, and area characteristics.

Relationships among the different constructs are shown in Figure 4.1, with solid lines representing consistent relationships established by previous research and dashed lines representing factors and mechanisms relating to the current research questions. Whereas other health models (e.g., the Health Belief Model) suggest that perceived risk should precede health behavior, this conceptual model proposes the opposite relationship as a way to explain the development of drink/driving behavior as a process (Brown, 2005). The conceptual model proposes that among young adults, risk perceptions are associated with past drinking and drink/driving behaviors (Jones & Lacey, 2001). A driver's perception of drink/driving as dangerous may be partly explained by social influences (i.e., social approval for drink/driving) and negative consequences (i.e., alcohol-related crashes) from prior drink/driving experiences.

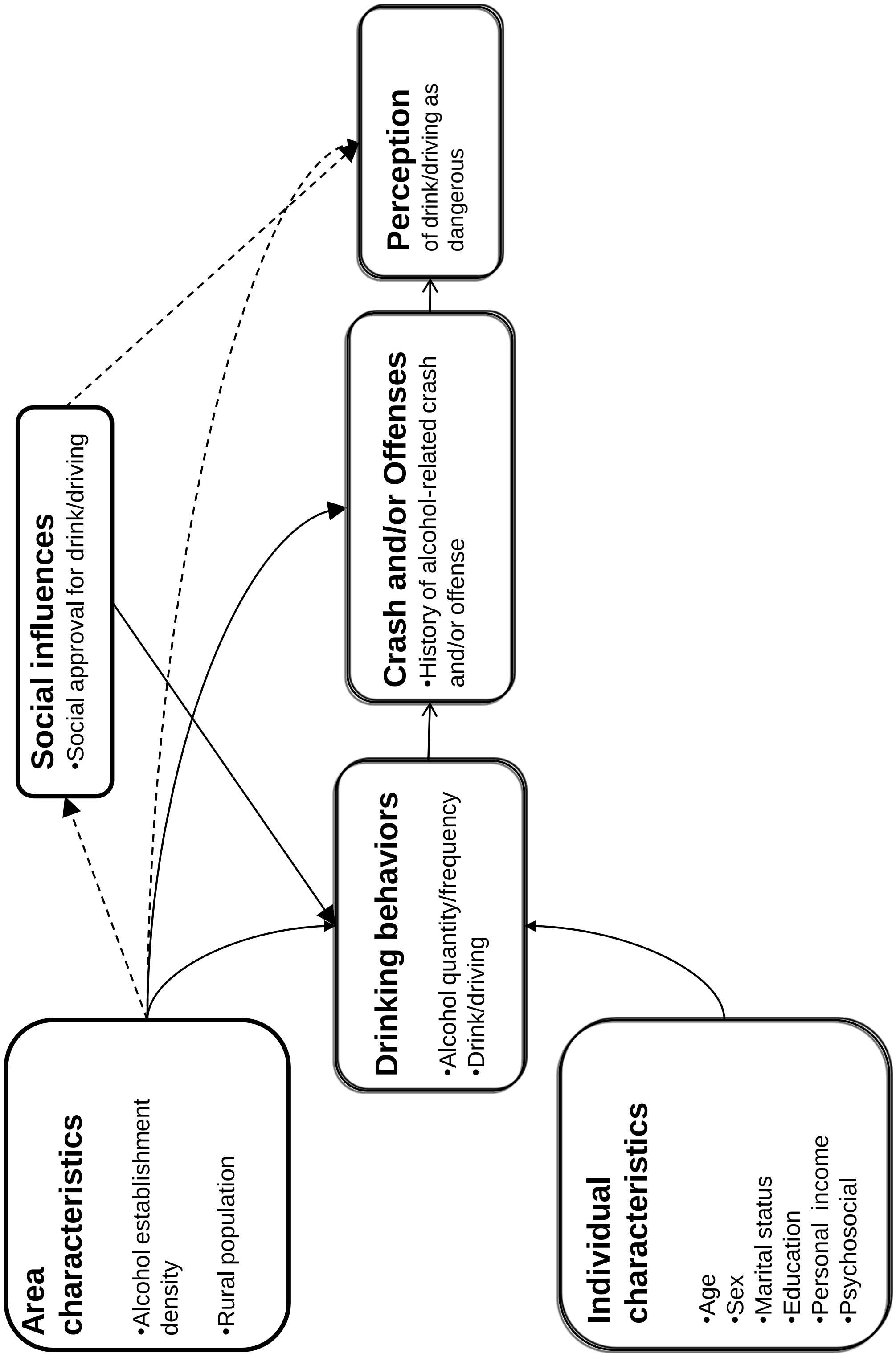
However, there are drivers who perceive drink/driving as dangerous, even though they have never engaged in drink/driving or experienced negative drink/driving consequences. The conceptual model seeks to clarify the role of alcohol-related crashes and/or offenses in relation to a driver's perceived risk of drink/driving as dangerous.

Furthermore, prior research demonstrated that the inverse association between alcohol establishments and alcohol-related crashes in Michigan could partly be explained by greater alcohol use and misuse in areas with less establishments in comparison with those with more alcohol establishments (see Chapter 3). However, the reason for more alcohol use and drink/driving in areas with fewer alcohol establishments is unclear. One possibility is that young adults may perceive drink/driving as less dangerous in areas with fewer alcohol establishments. Therefore, the conceptual model proposes that area characteristics are associated with young adult perceptions of drink/driving as dangerous and examines the impact of social approval for drink/driving of parents and peers on young adults' perception of drink/driving as dangerous.

RESEARCH QUESTIONS

1. Are area characteristics (i.e., alcohol establishment density and proportion of rural population) associated with young adult perceptions of drink/driving as dangerous, while adjusting for individual characteristics, drinking behaviors, and crashes and or/offenses?
2. Does social approval for drink/driving mediate the relationship between area characteristics and young adults' perceived danger of drink/driving, while adjusting for individual characteristics, drinking behaviors, and crashes and/or offenses.

Figure 4.1. Conceptual model outlining proposed relationships among area characteristics, individual characteristics, social influences, and young adult perceptions of drink/driving as dangerous. (*Solid lines represent consistent associations based on previous research and dashed lines represent associations under investigation.)*



METHODS

Sample and Survey

*Data sources: Individual characteristics***.** Data used in these secondary analyses are cross sectional in nature and came from a study titled "Psychosocial Correlates of Adolescent Driving Behavior" conducted by the University of Michigan Transportation Research Institute. These data are part of an ongoing longitudinal study that began in 1984. Additional details on the original school-based substance use intervention studies are provided elsewhere (Shope, Copeland, Kamp, & Lang, 1998; Shope, Copeland, Maharg, & Dielman, 1996a; Shope, Copeland, Marcoux, & Kamp, 1996b; Shope, Dielman, Butchart, & Campanelli, 1992).

All respondents who had participated in previous school surveys were eligible for this study if they held a Michigan driver's license or personal state identification. Addresses of eligible participants were obtained from the Michigan Department of State. Participants in the earlier school surveys were students attending southeast Michigan public schools and did not necessarily represent the statewide population. However, the young adults who participated in the school surveys and individuals from the same Michigan birth cohorts have been shown to have comparable frequencies of driving offenses and crashes (Elliott, Waller, Raghunathan, Shope, & Little, 2000).

A telephone survey was conducted over 4 years; the cross-sectional data used in this analysis were chosen because respondents were in their early 20's (N = 5,464; mean age = 23.5 years), an age group characterized by the highest rates of drink/driving (NHTSA, 2008a). Tracking and interviewing for the original longitudinal study began in November 1997 and continued through January 2000. The response rate of the original eligible sample was 58.5% (using definition Response Rate 5 from the American Association for Public Opinion Research, 2000). Survey completion took approximately 30 minutes, and respondents received $15 for their participation.

Outcome Measure: Perceived Risk of Drink/Driving as Dangerous

Perceived risk of drinking/driving was assessed by one item that asked respondents "how dangerous do you think it would be for a man or woman to drive within an hour of having 3 (if male) or 2 (if female) alcohol drinks?" Responses were coded 1 = *very dangerous*, 2 = *somewhat dangerous*, 3 = *a little dangerous*, and 4 = *not at all dangerous*. The item was reverse coded so that a higher score represents a higher perceived risk. This item was developed for the "Psychosocial Correlates of Adolescent Driving Behavior" study.

Predictor Measures: Area Characteristics

Alcohol establishment density. A file of 16,013 licensed alcohol establishments in Michigan was obtained in November 2006 from the Michigan Liquor Control Commission (MLCC) website and geocoded.[24] For the purposes of this research, alcohol establishment density was measured by the number of alcohol establishments per mile of road, which captures how alcohol is accessed by drivers using the road network. Roadway miles were measured using Michigan road data files (i.e., shapefiles)

[24]To generate a geocoded address, each business address was inputted and translated into a point on a map with a score (from 0 = *no match* to 100 = *perfect match*) showing how successfully addresses matched to a reference street map. Of 16,013 business addresses, 14,485 (90%) were matched with scores from 70 to 100; 423 (3%) addresses were matched with a score less than 70 but greater than 0; and 1,105 (7%) addresses were considered unmatched. Unmatched addresses were manually cleaned, or geocoded according to zip code centroid, and indexed.

obtained from the 2004 Michigan Geographic Data Library version 6b. The density of alcohol establishments per mile of road was aggregated to the census tract level. Alcohol establishment density was dichotomized by a cut-off point chosen based on the Michigan state-wide mean of alcohol establishments per mile of road.

Proportion of rural population. The U.S. Census Bureau defines rural in relation to urban. Urban consists of "core census block groups or blocks that have a population density of at least 1,000 people per square mile and surrounding census blocks that have an overall density of at least 500 people per square mile" (U.S. Census Bureau, 2002, p. 1). Rural population consists of the population that is not classified as urban. Because census block groups and blocks are smaller than census tracts, there could be portions of a census tract with a rural population. Rural population for this study was defined as the proportion of a census tract population that was rural divided by the total census tract population. The square root transformation of the proportion of rural population was used in multivariate regression analyses because it provided a better fit.[25] Proportion of rural population was dichotomized based on a cut-off point chosen based on the Michigan state-wide median.

Estimating respondents' exposure to area characteristics. To create a measure of individualized exposure to area characteristics, each survey respondent's residential address at the time of the telephone survey was geocoded using a computer program called ArcView 9.1. Geocoding is a process in which physical addresses (e.g.,

[25]Proportion of rural population exhibited positive skewness (2.15) and positive kurtosis (5.69). Square root transformation resulted in a relatively normal distribution (skewness = 0.50 and kurtosis = 0.20). The transformation was verified by plot examinations of residuals versus predicted values.

residential) are assigned a latitude and longitude.[26] To estimate an individual's exposure to area characteristics, a circular buffer was created around each respondent's address with a radius of 12.1 miles because this is the average one-way vehicle trip length to and from work, as determined by the 2001 National Household Travel Survey (Energy Information Administration, 2005). Because area characteristics were measured at the census tract level, the areal apportionment method was used to allocate data between census geography and the 12.1-mile buffers to create an individualized exposure estimate for each survey respondent (Cummins, Curtis, Diez-Roux, & Macintyre, 2007; Mohai & Saha, 2006; Saporito, Chavers, Nixon, & McQuiddy, 2007).[27]

Additional Covariates- Individual Characteristics, Drinking Behaviors, and Crashes and/or Offenses

Information on individual characteristics (age, sex, marital status, education, personal income, psychosocial characteristics) and drinking behaviors (alcohol

[26]Each survey respondent's residential address was geocoded using the same procedure as for the alcohol establishments. Of 5,464 respondent addresses, 5,026 (92%) were matched with scores from 80 to 100; 268 (5%) addresses were matched with a score less than 80 but greater than 0; and 170 (3%) addresses were considered unmatched. Addresses with a score less than 80 and unmatched geocoded records were manually cleaned. For example, some unmatched geocoded records represented post office box addresses (n = 35), which were mostly found in rural areas. If these records had not been manually processed, a bias against rural areas could have been introduced. In these cases, the software assigned a latitude and longitude point in the middle (or centroid) of the respondent's zip code (Krieger et al., 2002).

[27]An ArcGIS version 9.2 tool called Spatial Overlay was used to extract census tract data from one layer and join it to the buffer layer. In other words, for one buffer (representing a survey respondent), there are data from multiple and partial census tracts. SAS version 9.1 and the areal apportionment method were used to calculate an individual's exposure for each buffer. The areal apportionment method formula allocates data between census geography and the respondent's buffer, where an area environmental characteristic (c_i) is weighted by population (p_i) and proportion of area (a_i/A_i) of the census tract captured by the buffer (Mohai & Saha, 2006). An individualized exposure estimate (C) was obtained by summing the allocated census tract data captured by each buffer.

quantity/frequency and drink/driving) was obtained during the telephone interview and will be used as covariates in the analyses. In addition, each individual's history of vehicle crashes and/or offenses was also obtained and will be included in the analyses as an additional covariate.

Individual Characteristics

Demographic variables. Age, education, personal income, marital status, and sex are included in this study. Age was calculated by subtracting a respondent's date of birth from the date of interview. Education was determined by asking respondents to report the highest grade in school completed (categorized as 1 = *less than eighth grade*, 2 = *finished eighth grade*, 3 = *some high school*, 4 = *graduated high school*, 5 = *graduated technical or trade school*, 6 = *some college*, 7 = *graduated college*, 8 = *some graduate or professional school*, and 9 = *earned a postgraduate degree*). Personal income was coded 1 = *under $5,000*, 2 = *$5,000 to $14,999*, 3 = *$15,000 to $24,999*, 4 = *$25,000 to $34,999*, 5 = *$35,000 to $44,999*, 6 = *$45,000 to $54,999*, and 7 ≥ *$55,000*. Marital status was reported as 1 = *currently married*, 2 = *separated*, 3 = *divorced*, 4 = *widowed*, or 5 = *never married*. Marital status was recoded to a dichotomous variable, *ever married*, which includes married, separated, divorced, or widowed, versus *never married*.

Psychosocial variables. Individual-level psychosocial variables were selected for their relevance to driving behaviors and their past performance as predictors. Tolerance of deviance (TOD) was a 10-item measure asking respondents to rate the wrongness of specific behaviors: "to give a fake excuse for missing work, not showing up for a meeting, or cutting class," "to damage public or private property on purpose," "to start a fight and hit someone," "to give false information when filling out a job or loan application," "to shoplift something of value from a store," "to start an argument and insult the other person even though it isn't really called for," "to damage something of value because you are angry with the person it belongs to," "to write a check even though you know it might bounce," "to lie to people close to you to cover up something you did," and "to take things of value that do not belong to you" (Donovan, 1993; α = 0.81). Each TOD item was coded 1 = *very wrong*, 2 = *wrong*, 3 = *a little wrong*, or 4 = *not at all wrong*. An overall score was calculated by averaging the responses to all 10 items. A higher score indicated greater TOD. Respondents missing responses for three or more of the 10 items were assigned a missing value for the measure.

Risk-taking propensity was a four-item measure (Donovan, 1993; α = 0.77). Participants were asked to rate how well the following statements described them, "I'd do almost anything on a dare," "I enjoy the thrill I get when I take risks," "I like to live dangerously," and "I like to take chances even when the odds are against me." Responses for each item were coded 1 = *not at all like me*, 2 = *a little like me*, or 3 = *a lot like me*. An overall score was calculated by averaging responses to the four items with a higher score indicating greater risk-taking propensity. Respondents missing responses for one or more of the four items were assigned a missing value for the measure.

Physical/verbal hostility (Donovan, 1993; α = 0.63) was a seven-item measure asking participants to rate how well the following statements described them: "I don't think there is ever a good reason for hitting anyone," "If people annoy me, I let them know exactly what I think of them," "I like to argue with other people just to get them annoyed," "If I have to use force to defend my rights, I will," "When I get angry at someone, I often say really nasty things," "When I really lose my temper, I've been known to hit or slap someone," and "If people push me around, I hit back." Responses to each item were coded 1 = *not at all like me*, 2 = *a little like me*, or 3 = *a lot like me*. After reverse coding one item (“I don’t think there is ever a good reason for hitting anyone”), an overall score was calculated by averaging responses to the seven items such that higher scores indicated greater hostility. Respondents missing responses to one or more of the seven items were assigned a missing value for the measure.

Drinking behaviors

Two measures of drinking behavior were used in this study: alcohol quantity/frequency and drink/driving. Respondents’ quantity/frequency of alcohol consumption was a product of two survey items: quantity and frequency of alcohol consumption. Quantity of alcohol consumption asked how many drinks containing alcohol respondents had on a typical drinking day, with responses coded from 1 = *1 to 2 drinks*, 2 = *3 or 4 drinks*, 3 = *5 or 6 drinks*, 4 = *7 to 9 drinks*, to 5 = *10 or more drinks*. Frequency of alcohol consumption asked how often respondents had a drink containing alcohol, with responses coded 1 = *never*, 2 = *once a month or less*, 3 = *2 to 4 times a month*, 4 = *2 to 3 times a week*, and 5 = *4 or more times a week*. A missing value on either item resulted in a missing value for the measure (Bingham, Elliott, & Shope, 2007).

Drink/driving included 5 items that asked how many times in the last 12 months did the respondent, “drive within an hour of having 1 or 2 beers or other alcoholic beverages,” “drive within an hour of having 3 or more beers or other alcoholic beverages,” “drive while [they] felt high or light-headed from drinking,” “drive when [they] knew drinking had affected [their] coordination,” and “drink while driving a car” (Donovan, 1993; $\alpha = 0.94$). The responses for each of the five items were collapsed into 14 ordinal categories (range 0–13), and a scale score was calculated by averaging across items, so that a higher score represented more frequent drink/driving behavior. Respondents missing responses for two or more of the five items were assigned a missing value for the measure.

Crashes and/or Offenses

Each study participant's history of an alcohol-related crash and/or offense was obtained from the Michigan Secretary of State. A dichotomous variable was constructed describing whether the respondent had a history of alcohol-related offense or crash. Offense and crash data three years prior to the interview were included in analyses.[28] Variables of interest included whether or not a respondent ever committed an alcohol-related offense or was ever involved in an alcohol-related crash or single-vehicle nighttime crash. Single-vehicle nighttime crashes, which involve only one vehicle and occur between 12:00 a.m. and 4:00 a.m., often involve alcohol and are used as a proxy for alcohol-involved crashes (Heeren, Smith, Morelock, & Hingson, 1985). If a respondent was involved in a single-vehicle nighttime crash, the crash was considered to have been an alcohol-related crash and was coded as 1; all other respondents, who were either involved in a non-alcohol-related crash or had no record of a crash with the Michigan Secretary of State, were coded as zero.

Alcohol-related offenses were identified using the *Offense Code Index for Traffic Violations* (Michigan Department of State, 2005). The original charge for convictions was used in all analyses to reduce bias from respondents who might have pled down to

[28]Three years of crash and offense data provided a history of respondents' alcohol-related encounters with law enforcement that may have altered their perceptions of drink/driving risks and subsequent alcohol-related outcomes, yet omits offenses and crashes occurring when respondents were beginning drivers with little driving experience.

lesser charges.[29] Alcohol-related offense codes were 1000, operating under the influence of liquor; 1010, unlawful bodily alcohol content (BAC ≥ 0.10); 1020, combined operator under influence of liquor/unlawful bodily alcohol content (BAC ≥ 0.10); 1025, operating while intoxicated; 1030, operated under influence or while impaired by liquor causing death; 1040, operated under influence or while impaired by liquor causing serious injury; 1100, operated under influence of controlled substance; 1110, combined operated under influence of liquor and controlled substance; 1200, operated while impaired by liquor; 1200, combined operated while impaired by liquor and controlled substance; 1240, persons under 21 with BAC (zero tolerance; BAC ≥ 0.20–0.80); and 1300, open intoxicants in vehicle (reporting violations for vehicle driver only). Any alcohol-related offense was coded as 1; no alcohol-related offense was coded as zero.[30]

Mediator Variable: Social Approval for Drink/Driving

Social approval for drink/driving consisted of four items measuring respondents' perceptions of friends and family regarding drink-driving. Respondents were asked, "How much do you think your best friend would approve or disapprove if you were to drive within an hour of having 3 or 4 alcohol drinks?" Responses for this item were coded 1 = *approve strongly*, 2 = *approve*, 3 = *neither approve or disapprove/don't care*, 4 = *disapprove*, 5 = *disapprove strongly*, and 6 = *don't have a best friend*. The second item asked respondents, "How much do you think your parents would approve or disapprove if you were to drive within an hour of having 3 or 4 alcohol drinks?"

[29]Prior to September 30, 2003, Michigan had a two-tiered standard, with BAC ≥ 0.10 considered drunk driving and BAC ≥ 0.08–0.09 considered impaired driving. On September 30, 2003, Michigan became the 44th state to adopt BAC ≥ 0.08 as standard for drunk driving offenses.

[30]There were 91 respondents with an alcohol-related offense in the prior 3 years from the interview date, 9 of which had multiple alcohol-related offenses.

Responses for this item were coded 1 = *approve strongly*, 2 = *approve*, 3 = *neither approve or disapprove/don't care*, 4 = *disapprove*, 5 = *disapprove strongly*, and 6 = *parents deceased/don't see or talk to parents*. Additionally, respondents were asked, "How likely is it that your best friend would be willing to ride with you if you were to drive within an hour of having 3 or more alcohol drinks?" Responses for this item were coded 1 = *very likely*, 2 = *somewhat likely*, 3 = *somewhat unlikely*, 4 = *very unlikely*, and 5 = *don't have a best friend*. Respondents were also asked, "How likely is it that your parents would be willing to ride with you if you were to drive within an hour of having 3 or more alcohol drinks?" Responses for this item were coded 1 = *very likely*, 2 = *somewhat likely*, 3 = *somewhat unlikely*, 4 = *very unlikely*, and 5 = *parents deceased/don't see or talk to parents*. This measure was developed for this research by taking items from an existing six item scale of the "Psychosocial Correlates of Adolescent Driving Behavior" study. An overall score was calculated by reverse coding the item responses and calculating the mean of the responses on the four items. A higher score indicated greater social approval for drink/driving. Respondents who were missing responses for any of the four items or who answered that they didn't have a best friend or that their parents were deceased/don't see or talk to parents were assigned a missing value for the measure.

Statistical Analyses

Analyses for this paper were restricted to respondents with a 12.1-mile buffer inside the Michigan state boundary during the time of the survey, who had driven a motor vehicle on a public road, and who drank alcohol within the past year (n = 4,935).

The sample size for all analyses was 3,911.[31] Respondents with missing data (n = 239) for any measure were excluded from all analyses. Compared to persons included in the analyses, persons excluded were significantly more likely to have lower education, less personal income, and more physical/verbal hostility and to reside in an area of greater alcohol density, although the differences were generally small.

Because the outcomes may be spatial autocorrelated, there is concern that the linear regression assumption of independent observation could have been violated (Waller & Gotway, 2004). In response to this concern, spatial autocorrelation was empirically tested for each sex and outcome using GeoDa software, version 0.9.5-i5 (2004; Anselin, Syabri, & Kho, 2006) for exploratory spatial data analysis and estimation of spatial regression models. Otherwise, regression models that assume spatial independence were estimated using SAS version 9.1.3. Spatial autocorrelation was tested separately for men and women and for linear surface trend and quadratic surface trend.[32] None of the spatial trend models were statistically significantly different from zero (i.e., a plane); therefore, all subsequent analyses will not include spatial regression.

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[31]Five-hundred and five respondents were excluded from the original sample (N = 5,464) because they did not live in Michigan during the time of the interview. Also excluded were 24 respondents who had buffers that overlapped with nearby states (e.g., 2 overlapped in Wisconsin, 15 overlapped with Ohio, and 7 overlapped with Indiana). Additionally, 41 respondents were excluded because they had not driven a motor vehicle on a public road in the year prior to the survey interview, and 786 respondents were excluded because they did not drink alcohol in the previous year. Finally, 239 respondents were excluded because they were missing data on one or more measures.

[32]Moran's I coefficient was derived from a row-standardized Arc distance weight of 12.1 miles, and the p value was derived from 999 permutations of the distribution. For women, Moran's I = 0.0093 (p = 0.021), and for men, Moran's I = 0.0051 (p = 0.142). For women, spatial dependence diagnostics suggested a spatial lag model, Lagrange Multiplier (lag) = 4.101 (p = 0.043). However, model fit from the spatial lag model (log likelihood = -2099.53) did not improve from OLS for Model 8 (log likelihood = -2064.71); therefore, ordinary least square results are reported.

First, the distribution of individual-level variables was examined using classifications of rural population and alcohol establishment density. Analysis of variance was used to examine mean differences for continuous variables, while the chi-square statistic was used for categorical variables.

To examine the first research question, multiple linear regression was used to assess the association between area characteristics (i.e., rural population and alcohol establishment density) and respondents' perceptions of drink/driving as dangerous, adjusting for individual characteristics, drinking behaviors, and crashes and/or offenses. All models were estimated separately by sex because there is evidence suggesting that men and women represent two different populations with different influences on drink/driving behavior and perceptions of drink/driving as dangerous (Bingham, Elliott, & Shope, 2007; Bingham, Shope, Zakrajsek, & Raghunathan, 2008; Chou et al., 2006; Jones & Lacey, 2001; NHTSA, 2008a; Quinlan et al., 2005; Voas, Wells, Lestina, Williams, & Greene, 1998;). The regression models delineated whether the coefficients changed when variables were added to the model in conceptually associated groups.

To examine the second research question regarding mediation, the models were examined with and without adjustment for social approval for drink/driving. The mediator, social approval for drink/driving, investigates one possible mechanism by which area characteristics may be associated with the perception of drink/driving as dangerous. Baron and Kenny (1986) list necessary conditions that a variable must meet before mediation may be inferred. Applying these conditions to this study, in order for social approval for drink/driving to be a mediator: (a) variations in levels of area characteristics must account for variations in social approval of drink/driving, while adjusting for individual characteristics, drinking behaviors, and crashes and/or offenses (b) variations in social approval of drink/driving must significantly account for variations in perceived risk of drink/driving as dangerous, while adjusting for individual characteristics, drinking behaviors, and crashes and/or offenses and (c) when both area characteristics and social approval are in the model, and while adjusting for individual characteristics, drinking behaviors, and crashes and/or offenses, any previously significant association between area characteristics and perceptions of drink/driving as dangerous must no longer be present for perfect mediation or reduced for possible mediation when social approval for drink/driving is added to the statistical model. The log-likelihood statistic is reported as a measure of the goodness-of-fit for each specific model. To contrast and evaluate competing models, the differences between two log-likelihood statistics were compared.

RESULTS

Descriptive Statistics

The aim of this paper was to examine associations among area characteristics (i.e., rural population and alcohol establishment density), social approval for drink/driving, and individual perceptions of drink/driving as dangerous. Table 4.1 shows descriptive statistics for the final sample (n = 3,869). The mean respondent age was 23.48 years; 26.26% were ever married; 49.68% were male; 96.05% had a high school education or more; and 17.24% made more than $35,000 in personal income in the past year. Alcohol establishment density was positively associated with perception of drink/driving as dangerous (Spearman's rank correlation coefficient [r] = 0.06) and negatively associated with social approval for drink/driving (r = -0.06; bivariate correlations not shown in table). Respondent's perceptions of drink/driving as dangerous were also negatively correlated with tolerance of deviance (r = -0.23), alcohol quantity/frequency (*r* = -0.34), drink/driving (*r* = -0.44), and social approval for drink/driving (*r* = -0.40; bivariate correlations not shown in table).

Association of Area Characteristics with Perceptions of Drink/Driving as Dangerous (Research Question 1)

Tables 4.2 and 4.3 show the associations between area characteristics and perceptions of drink/driving as dangerous for men and women, respectively. For men, the inverse relationship between rural population and perceptions of drink/driving as dangerous was eliminated with the addition of alcohol establishment density (see Table 4.2; Model 3). Perceptions of drink/driving as dangerous was positively associated with alcohol establishment density, after adjustment for demographic and psychosocial variables (Models 4 and 5). The addition of history of alcohol-related crash or offense did not substantially alter the association between alcohol establishment density and perceptions of drink/driving as dangerous, yet the positive association was eliminated with the inclusion of drinking behaviors (i.e., alcohol quantity/frequency and drink/driving behavior).

For women (see Table 4.3), the negative relationship between rural population and perceptions of drink/driving as dangerous was eliminated with the inclusion of alcohol establishment density (Model 3). The addition of drinking behaviors (Model 7; log-likelihood from -2209.06 to -2092.09) did weaken but did not eliminate the positive association between alcohol establishment density and perceptions of drink/driving as dangerous.

Possible Role of Social Approval for Drink/Driving as a Mediator of the Relationship Between Area Characteristics and Young Adults' Perceptions of Drink/Driving as Dangerous (Research Question 2)

For men, the additional adjustment for drinking behaviors had a large impact on model fit (Table 4.2. Model 7; log-likelihood from -2261.81 to -2113.82) and resulted in a non-significant association between alcohol establishment density and perceptions of drink/driving as dangerous. The addition of the presumed mediator, social approval for drink, further weakened the association, however, given the influence of drinking behaviors on the relationship between alcohol density and perception of drink/driving as dangerous, social approval for drink/driving does not appear to be mediating the relationship.

For women, the inclusion of drinking behaviors increased model fit (Model 7; log-likelihood from -2209.06 to -2092.09) and the inclusion of social approval for drink/driving in the final model increased model fit (Model 8; log-likelihood from -2092.09 to -2064.71), but alcohol establishment density remained significant in both of these models, suggesting a weak mediation effect of social approval for drink/driving.

DISCUSSION

The aim of this cross-sectional study was to examine whether area characteristics were associated with perception of drink/driving as dangerous and whether social approval for drink/driving mediated this association. In general, alcohol density, as a measure of area characteristics, was positively associated with Michigan young adults' perception of drink/driving as dangerous among both men and women, while the second measure of area characteristics, proportion of rural population, was only associated when the sole independent variable in the model. One explanation for this association is that respondents living in areas with more alcohol establishments (i.e., urban areas) may perceive greater consequences from drink/driving because of more law enforcement which may result in more stops and tickets. Although most explanations of urban–rural differences in drink/driving focus on the lack of alternative transportation options as the explanation for why there is more drink/driving in rural areas (Meliker et al., 2004), given this finding, it may be that alcohol establishment density is the area characteristic specific to the phenomena of drink/driving as dangerous rather than being part of a rural population. Future research on drink/driving should examine how or why social approval for drink/driving differs between high and low alcohol establishment areas and investigate how these social influences may be ameliorated.

This is the first study, however, to show that relationships among area characteristics and perceptions of drink/driving as dangerous were different for men and women. For men, the association of alcohol establishment density to perceptions of drink/driving was no longer significant after drinking behaviors was added to the model and remained non-significant when social approval for drink/driving was added to the full model. For women, however, there was a direct and positive relationship between alcohol establishment density and perceptions of drink/driving as dangerous, even after adjusting for drinking behaviors and social approval of drink/driving, suggesting that factors unique to alcohol establishment density may influence a woman's perception of drink/driving as dangerous.

The results also indicate that the perception of drink/driving as dangerous for respondents who had a history of alcohol-related offenses was not significantly different from those who had not. This is not surprising, as drink/drivers often drive with little or no consequences. For example, research suggests that for every 27,000 miles driven by a drink/driver, there is a probability of one arrest (Miller, Spicer, & Levy, 1999).

Moreover, this study showed an inverse association between drink/driving behavior and perceptions of drink/driving as dangerous. This finding is consistent with other research showing that drivers who repeatedly drink/drive had lower perceived negative consequences of their behavior compared to non-drink/drivers (Albery & Guppy, 1995), indicating that drink/driving behavior can be reinforced when negative consequences do not result.

In addition, drinking behaviors such as alcohol quantity/frequency and drink/driving were found to contribute to an individual's perception of drink/driving as dangerous. Specifically, men and women who reported more alcohol use and drink/driving, perceived drink/drinking as less dangerous. Furthermore, both men and women with lower perceptions of drink/driving as dangerous had parents and peers they reported as being accepting of drink/driving.

The conceptual model suggested that social approval of drink/driving mediates the relationship between area characteristics and a driver's perception of drink/driving as dangerous. However, social approval of drink/driving was not shown to be a mediator for men. For women, the association of alcohol establishment density and perception of drink/driving as dangerous was reduced after adjustment for social approval of drink/driving, suggesting that social approval of drink/driving may have a mediating role within the complex relationships among area characteristics and drink/driving.

Strengths and Limitations

The generalizability of these findings may be limited because the Michigan alcohol establishment density and rurality in this study may not adequately reflect other geographic areas (Hall, Kaufman, & Ricketts, 2006). Additionally, this study focused only on a sample of young adults in the state of Michigan. There are regional differences across the U. S. in drinking behaviors and drink/driving among different age cohorts (Borders & Booth, 2007; Voas et al., 1998). Drinking patterns and subsequent drink/driving exposure might change according to age cohort and residence. Despite these limitations, this is one of the few studies to have examined a general sample of young adults in regard to drink/driving perceptions and the first study to examine whether there is an association between area characteristics and perceptions of drink/driving as dangerous. Past research has focused on convicted drink/drivers, missing a substantial portion of the population who drink/drive but have never been convicted and, therefore, may have different perceptions of drink/driving (Jones & Lacy, 2001).

Another limitation is the potential measurement issues with the measure, social approval of drink/driving. The first potential measurement issue is that this measure equally combined the respondent's perceptions of family and peer responses towards drink/driving behaviors. That is, parent and peer social approval was weighted equally in the construction of the measure. Some research shows that during their early 20s, young adults' parental ties are weakening as they form stronger relationships among peer groups (Arnett, 1998). If this finding is present in this sample, then the measure construction should have put more emphasis on the social approval of friends than of family. Additional analyses for this paper refined the measure by separating the social approval measure into the two different influences (i.e., parent and peers) and examined the unique contributions of these social influences to driver's perceptions of drink/driving. The model fit for the two different influences (i.e., parents or peers) did not improve over the combined measure, suggesting that the combined influence of parents and peers better explains the respondents' perception of drink/driving as dangerous (results not shown).

The second potential measurement issue is that social approval was based on the respondent's subjective assessment of parents' and peers' perceived approval of drink/driving, and not on a direct assessment of parents or peers about their approval of drink/driving. However, the literature suggests that the perceived approval or disapproval is a more important influence on behavior than an objective measure (O'Callaghan, Chant, Callan, & Baglioni, 1997).

Table 4.1. *Individual and Area Characteristics for the Final Sample, Stratified by Proportion of Rural Population and Alcohol Establishment Density* (n = 3,869)

	FULL SAMPLE (n = 3,869)		URBAN[a] (n = 3,183)		RURAL (n = 686)		HIGH ALCOHOL DENSITY (n = 1,786)		LOW ALCOHOL DENSITY (n = 2,083)	
			Proportion of rural pop. ≤ 25%		Proportion of rural pop. > 25%		Alcohol density > 16.25		Alcohol density ≤ 16.25	
	(Count & Column %) or *M*	*SD*	(Count & Column %) or *M*	*SD*	(Count & Column %) or *M*	*SD*	(Count & Column %) or *M*	*SD*	(Count & Column %) or *M*	*SD*
Demographic										
Age (years)	23.48	0.83	23.45*	0.82	23.59*	0.82	23.48	0.79	23.47	0.86
Marital status (ever married)	1,016 (26.26%)		767 (24.10%)*		249 (36.30%)*		421 (41.44%)*		595 (58.56%)*	
Sex (male)	1,922 (49.68%)		1,567 (49.23%)		355 (51.75%)		842 (43.81%)*		1,080 (56.19%)*	
Education[b]										
< High School	153 (3.95%)		116 (3.64%)*		37 (5.39%)*		77 (3.65%)*		76 (3.65%)*	
High School	862 (22.28%)		676 (21.24%)*		186 (27.11%)*		361 (20.21%)*		501 (24.05%)*	
> High School	2,854 (73.77%)		2,391 (75.12%)*		463 (67.49%)*		1,348 (75.48%)*		1,506 (72.30%)*	
Personal Income										
< $15,000	1,064 (27.50%)		869 (27.30%)		195 (28.43%)		449 (25.14%)*		615 (29.52%)*	
≥ $15,000 - < $35,000	2,138 (55.26%)		1,762 (55.36%)		376 (54.81%)		1,008 (56.44%)*		1,130 (54.25%)*	
≥ $35,000	667 (17.24%)		552 (17.34%)		115 (16.76%)		329 (18.42%)*		338 (16.23%)*	
Psychosocial										
Tolerance of deviance	1.31	0.30	1.31	0.29	1.30	0.30	1.32	0.30	1.30	0.29
Risk-taking propensity	1.33	0.40	1.32	0.40	1.35	0.42	1.31	0.38	1.34	0.42
Physical/verbal hostility	1.63	0.38	1.62	0.38	1.65	0.38	1.62	0.38	1.63	0.39
Drinking behaviors										
Alcohol quantity/frequency	4.02	3.10	4.05	3.08	3.89	3.18	3.81*	2.85	4.20*	3.30
Drink/driving	1.58	2.32	1.59	2.29	1.51	2.44	1.39*	2.09	1.73*	2.48
History of crashes/offenses										
Alcohol-related crash	64 (1.65%)		48 (1.51%)		16 (2.33%)		22 (1.23%)		42 (2.02%)	
Alcohol-related offense	79 (2.04%)		59 (1.85%)		20 (2.92%)		23 (1.29%)*		56 (2.69%)*	
Mediator										
Social approval for drink/driving	1.68	0.63	1.68	0.63	1.72	0.67	1.62*	0.59	1.74*	0.66
Outcome										
Drink/driving as dangerous	3.02	0.80	3.03	0.80	2.99	0.82	3.10*	0.77	2.96*	0.82
Area characteristics										
Alcohol establishment density[c]	0.20	0.09	0.22	0.08	0.10	0.05	0.29	0.05	0.12	0.04
Proportion of rural population	0.15	0.17	0.09	0.07	0.45	0.18	0.05	0.08	0.23	0.18

*****$p < 0.05$ using F-tests for continuous variables and Chi-square tests for categorical variables.

[a]Proportion of rural population cut-off point was chosen based on state-wide median. Alcohol establishment density cut-off point was chosen based on state-wide mean.

[b]Education and personal income were collapsed into three categories for the descriptive table only.

[c]Alcohol establishment density is expressed as the number of alcohol establishments per mile of road.

Table 4.2. *Ordinary Linear Regression Models of Perceptions of Drink/Driving as Dangerous With Area and Individual Characteristics for Men* (*n* = 1,922)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
	B (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)
Area characteristics								
Proportion of rural population	-0.180* (0.091)		-0.026 (0.119)	-0.087 (0.118)	-0.079 (0.115)	-0.069 (0.115)	-0.110 (0.106)	-0.117 (0.100)
Alcohol establishment density[a]		0.575** (0.205)	0.537* (0.270)	0.559* (0.266)	0.677** (0.259)	0.655* (0.259)	0.298 (0.241)	0.145 (0.227)
Demographic								
Age				0.042 (0.023)	0.034 (0.022)	0.035 (0.022)	0.033 (0.020)	0.035 (0.019)
Marital status (ever married)				0.292*** (0.047)	0.251*** (0.046)	0.240*** (0.046)	0.106* (0.043)	0.135** (0.041)
Education				0.040** (0.014)	0.033* (0.014)	0.030* (0.014)	0.020 (0.013)	0.020 (0.012)
Personal income				-0.063*** (0.014)	-0.062*** (0.013)	-0.060*** (0.013)	-0.046** (0.012)	-0.032** (0.012)
Psychosocial								
Tolerance of deviance					-0.466*** (0.059)	-0.463*** (0.059)	-0.299*** (0.056)	-0.237*** (0.053)
Risk-taking propensity					-0.021 (0.043)	-0.017 (0.043)	0.075 (0.041)	0.075* (0.038)
Physical/verbal hostility					-0.213*** (0.052)	-0.215*** (0.052)	-0.045 (0.049)	0.005 (0.046)
Alcohol-related offense and/or crash								
Alcohol-related crash						-0.093 (0.119)	-0.004 (0.110)	0.012 (0.104)
Alcohol-related offense						-0.229* (0.106)	-0.083 (0.098)	-0.095 (0.093)
Drinking behaviors								
Alcohol quantity/frequency							-0.050*** (0.006)	-0.037*** (0.006)
Drink/driving behavior							-0.075*** (0.008)	-0.035*** (0.008)
Mediator								
Social approval for drink/driving								-0.430*** (0.028)
Log-Likelihood	-2351.95	-2349.98	-2349.96	-2320.44	-2264.71	-2261.81	-2113.82	-2000.71

*$p < .05$. **$p < .01$. ***$p < .001$.

[a]Density is expressed as the number of alcohol establishments per mile of road.

Table 4.3. *Ordinary Linear Regression Models of Perceptions of Drink/Driving as Dangerous with Area and Individual Characteristics for Women* (*n* = 1,947)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
	B (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)	*B* (*SE*)
Area characteristics								
Proportion of rural population	-0.182* (0.085)		0.016 (0.112)	0.008 (0.112)	-0.003 (0.109)	-0.006 (0.109)	-0.045 (0.102)	-0.038 (0.101)
Alcohol establishment density[a]		0.664** (0.193)	0.688** (0.254)	0.760** (0.254)	0.729** (0.247)	0.715** (0.247)	0.505* (0.233)	0.452* (0.230)
Demographic								
Age				0.056* (0.022)	0.054* (0.021)	0.054* (0.021)	0.040* (0.020)	0.037 (0.020)
Marital status (ever married)				0.161*** (0.039)	0.121** (0.038)	0.116** (0.038)	0.019 (0.037)	0.033 (0.036)
Education				0.008 (0.014)	0.015 (0.014)	0.015 (0.014)	0.003 (0.013)	-0.003 (0.013)
Personal income				0.020 (0.015)	0.017 (0.014)	0.016 (0.014)	0.029* (0.014)	0.030* (0.013)
Psychosocial								
Tolerance of deviance					-0.547*** (0.071)	-0.532*** (0.071)	-0.357*** (0.068)	-0.312*** (0.067)
Risk-taking propensity					-0.106 (0.058)	-0.104 (0.058)	0.069 (0.055)	0.050 (0.055)
Physical/verbal hostility					-0.159** (0.052)	-0.161** (0.052)	-0.108* (0.049)	-0.080 (0.049)
Alcohol-related offense and/or crash								
Alcohol-related crash						-0.069 (0.179)	0.158 (0.169)	0.149 (0.167)
Alcohol-related offense						-0.368* (0.170)	-0.177 (0.160)	-0.232 (0.158)
Drinking behaviors								
Alcohol quantity/frequency							-0.049*** (0.009)	-0.043*** (0.009)
Drink/driving behavior							-0.110*** (0.011)	-0.084*** (0.011)
Mediator								
Social approval for drink/driving								-0.251*** (0.034)
Log-Likelihood	-2279.14	-2275.49	-2275.48	-2261.49	-2211.52	-2209.06	-2092.09	-2064.71

**p* < .05. ***p* < .01. ****p* < .001.

[a]Density is expressed as the number of alcohol establishments per mile of road.

REFERENCES

Albery, I. P., & Guppy, A. (1995). Drivers' differential perceptions of legal and safe driving consumption. *Addiction, 90*(2), 245-254.

American Association for Public Opinion Research. (2000). Standard definitions: Final dispositions of case codes and outcome rates for surveys. Retrieved May 10, 2007, from http://www.aapor.org/pdfs/standarddefs_4.pdf

Anselin, L., Syabri, I., & Kho, Y. (2006). GeoDa: An introduction to spatial data analysis. *Geographical Analyses*, *38*(1), 5-22.

Arnett, J. (1998). Risk behavior and family role transitions during the twenties. *Journal of Youth and Adolescence, 27*(3), 301-320.

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51*(6), 1173-1182.

Ben-Ari, O. T., Mikulincer, M., & Gillath, O. (2005). From parents to children—similarity in parents and offspring driving styles. *Transportation Research Part F: Traffic Psychology and Behaviour, 8*(1), 19-29.

Bingham, C. R., Elliott, M. R., & Shope, J. T., (2007). Social and behavioral characteristics of young adult drink/drivers adjusted for level of alcohol use. *Alcoholism: Clinical and Experimental Research, 31*(4), 655-664.

Bingham, C. R., Shope, J. T., Zakrajsek, J., & Raghunathan, T. E. (2008). Problem driving behavior and psychosocial maturation in young adulthood. *Accident Analysis & Prevention, 40*(5), 1758-1764.

Blincoe, L. J., Seay, A. G., Zaloshnja, E., Miller, T. R., Romano, E. O., et al. (2002). *The economic impact of motor vehicle crashes 2000* (DOT HS-809-446). Washington, DC: U.S. Department of Transportation.

Borders, T. F., & Booth, B. M. (2007). Rural, suburban, and urban variations in alcohol consumption in the United States: Findings from the national epidemiologic survey on alcohol and related conditions. *Journal of Rural Health, 23*(4), 314-321.

Brown, S. L. (2005). Relationships between risk-taking behavior and subsequent risk perceptions. *British Journal of Psychology, 96*, 155-164.

Chou, S. P., Dawson, D. A., Stinson, F. S., Huang, B. J., Pickering, R. P., et al. (2006). The prevalence of drinking and driving in the United States, 2001-2002: Results from the national epidemiological survey on alcohol and related conditions. *Drug and Alcohol Dependence, 83*(2), 137-146.

Cummins, S., Curtis, S., Diez-Roux, A. V., & Macintyre, S. (2007). Understanding and representing 'place' in health research: A relational approach. *Social Science & Medicine, 65*(9), 1825-1838.

Dionne, G., Fluet, C., & Desjardins, D. (2007). Predicted risk perception and risk-taking behavior: The case of impaired driving. *Journal of Risk and Uncertainty, 35*(3), 237-264.

Donovan, J. E. (1993). Young adult drink-driving: Behavioral and psycho-social correlates. *Journal Studies of Alcohol, 54*(5), 600-613.

Elliott, M. R., Waller, P. F., Raghunathan, T. E., Shope, J. T., & Little, R. J. (2000). Persistence of violation and crash behavior over time. *Journal of Safety Research, 31*(4), 229-242.

Energy Information Administration. (2005). *Household vehicles energy use: Latest data and trends* (DOE/EIA-0464). Retrieved November 11, 2007, from, http://www.eia.doe.gov/emeu/rtecs/nhts_survey/2001/index.html

Flowers, N. T., Naimi, T. S., Brewer, R. D., Elder, R. W., Shults, R. A., & Jiles, R. (2008). Patterns of alcohol consumption and alcohol-impaired driving in the United States. *Alcoholism: Clinical and Experimental Research, 32*(4), 639-644.

Gulliver, P., & Begg, D. (2004). Influences during adolescence on perceptions and behaviour related to alcohol use and unsafe driving as young adults. *Accident Analysis & Prevention, 36*(5), 773-781.

Guppy, A. (1993). Subjective probability of accident and apprehension in relation to self-other bias, age, and reported behavior. *Accident Analysis & Prevention, 25*(4), 375-382.

Hall, S. A., Kaufman, J. S., & Ricketts, T. C. (2006). Defining urban and rural areas in US epidemiologic studies. *Journal of Urban Health-Bulletin of the New York Academy of Medicine, 83*(2), 162-175.

Heeren, T., Smith, R. A., Morelock, S., & Hingson, R. W. (1985). Surrogate measures of alcohol involvement in fatal crashes: are conventional indicators adequate? *Journal of Safety Research, 16*(3), 127-134.

Jones, R. K., & Lacey, J. H. (2001). Alcohol and highway safety 2001: A review of the state of knowledge (DOT HS 809 383). Retrieved October 2, 2007, from http://www.nhtsa.dot.gov/people/injury/research/AlcoholHighway/

Karlamangla, A., Zhou, K., Reuben, D., Greendale, G., & Moore, A. (2006). Longitudinal trajectories of heavy drinking in adults in the United States of America. *Addiction, 101*(1), 91-99.

Leadbeater, B. J., Foran, K., & Grove-White, A. (2008). How much can you drink before driving? The influence of riding with impaired adults and peers on the driving behaviors of urban and rural youth. *Addiction, 103*(4), 629-637.

Maio, R. F., Burney, R. E., Gregor, M. A., & Baranski, M. G. (1996). A study of preventable trauma mortality in rural Michigan. *Journal of Trauma: Injury. Infection, and Critical Care, 41*(1), 83-90.

Maio, R. F., Green, P. E., Becker, M. P., Burney, R. E., & Compton, C. (1992). Rural motor-vehicle crash mortality: The role of crash severity and medical resources. *Accident Analysis & Prevention, 24*(6), 631-642.

Meliker, J. R., Maio, R. F., Zimmerman, M. A., Kim, H. M., Smith, S. C., & Wilson, M. L. (2004). Spatial analysis of alcohol-related motor vehicle crash injuries in southeastern Michigan. *Accident Analysis & Prevention, 36*(6), 1129-1135.

Michigan Department of State. (2005). *Michigan Department of State court manual: Offense code index for traffic violations*. Retrieved October 31, 2008, http://www.michigan.gov/documents/OffenseCode_73877_7.pdf

Michigan November 2006 licensed alcohol establishments. (2006). Lansing, MI: Michigan Liquor Control Commission. Retrieved November 11, 2006, from http://www.michigan.gov/cis/0,1607,7-154-10570_12905---,00.html

Miller, T. R., Spicer, R. S., & Levy, D. T. (1999). How intoxicated are drivers in the United States? Estimating the extent, risks and costs per kilometer of driving by blood alcohol level. *Accident Analysis & Prevention, 31*(5), 515-523.

Mohai, P., & Saha, R. (2006). Reassessing racial and socioeconomic disparities in environmental justice research. *Demography, 43*(2), 383.

National Highway Traffic Safety Administration, National Center for Statistics and Analysis. (2008a). *Traffic safety facts 2006: Alcohol-impaired driving* (DOT HS 809 905). Retrieved October 2, 2008, from http://www-nrd.nhtsa.dot.gov/Pubs/810616.PDF

National Highway Traffic Safety Administration, National Center for Statistics and Analysis. (2008b). *Traffic safety facts 2006: Overview* (DOT HS 810 809). Retrieved October 2, 2008, from http://www-nrd.nhtsa.dot.gov/Pubs/810623.PDF

O'Callaghan, F. V., Chant, D. C., Callan, V. J., & Baglioni, A. (1997). Models of alcohol use by young adults: An examination of various attitude-behavior theories. *Journal of Studies on Alcohol, 58*(5), 502-507.

Quinlan, K. P., Brewer, R. D., Siegel, P., Sleet, D. A., Mokdad, A. H., et al. (2005). Alcohol-impaired driving among US adults, 1993-2002. *American Journal of Preventive Medicine, 28*(4), 346-350.

Rice, N., Carr-Hill, R., Dixon, P., & Sutton, M. (1998). The influence of households on drinking behaviour: A multilevel analysis. *Social Science & Medicine, 46*(8), 971-979.

Saporito, S., Chavers, J. M., Nixon, L. C., & McQuiddy, M. R. (2007). From here to there: Methods of allocating data between census geography and socially meaningful areas. *Social Science Research, 36*(3), 897-920.

Shope, J. T., Copeland, L. A., Kamp, M. E., & Lang, S. W. (1998). Twelfth grade follow-up of the effectiveness of a middle school-based substance abuse prevention program. *Journal of Drug Education, 28*(3), 185-197.

Shope, J. T., Copeland, L. A., Maharg, R., & Dielman, T. E. (1996a). Effectiveness of a high school alcohol misuse prevention program. *Alcoholism: Clinical and Experimental Research, 20*(5), 791-798.

Shope, J. T., Copeland, L. A., Marcoux, B. C., & Kamp, M. E. (1996b). Effectiveness of a school-based substance abuse prevention program. *Journal of Drug Education, 26*(4), 323-337.

Shope, J. T., Dielman, T. E., Butchart, A. T., & Campanelli, P. C. (1992). An elementary school-based alcohol misuse prevention program: Follow-up evaluation. *Journal Studies of Alcohol, 53,* 106-120.

Slovic, P. (2000). Public perception of risk. *Journal of Environmental Medicine, 59*(9), 22-25.

U.S. Census Bureau. (2000). *Urban and rural classification*. Retrieved May 9, 2006, from http://www.census.gov/geo/www/ua/ua_2k.html

Voas, R. B., Wells, J., Lestina, D., Williams, A., & Greene, M. (1998). Drinking and driving in the United States: The 1996 national roadside survey. *Accident Analysis & Prevention, 30*(2), 267-275.

Waller, L. A., & Gotway, C. A. (2004). *Applied spatial statistics for public health data*. New York: John Wiley.

Yu, J., & Williford, W. R. (1993). Problem drinking and high-risk driving - an analysis of official and self-reported drinking-driving in New York state. *Addiction, 88*(2), 219-228.

Zador, P. L. (1991). Alcohol-related relative risk of fatal driver injuries in relation to driver age and sex. *Journal of Studies on Alcohol, 52*(4), 302-310.

Zador, P. L., Krawchuk, S. A., & Voas, R. B. (2000). Alcohol-related relative risk of driver fatalities and driver involvement in fatal crashes in relation to driver age and gender: An update using 1996 data. *Journal of Studies on Alcohol, 61*(3), 387-395.

CHAPTER 5

CONCLUSION

This dissertation examined multiple characteristics of the urban–rural area environment from the state of Michigan that may influence driving behaviors and, ultimately, driving outcomes. Using cross-sectional data from a young adult survey, this research examined the relationship of urban-rural area characteristics to driving behaviors, motor vehicle crashes, perception of drink/driving behaviors, all while adjusting for individual characteristics..

The three main objectives of this research were: 1) to explore the association between roadway characteristics, young adult driving behaviors, crashes, and casualty crashes; 2) to explore the relationships between area characteristics, such as alcohol establishment density and proportion of rural population, alcohol use, binge drinking, drink/driving, and alcohol-related crashes, and 3) to explore the relationships between area characteristics, such as alcohol establishment density and proportion of rural population, perceptions of drinking/driving, and social approval for drink/driving.

CONCEPTUAL MODEL

The conceptual model presented here (see Figure 5.1) was the overall guiding model for this dissertation and is further represented by the conceptual models guiding each of the three separate papers (see Figures 2.1, 3.1, and 4.1). The model was developed by integrating the social ecological theory (McLeroy, Bibeau, Steckler, & Glanz, 1988), the fundamental determinants of health framework (Link & Phelan, 1995), and the Haddon Matrix (Haddon, 1972; Runyan, 2003). Each of these models/frameworks discusses the importance of area characteristics and why they should be included when examining factors that contribute to an individual's health behaviors. Health behaviors, which are actions undertaken by individuals or groups that have health consequences, are often influenced by area characteristics, which provide access and availability to health promoting resources (Glanz, Lewis, & Rimer, 2002). The health behaviors examined in this dissertation include driving behaviors (**Chapter 2**) and drinking behaviors (**Chapters 3 & 4**) that influence the likelihood of motor vehicle crash or offense.

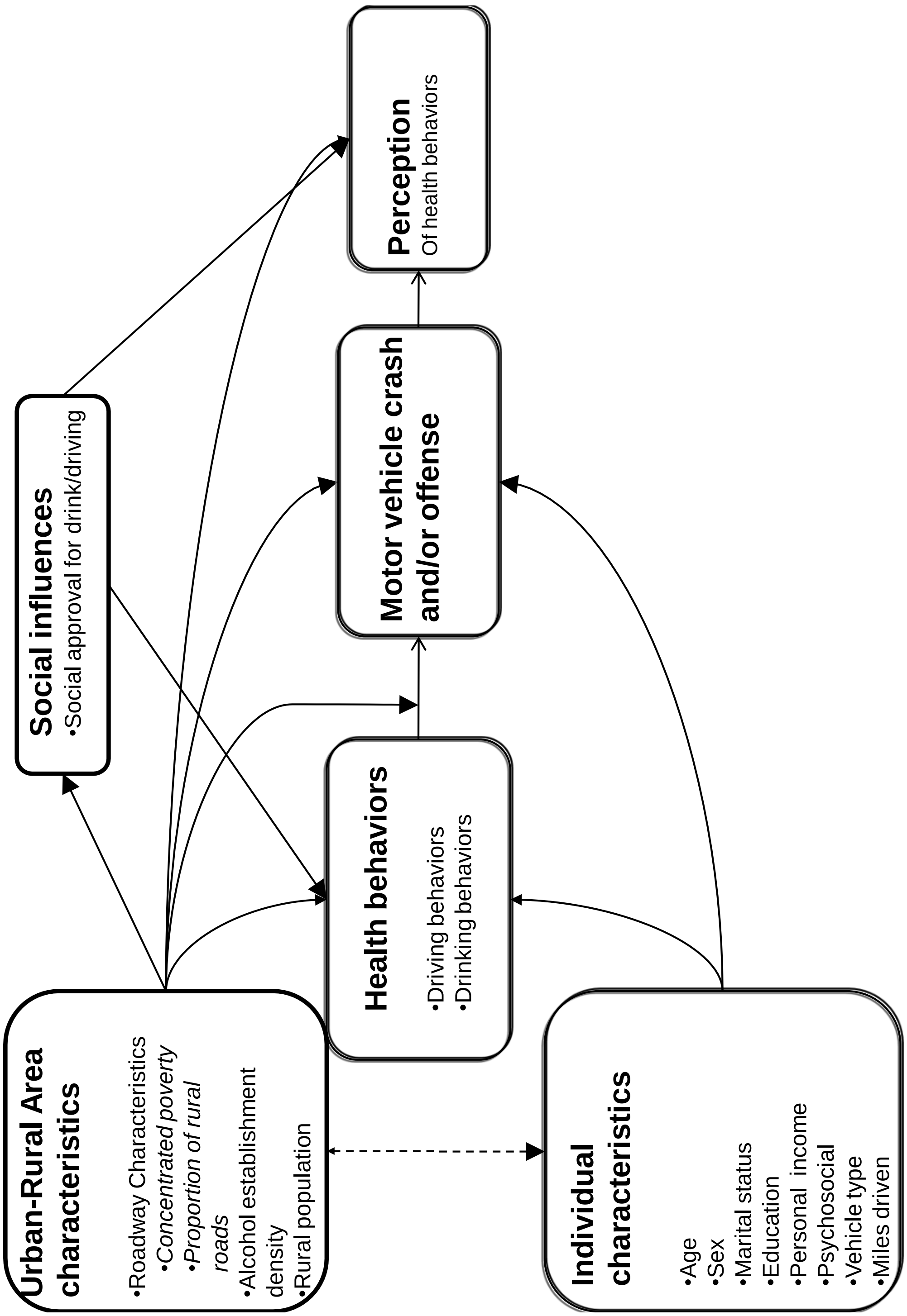
Despite the evidence for the contribution of area characteristics to individual health behaviors (Bingham, Shope, Zakrajsek, & Raghunathan, 2008; Chipman, Macgregor, Smiley, & Leegosselin, 1993; Glassbrenner, Carra, & Nicholas, 2004; Kim, Nitz, Richardson, & Li, 1995; Li, Baker, Langlois, & Kelen, 1998; Ulfarsson & Mannering, 2004; Williams & Umberson, 2004), there continues to be debate on whether and/or how area characteristics affect driving outcomes. Specifically, questions remain as to whether there are specific characteristics of rural versus urban areas that are associated with driving outcomes and if so, what are they? A potential limitation of past research on rural area characteristics, is that rural researchers have relied on using U.S. Census data (e.g., population density) to explore the associations between individuals and health outcomes (Hart, Larson, & Lishner, 2005), a method that may limit identification of aspects of rural areas that go beyond population density. To address this potential limitation, this dissertation included area characteristics beyond population density, by utilizing data from the Michigan Liquor Control Commission (MLCC), the Michigan Geographic Data Library (MGDL), and the U.S. Census Bureau to construct an individualized area exposure for each respondent.

This dissertation examined different mechanisms by which area characteristics may influence health behaviors, motor vehicle crashes, or the perceptions of health behaviors. Analysis of each of these mechanisms was done separately by sex based on prior research findings of distinct influences on drinking behaviors (Jones & Lacey, 2001; Voas, Wells, Lestina, Williams, & Greene, 1998), driving behaviors, and driving outcomes (Bingham, Elliott, & Shope, 2007; Bingham, Shope, Zakrajsek, & Raghunathan, 2008; Ulfarsson & Mannering, 2004). The findings from all three studies showed different relationships for men and women, thus supporting past findings that men and women have unique drinking behaviors, driving behaviors, and driving outcomes.

The first mechanism investigated in the present studies was whether there was an association between area characteristics and health behaviors, or actions undertaken by individuals or groups that have health consequences (Glanz et al., 2002). The health behaviors examined included those, such as driving behaviors (**Chapter 2**) and drinking behaviors (**Chapters 3 & 4**), which influence the likelihood of motor vehicle crash or offense. Perhaps not surprisingly, the direction and strength of these associations differed depending on the area characteristic and health behavior being studied. For example, respondents in areas with less alcohol establishments (i.e., rural areas) reported more alcohol use, more binge drinking, and more drink/driving (**Chapter 3**) (all associations were significant). However, there was no significant association between respondents who lived near more rural roads and high-risk driving (**Chapter 2**).

The second mechanism which was investigated was whether area characteristics may moderate the association between health behaviors and the likelihood of motor vehicle crashes. In other words, the relationship between health behavior and motor vehicle crashes may depend on the level of the area characteristic.

Figure 5.1. Basic conceptual model outlining relationships found among urban–rural area characteristics, individual characteristics, health behaviors, motor vehicle outcomes, and perceptions of health behaviors.



This relationship was investigated in two chapters, and findings suggest that area characteristics moderate the association between individual driving behaviors for men (**Chapter 2**) and drinking behaviors for women (**Chapter 3**) to predict motor vehicle crash outcomes. For example, the association between men who engaged in more high-risk driving and the odds of being involved in a casualty crash were greater for men who lived near rural roads than near urban roads (**Chapter 2**).

The third mechanism which was investigated was whether area characteristics may be directly associated with motor vehicle crashes by influencing the availability and access to health-promoting resources. The motor vehicle crashes examined in this dissertation included casualty and non-casualty crashes (**Chapter 2**) and alcohol-related and non-alcohol-related crashes (**Chapter 3**). Again, the results of this relationship found that the association depended on the area characteristics and MVC outcome being studied. Specifically, although roadway characteristics did not predict casualty or non-casualty crashes (**Chapter 2**), greater alcohol establishment density did predict less alcohol-related crashes for men (**Chapter 3**), even while adjusting for individual characteristics and with drinking behaviors as a mediator.

The fourth mechanism which was investigated was whether area characteristics may influence an individual's perception of health behaviors. Specifically, the perception of drink/driving as dangerous (**Chapter 4**) is proposed to be influenced by drinking behaviors and drinking consequences (e.g., history of motor vehicle crash or offense) and may also be associated with the density or proximity of area characteristics. The purpose of this study was to test whether urban–rural differences in the perception of drink/driving as dangerous are a possible reason for past findings of urban–rural disparities in alcohol-related crashes (Meliker, Maio, Zimmerman, Kim, Smith, & Wilson, 2004). Results show that for both men and women there was a positive relationship between alcohol establishment density and perceptions of drink/driving as dangerous, such that respondents who lived near a greater density of alcohol establishments reported greater perceptions of drinking/driving as dangerous. Finally, the fifth mechanism which was investigated was whether social influences (i.e., social approval for drink/driving) mediated the association between (**Chapter 4**) area characteristics and an individual's perception of health behaviors (.e.g., drink/driving). Although results show that respondents living in areas with lower alcohol establishment density reported more social approval for drink/driving, social influences were a possible, albeit weak mediator for women's perception of health behaviors.

The key findings for each chapter are summarized in the section below.

CHAPTER 2

The research described in Chapter 2 examined three possible mechanisms by which roadway characteristics, while adjusting for individual characteristics, may influence driving behaviors and the likelihood of a non-casualty crash or a casualty crash. The first mechanism posited that roadway characteristics were associated with driving behaviors. Results, however, suggested no direct relationship between roadway characteristics and driving behaviors (i.e., high-risk driving or seat belt use) for either men or women. The second mechanism proposed that roadway characteristics are directly associated with the likelihood of a non-casualty crash or casualty crash while adjusting for individual characteristics and with driving behaviors as a mediator. This study found no direct relationship between roadway characteristics and the likelihood of a crash for either men or women. The third mechanism posited that the association between driving behaviors and the likelihood of crash was moderated by roadway characteristics. There was no significant interaction for women. For men, the results suggested that the association between the likelihood of casualty crash involvement and high-risk driving was higher with rural roads than urban roads, *OR* = 1.42, 95% CI [1.08, 1.86].

CHAPTER 3

The research in Chapter 3 investigated whether area characteristics (i.e., alcohol establishment density and rural population) were associated with a driver's drinking behaviors (i.e., alcohol use, binge drinking, and drink/driving) and subsequent alcohol-related crashes, while adjusting for individual characteristics. Urban–rural differences among alcohol-related crashes have been documented in southeast Michigan (Meliker et al., 2004), yet no study to date has investigated whether there are also differences in drinking behaviors. Guided by the proposed conceptual model, this paper examined three possible mechanisms by which area characteristics could be associated with, drinking behaviors, and alcohol-related driving outcomes, while adjusting for individual characteristics. The first proposed mechanism examined was whether area characteristics were directly associated with drinking behaviors. The results of this study found that a greater density of alcohol establishments was associated with less alcohol consumption for both sexes; however, the association was slightly stronger for women. The second proposed mechanism examined was whether area characteristics were directly associated with the likelihood of an alcohol-related crash while adjusting for individual characteristics and with drinking behaviors as a mediator. For men, living in an area with a higher density of alcohol establishments resulted in a greater likelihood of being involved in an alcohol-related crash; moreover, the association with alcohol establishment density was weakened after adjusting for drinking behaviors, suggesting that the level of alcohol consumption may play a mediating role in explaining the greater likelihood of alcohol-related crash involvement. For women, a direct relationship between area characteristics and alcohol-related crashes was not supported. Lastly, there was an examination of the moderating influence of roadway characteristics on the association between driving behavior and the likelihood of any crash and a casualty crash. For women, the association between drink/driving and the likelihood of an alcohol-related crash was higher with greater alcohol establishment density. Additionally, for women, the association between drink/driving and likelihood of an alcohol-related crash was higher with a greater rural population than urban population. Both of these interactions increased the likelihood of involvement in an alcohol-related crash for women. However, the small number of women involved in alcohol-related crashes (n = 33) generated large and unstable odds ratios and confidence intervals; therefore, results should be interpreted cautiously.

CHAPTER 4

The research described in Chapter 4 built on the research described in Chapter 3 by examining the potential role of social influences (i.e., social approval for drink/driving) in explaining any association between area characteristics and young adult perceptions of drink/driving as dangerous. Few studies have examined how drink/driving may be influenced by the driver's broader social and area characteristics. Thus, this research investigated the relationships among the broader social (i.e., social approval for drink/driving) and area (i.e., rural population and alcohol establishment density) characteristics that may influence a driver's perceived risk of drink/driving. For men and women, a greater density of alcohol establishments was associated with perceptions of drink/driving as more dangerous. Social approval for drink/driving was found to be a potential mediator for women, although not a strong mediator. The results from this study suggest that individuals in geographic areas where alcohol establishments are less dense are a high-risk group. More investigation is needed of the relationship of social approval for drink/driving, risk behavior, and density of alcohol establishments.

LIMITATIONS AND STRENGTHS

Confounding and Self-Selection

A strength of the work presented here is that the data represent an age group with the highest rates of risky driving (NHTSA, 2008) and drink/driving (Voas et al., 1998). However, the generalizability of these findings is limited because the Michigan alcohol establishment density and rurality in this study may not adequately reflect other geographic areas, the age range of the participants is not representative of all age groups and the influence of certain area characteristics may vary depending on the states or regions under investigation (Esposito, 1995; Maio, Burney, Gregor, & Baranski, 1996).

The data used in all analyses come from a cross-sectional survey that was part of an ongoing longitudinal study. When the study first began in 1984 (Shope, Dielman, Butchart, & Campanelli, 1992), all respondents attended school in southeast Michigan. At the time of the young adult survey (1997–2000), however, individuals were not necessarily in the same communities. They were in their early 20's, a highly mobile age group. Indeed, of the 5,464 respondents who completed the telephone interview, 505 (10.8%) were excluded a priori from analyses because they had moved from Michigan to other states. Moreover, the young adults who continued to live in Michigan at the time of this survey may have moved away from southeast Michigan, raising the possibility that respondents could have been self-selected. To partially address these issues of self-selection and confounding, each of the dissertation studies adjusted multivariate models for individual-level characteristics.

Measurement Issues

There were potential sources of measurement error for the individual as well as for the area characteristic measures used in these analyses. Crash records for all chapters (and offense records for Chapter 4 only) were obtained from the Michigan Secretary of State. The strengths of Secretary of State records are that they were collected by law enforcement officers who are trained in the collection of offense and crash data and may be assumed to be unbiased toward individuals involved in a crash event. However, the crashes used in this dissertation represent only those that were reported by police and may not represent all the crashes in which these respondents were drivers. In fact, researchers agree that crashes are under-reported to the police (Agran, Castillo, & Winn, 1990; Cummings, Koepsell, & Mueller, 1995), which results in an underestimate of crashes. Under-reporting may also differ by urban–rural area due to differences in law enforcement coverage, which would result in misclassification and contribute to underestimates of area effects. For example, rural areas may have less law enforcement personnel, which may lead to less citations and/or reporting of MVCs. If there were under-reporting of rural MVCs, area effects would be underestimated for rural areas.

A strength of this dissertation was the use of multiple measures and characteristics of an area to examine and determine the relationships between area characteristics and health-related outcomes. However, a potential limitation of this study is the use of proxy measures for those characteristics for which there were not readily available data. Proxy measures were used for specific road conditions and alcohol-related crashes. The proxies for specific road condition were the proportion of rural collector and local roads and concentrated poverty. Although concentrated poverty has not been used as a proxy for roadway condition previously, it is often used in sociology to characterize local physical and social conditions and has exhibited a positive relationship with injury outcomes (Cubbin & Smith, 2002; Ferrando, Rodríguez-Sanz, Borrell, Martínez, & Plasència, 2005; Williams, Currie, Wright, Elton, & Beattie, 1997). Yet, the results of this study found that there was an inverse relationship between concentrated poverty and the proportion of rural collector and local roads, suggesting that concentrated poverty is an invalid proxy of rural road conditions in Michigan. The associations found in past research could exist because of confounding due to transportation mix (e.g. pedestrians and drivers) and land use mix (i.e. urban design), which may differ between low and high poverty areas.

Single-vehicle nighttime crash (SVNT) was used as a proxy for an alcohol-related crash, yet there continues to be a debate on whether this proxy is adequate (Meliker et al., 2004). Although there is agreement on what constitutes a single vehicle crash, there is no consensus on how to define *nighttime*. The variation in time periods that constitute nighttime could reflect how well the proxy captures potential alcohol-related crashes.

Another possible limitation of this dissertation was the use of only one measure of alcohol establishment density (i.e., total number of licensed alcohol establishments per mile of road). Previous studies (Gruenewald, Remer, & Lipton, 2002; Gruenewald, & Ponicki, 1995; Treno, Grube, & Martin, 2003) have found differences in the associations (i.e., size and direction) of other alcohol establishment characteristics (e.g., license types specifying whether alcohol must be consumed on or off the business premises) and drink/driving events. These previous findings suggest that utilizing the total number of alcohol establishments, instead of examining specific license types, may have altered the magnitude of the associations observed. Future studies should investigate specific alcohol establishment characteristics and determine whether different license types are also associated with drinking behaviors and alcohol-related crashes, which may further improve understanding of area characteristics on health-related outcomes.

Methodological Contributions

The use and investigation of area characteristics and health-related outcomes is increasing (Diez-Roux, 2000). With this growing popularity, epidemiological methods have become more sophisticated in infectious and chronic disease studies, especially around issues of estimating individual exposure to area characteristics. Exposure to crash risk is, in general, difficult to estimate because of both individual variation in miles driven and trip purposes and the possibility that "traditional" administrative boundaries used as denominators in miles driven (e.g., census tracts or zip codes) may not realistically reflect an individual's driving environment. To address these difficulties, past researchers have used a variety of geographic boundaries, for example, state (Colón, 1982), county (Blose & Holder, 1987; Jewel & Brown, 1987), city (Scribner, Mackinnon, & Dwyer, 1994), and neighborhood (VanOers & Garretsen, 1993), to investigate the independent influence of area effects with very little consideration of how driving may change an individual's exposure to specific area characteristics. This dissertation has attempted to address these challenges by developing an estimated exposure area (i.e., a circular buffer with a 12.1-mile radius) around each respondent's geocoded residence. By using this circular buffer and the areal apportionment method (Cummins, Curtis, Diez-Roux, & Macintyre, 2007; Mohai & Saha, 2006; Saporito, Chavers, Nixon, & McQuiddy, 2007), an effort was made to more realistically reflect an individual's exposure to area characteristics.

FINAL CONCLUSIONS AND RESEARCH IMPLICATIONS

Overall, the three studies in this dissertation found that certain urban–rural area characteristics are associated with driving behaviors and drinking behaviors. Findings suggest that researchers need to devote more attention to defining and investigating specific characteristics by using integrated variables and by examining the complex relationships between urban–rural areas and individual health behaviors. Given the complex interactions between individuals, vehicles, and area characteristics such as roadway characteristics and alcohol establishments, the associations reported in these studies indicate that certain area characteristics are associated with health behaviors and warrant further investigation. Findings also support the inclusion of rural areas (specifically, areas with low alcohol establishment density) in public health surveillance of health behaviors such as drinking behaviors and drink/driving. Although surveillance of rural areas may not seem economically feasible, these studies and others (e.g., Borders & Booth, 2007) suggest that rural areas may suffer disproportionately from risky driving and drinking behaviors and thus may need more attention paid to them.

Given the burden of alcohol-related crashes and fatalities in the United States, this dissertation is an important foundation for future research. For example, while these studies has identified significant associations between alcohol establishment density, drinking behaviors, and alcohol-related crashes, the cross-sectional nature of this study prevents causal inferences regarding these associations. Future research should utilize available longitudinal data to examine whether changes in alcohol establishment density (e.g., if a survey participant moves from an area located with greater alcohol establishment density to lower alcohol establishment density) are associated with changes in drinking behaviors and/or the likelihood of an alcohol-related crash. Investigating possible causal relationships between area characteristics, drinking behaviors, and alcohol-related crashes is essential to identifying effective targets (e.g., individual or area characteristics) of public health interventions.

REFERENCES

Agran, P. F., Castillo, D. N., & Winn, D. G. (1990). Limitations of data compiled from police reports on pediatric pedestrian and bicycle motor-vehicle events. *Accident Analysis & Prevention, 22*(4), 361-370.

Bingham, C. R., Elliott, M. R., & Shope, J. T. (2007). Social and behavioral characteristics of young adult drink/drivers adjusted for level of alcohol use. *Alcoholism-Clinical and Experimental Research, 31*(4), 655-664.

Bingham, C. R., Shope, J. T., Zakrajsek, J., & Raghunathan, T. E. (2008). Problem driving behavior and psychosocial maturation in young adulthood. *Accident Analysis & Prevention, 40*(5), 1758-1764.

Blose, J. O., & Holder, H. D. (1987). Liquor-by-the-drink and alcohol-related traffic crashes - a natural experiment using time-series analysis. *Journal of Studies on Alcohol, 48*(1), 52-60.

Borders, T. F., & Booth, B. M. (2007). Rural, suburban, and urban variations in alcohol consumption in the United States: Findings from the national epidemiologic survey on alcohol and related conditions. *Journal of Rural Health, 23*(4), 314-321.

Chipman, M. L., Macgregor, C. G., Smiley, A. M., & Leegosselin, M. (1993). The role of exposure in comparisons of crash risk among different drivers and driving environments. *Accident Analysis & Prevention, 25*(2), 207-211.

Colón, I. (1982). The influence of state monopoly of alcohol distribution and the frequency of package stores on single motor vehicle fatalities. *American Journal of Drug Abuse* (9), 325-331.

Cubbin, C., & Smith, G. S. (2002). Socioeconomic inequalities in injury: Critical issues in design and analysis. *Annual Review of Public Health, 23*, 349-375.

Cummins, S., Curtis, S., Diez-Roux, A. V., & Macintyre, S. (2007). Understanding and representing ‘place’ in health research: A relational approach. *Social Science & Medicine, 65*(9), 1825-1838.

Cummings, P., Koepsell, T. D., & Mueller, B. A. (1995). Methodological challenges in injury: Epidemiology and injury prevention research. *Annual Review of Public Health, 16*, 381-400.

Diez-Roux, A. V. (2000). Multilevel analysis in public health research. *Annual Review of Public Health, 21*, 171-192.

Energy Information Administration. (2005). *Household vehicles energy use: latest data and trends* (DOE/EIA-0464). Washington, DC: U.S. Department of Energy. Retrieved November 11, 2007, from http://www.eia.doe.gov/emeu/rtecs/nhts_survey/2001/index.html

Esposito, T. (1995). Analysis of preventable trauma and inappropriate trauma care in a rural state. *The Journal of Trauma, 39*(5), 955-962.

Ferrando, J., Rodriguez-Sanz, M., Borrell, C., Martinez, V., & Plasencia, A. (2005). Individual and contextual effects in injury morbidity in Barcelona (Spain). *Accident Analysis & Prevention, 37*(1), 85-92.

Glanz, K., Lewis, F. M., & Rimer, B. K. (Eds.). (2002). *Health behavior and health education: Theory, research, and practice* (3rd ed.). San Francisco, CA: Jossey-Bass.

Glassbrenner, D., Carra, J. S., & Nichols, J. (2004). Recent estimates of safety belt use. *Journal of Safety Research, 35*(2), 237-244.

Goodall, C. R., Kafadar, K., & Tukey, J. W. (1998). Computing and using rural versus urban measures in statistical applications. *American Statistician, 52*(2), 101-111.

Gruenewald, P. J., & Ponicki, W. R. (1995). The relationship of the retail availability of alcohol and alcohol sales to alcohol-related traffic crashes. *Accident Analysis & Prevention, 27*(2), 249-259.

Gruenewald, P. J., Remer, L., & Lipton, R. (2002). Evaluating the alcohol environment: Community geography and alcohol problems. *Alcohol Research & Health, 26*(1), 42-48.

Haddon, W. (1972). A logical framework for categorizing highway safety phenomena and activity. *Journal of Trauma, 12*, 193-207.

Hall, S. A., Kaufman, J. S., & Ricketts, T. C. (2006). Defining urban and rural areas in U.S. epidemiologic studies. *Journal of Urban Health: Bulletin of the New York Academy of Medicine, 83*(2), 162-175.

Hart, L. G., Larson, E. H., & Lishner, D. M. (2005). Rural definitions for health policy and research. *American Journal of Public Health, 95*(7), 1149-1155.

Jensen, L., McLaughlin, D. K., & Slack, T. (2003). Rural poverty: The persistent challenge. In D. L. Brown & L. E. Swanson (Eds.), *Challenges for rural America in the twenty-first century* (pp. 118-131). University Park, PA: The Pennsylvania State University.

Jewell, R. T., & Brown, R. W. (1995). Alcohol availability and alcohol-related motor-vehicle accidents. *Applied Economics, 27*(8), 759-765.

Jones, R. K., & Lacey, J. H. (2001). *Alcohol and highway safety 2001: A review of the state of knowledge* (NHTSA DOT HS-809-383).

Kim, K., Nitz, L., Richardson, J., & Li, L. (1995). Personal and behavioral predictors of automobile crash and injury severity. *Accident Analysis & Prevention, 27*(4), 469-481.

Li, G. H., Baker, S. P., Langlois, J. A., & Kelen, G. D. (1998). Are female drivers safer? An application of the decomposition method. *Epidemiology, 9*(4), 379-384.

Link, B. G., & Phelan, J. (1995). Social conditions as fundamental causes of disease. *Journal of Health & Social Behavior*, 80-94.

MacTavish, K., & Salamon, S. (2003). What do rural families look like today? In D. L. Brown & L. E. Swanson (Eds.), *Challenges for rural America in the twenty-first century* (pp. 73-85). University Park, PA: The Pennsylvania State University.

Maio, R. F., Burney, R. E., Gregor, M. A., & Baranski, M. G. (1996). A study of preventable trauma mortality in rural Michigan. *Journal of Trauma: Injury, Infection, and Critical Care, 41*(1), 83-90.

McLeroy, K. R., Bibeau, D., Steckler, A., & Glanz, K. (1988). An ecological perspective on health promotion programs. *Health Education Quarterly, 15*(4), 351-377.

Meliker, J. R., Maio, R. F., Zimmerman, M. A., Kim, H. M., Smith, S. C., & Wilson, M. L. (2004). Spatial analysis of alcohol-related motor vehicle crash injuries in southeastern Michigan. *Accident Analysis & Prevention, 36*(6), 1129-1135.

Mohai, P., & Saha, R. (2006). Reassessing racial and socioeconomic disparities in environmental justice research. *Demography, 43*(2), 383.

National Highway Traffic Safety Administration, National Center for Statistics and Analysis. (2008). *Traffic safety facts 2006: Overview* (DOT HS 810 809). Washington, DC: U.S. Department of Transportation. Retrieved October 1, 2008, from http://www-nrd.nhtsa.dot.gov/Pubs/810809.PDF

Runyan, C. W. (2003). Introduction: Back to the future – revisiting Haddon's conceptualization of injury epidemiology and prevention. *Epidemiologic Reviews, 25*, 60-64.

Saporito, S., Chavers, J. M., Nixon, L. C., & McQuiddy, M. R. (2007). From here to there: Methods of allocating data between census geography and socially meaningful areas. *Social Science Research, 36*(3), 897-920.

Scribner, R. A., Mackinnon, D. P., & Dwyer, J. H. (1994). Alcohol outlet density and motor-vehicle crashes in Los Angeles county cities. *Journal of Studies on Alcohol, 55*(4), 447-453.

Shope, J. T., Dielman, T. E., Butchart, A. T., & Campanelli, P. C. (1992). An elementary school-based alcohol misuse prevention program: Follow-up evaluation. *Journal of Studies of Alcohol, 53,* 106-120*.*

Treno, A. J., Grube, J. W., & Martin, S. E. (2003). Alcohol availability as a predictor of youth drinking and driving: A hierarchical analysis of survey and archival data. *Alcoholism-Clinical and Experimental Research, 27*(5), 835-840.

Tyson, D. (2004). Necronomicon: The wanderings of Alhazred. Saint Paul, MN: Llewellyn Publications.

Ulfarsson, G. F., & Mannering, F. L. (2004). Differences in male and female injury severities in sports-utility vehicle, minivan, pickup and passenger car accidents. *Accident Analysis & Prevention, 36*(2), 135-147.

VanOers, J. A. M., & Garretsen, H. F. L. (1993). The geographic relationship between alcohol use, bars, liquor shops and traffic injuries in Rotterdam. *Journal of Studies on Alcohol, 54*(6), 739-744.

Voas, R. B., Wells, J., Lestina, D., Williams, A., & Greene, M. (1998). Drinking and driving in the United States: The 1996 National Roadside Survey. *Accident Analysis & Prevention, 30*(2), 267-275.

Williams, J. M., Currie, C. E., Wright, P., Elton, R. A., & Beattie, T. F. (1997). Socioeconomic status and adolescent injuries. *Social Science & Medicine, 44*(12), 1881-1891.

Williams, K., & Umberson, D. (2004). Marital status, marital transitions, and health: A gendered life course perspective. *Journal of Health and Social Behavior, 45*(1), 81-98.