Title
The Importance of Place in Adults Approaching Midlife

Author
Trubenstein, Brittany Paige

Publication Date
2020

UNIVERSITY OF CALIFORNIA
RIVERSIDE

The Importance of Place in Adults Approaching Midlife

A Dissertation submitted in partial satisfaction
of the requirements for the degree of

Doctor of Philosophy

in

Psychology

by

Brittany Paige Trubenstein

September 2020

Dissertation Committee:
Dr. Chandra A. Reynolds, Chairperson
Dr. Rebekah Richert
Dr. Sergio Rey

The Dissertation of Brittany Paige Trubenstein is approved:

____

____

____

Committee Chairperson

University of California, Riverside

ACKNOWLEDGEMENTS

I would like to acknowledge and thank the amazing people in my life who have supported me through this adventure with for their unwavering support and encouragement. I know I could not have become the woman I am today without their influences.

I would like to say thank you to my advisor, Dr. Chandra Reynolds. Thank you for your continued support and instruction, for all the letters of support, and all of the lessons. I have learned so much from you in such a short amount of time. I have enjoyed my time as your student, and I look forward to working with you as a colleague in the future. I am grateful for the research support received from the CATSLife project which is supported by a grant from the National Institute on Aging (NIA AG046938; Reynolds & Wadsworth, MPIs). Additionally, I would like to extend a thank you to my committee members, Drs. Bekah Richert and Sergio Rey, for their continued support and guidance through this process. I also want to thank you for taking time from your summer to allow me to defend. Thank you to my unofficial co-mentor Tuppett Yates. I truly enjoyed each and every class, event, and moment that I spent with you. Thank you so much for all the knowledge you shared (both personal and professional), all of your letters of support, and just being an amazing person.

I know that I could not have survived graduate school without the love and support from my amazing lab mates. Liz, from day one you have been my sunshine. Your friendship and support were everything to me and even on the worse days, you always kept me laughing. I look forward to working on projects together in the future. Dianna and Shandell, I will always treasure our time together in lab, but especially all our Wednesday night, back porch get-together's. Thank you for all the laughs, all the tears, and all of the unconditional support. You made my time in the program a truly life changing experience and I am so thankful to have you both in my life. I would also like to thank my lab mates Brittany, Julia, Tina and Chloe for sitting through countless iterations of talks, models, posters, and paper drafts and with unending support and always-great feedback.

I also owe a thank you to my incredible cohort. Danielle, Travis, and Kyla, I could not have made it through this program without your support. I will never forget all the fun times we had together, especially the Whacky Waving Inflatable Arm-Flailing Tube Man Halloween costumes. Danielle, thank you for your friendship and support in our small classes. I could not have asked for a better person to have shared those experiences with (both good and bad). Additionally, thank you to my wonderfully supportive cohort. I there is no better group of people to learn and grow with and I always enjoyed our Friendsgiving party.

I would like to thank my undergraduate advisor, Dr. Crystal Kreitler. Thank you for always believing in me and pushing me to be better. You were the first one to teach me what I could do, and what is more, you helped me accomplish it! You are an amazing woman, mother and mentor and I am so lucky to have you in my life!

For my pseudo dad, Roger Allen. You always believed in me and pushed me to succeed. I love you and miss you so much! Thank you for all the knowledge you passed onto me about the most random things I could possibly imagine (how to screen-print

shirts, how to make “belly buttons”, and how to save the last bit of WD-40 from a can). Thank you for marrying Marcus and me. Thank you for being such an amazing friend to my Dad. Most of all, thank you for bringing color into my world for teaching me that “Life is a Chicken Farm”.

I would like to say thank you to the Torres family for welcoming us into your family and loving our children as if they were your own. From our first day in the neighborhood, the Torres family went above and beyond to make us feel welcomed. You truly were our family away from home and made our time in California so much better!

Thank you to my mom (Martha Keys) and to my dad and stepmom (Doug & Linda Keys) for your encouragement and support. I love you all and hope that I can continue to make you proud. Thank you to my mother and father in-law, Sherri and Matt Trubenstein, for their continued support. They have made me feel like part of the family from day one and have always been supportive of me, even though that meant moving their son and grandkids half-way across the country! In addition, I would like to thank my sister-in-law, Amber Trubenstein. You are truly the best friend and sister that anyone could ask for. I love you so much and I am looking forward to combing the beaches together when we are old (with our walkers of course)!

Bryce and Brooklyn, I am sorry that I missed so much time with you during these last few years, but please know that both of you have always been my inspiration and motivation to keep going. All of this is has been for you. Bryce, it has been so amazing watching you grow. You are without a doubt, the most caring and genuine person I know. I have learned so much about kindness and compassion from you, and every day you make me a better person. You were my first love, and you always will be. Brooklyn, even on the worse days you light up my life. Your laughter is contagious, your intelligence is astonishing, and your mouth (although it gets us in trouble sometimes) is just like mine! You truly are my mini-me, and I wouldn't want it any other way. I cannot wait to see what you both become. Whatever it may be, I know you will both be successful in any path you choose. I am so proud of you, and I love you both!

Lastly, I would like to thank my husband, Marcus, for his unyielding belief in me, even when I no longer believed in myself. You always kept pushing, kept encouraging, and always stayed strong, even when I could not anymore. We have been through hell and back as a couple, and as parents, but we are stronger for it and I would not trade our experiences for anything. I cannot wait to see what our next adventure entails but I know that it will be full of love and laughter. I love you moistest, to the moon and back, forever and ever, amen!

ABSTRACT OF THE DISSERTATION

The Importance of Place in Adults Approaching Midlife

by

Brittany Paige Trubenstein

Doctor of Philosophy, Graduate Program in Psychology
University of California, Riverside, September 2020
Dr. Chandra A. Reynolds, Chairperson

The primary purpose of this dissertation was to investigate rural-urban differences in cognitive performance by considering proximal and distal rurality differences in leisure time activity engagement and cognitive performance. Social capital, physical health, education and occupation were possible mediators. Data from the ongoing Colorado Adoption/Twin Study of Lifespan behavioral development and cognitive aging (i.e. CATSLife) were leveraged (ages 28-49 years), and potential selectivity of geospatial associations examined.

Study 1 evaluated the informativeness of continuous distal (IRRcounty) and proximal measures of rurality (IRRtract) to evaluate geographic differences in activity engagement. Results revealed that distal rurality was informative for some activity domains (social) whereas for others proximal rurality was informative (sedentary). Interestingly, distal and proximal rurality were associated with family activity engagement, but the distal measure was more informative.

Study 2 evaluated associations of distal and proximal rurality with a county-level social capital index (SCI) and individual level social capital facets (e.g., perceived support, number of close friends) and physical health (i.e., number of illnesses, somatic complaints, self-rated health). Results revealed few geographic differences in social capital or health. Of note, the more rural the county, the sparser the close friendship network and less frequent friend contact. However, while denser friendship networks were associated with less frequent somatic complaints, rurality was not a mediator.

Study 3 evaluated the relationship between activity engagement and cognitive performance as mediated by social capital (SCI) and moderated by rurality. Distal rurality moderated the association of SCI with Full Scale IQ (FSIQ) whereas cognitive engagement uniquely predicted FSIQ. Access to social capital may be more salient for individuals living in more urban counties than rural counties, whereas cognitive activity engagement and participating in cognitively demanding hobbies were salient irrespective of rurality, despite rurality differences in cognitively demanding hobbies.

Collectively these studies demonstrate geographic differences in leisure time activity engagement, social capital and cognitive functioning, showing value in constructing continuous proximal and distal rurality measures. Evaluating the interplay between individuals at midlife and their constructed and built environments is critical to further understand the etiology of rural disparities and impacts to later cognitive health.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Appendices

Chapter One:

Environmental Associations with Activity Engagement, Physical Health, and Cognition

Overview

Whether your childhood home brings back memories of a bucolic/pastoral/idyllic small town or a bustling city frenzied with activity, you likely have mental representations distinguishing rural and urban areas. For many, rural environments evoke images of or bring to mind small agricultural towns where individuals and their homes are dispersed between fields and forests. In contrast, urban areas are associated with density of both people and buildings, bringing to mind images of big cities full of skyscrapers and activity. The distinction between rural and urban living may seem nominal at first pass, but objective and perceived features of rural and urban environments may contribute to disparities in health including cognitive functioning, particularly in the opportunities and resources the living environment affords to individuals in terms of activity engagement, social support and social capital.

Developmental theorists such as Clark (Clark, 1999a) and Bronfenbrenner (e.g., (Bronfenbrenner & Ceci, 1994) have promoted the view that environmental, or ecological contexts can influence and indeed become inextricably embedded within cognitive development. Extensions of ecological theories in relation to healthy cognitive aging, and aging across domains, have been promoted as well, emphasizing the importance of place to lifespan cognitive functioning, maintenance, and change (see Cassarino & Setti, 2015; Wahl et al., 2012). The extent to which benefits and vulnerabilities to cognitive functioning may result from ‘place’ is of increasing interest, particularly for evaluating the disparities seen between rural and urban residing individuals (e.g., Befort et al., 2012; Behringer et al., 2007; Eberhardt & Pamuk, 2004; Harris et al., 2016; Patterson et al., 2004; Singh & Siahpush, 2014; Trivedi et al., 2015; Wen et al., 2018; Wilcox et al., 2000). Of further interest is studying environmental factors that can contribute to cognitive performance via direct or indirect influences on physical health and activity engagement, particularly among individuals who are approaching midlife. From a life-course perspective, it is important to recognize that influences on mid-life functioning could have cumulative effects on later life cognitive abilities (e.g. Gatz et al., 2006; Glymour & Manly, 2008; Infurna et al., 2020; Martin & Zimprich, 2005; Richards & Wadsworth, 2004; Salthouse, 2009).

Throughout the years, policy makers and researchers alike have developed methods for distinguishing between rural and urban areas to assess the numerous outcomes (physical functioning, cognitive health, activity engagement, social capital) that may be influenced by place of residence. A series of studies by Wu and colleagues have stressed the importance of understanding the differing associations found between cognitive abilities and geographic location (Wu, Prina, & Brayne, 2015; Wu, Prina, Jones, Matthews, et al., 2017). By evaluating land use patterns, or the mixture of residential, commercial, and recreational areas, these researchers were able to distinguish between highly rural areas (lowest mixed land use) and highly urban areas (highest mixed land use) and have suggested a U-shaped relationship between cognitive performance and land use patterns (Wu, Prina, & Brayne, 2015; Wu, Prina, Jones, Matthews, et al., 2017). Their findings suggest that individuals living at the furthest ends of the rural-urban spectrum may be at a cognitive disadvantage as a result of sensory stimulation extremes experienced in these different environments (Wu, Prina, Jones, Matthews, et al., 2017). Wu et al., (2017) suggests that individuals living at the rural extreme may be disadvantaged due to the lack of cognitive stimulation provided by the largely homogeneous environment, whereas those individuals living in the urban extreme may be at a cognitive disadvantage due to the overwhelming cognitive stimulation associated with bustling urban areas.

Physical health outcomes have also been well studied regarding the influence of rurality versus urbanicity, with poorer physical and mental health found to be associated with the former (Befort et al., 2012; Cassarino & Setti, 2015; Mainous & Kohrs, 1995; Weeks et al., 2004). Physical disparities seen in more rural residing individuals include greater reports of hypertension (Behringer et al., 2007; Eberhardt & Pamuk, 2004; Harris et al., 2016; Singh & Siahpush, 2014), diabetes (Eberhardt & Pamuk, 2004; Harris et al., 2016; Smith, Humphreys, & Wilson, 2008), and obesity (Befort et al., 2012; Eberhardt & Pamuk, 2004; Harris et al., 2016; Patterson, Moore, Probst, & Shinogle, 2004; Trivedi et al., 2015; Wen, Fan, Kowaleski-Jones, & Wan, 2018; Wilcox, Castro, King, Housemann, & Brownson, 2000). Regarding mental health, studies have shown urban residing individuals as having higher prevalence of disorders such as schizophrenia (Krabbendam & Van Os, 2005), and mood/anxiety disorders (Peen et al., 2010; Romans et al., 2011; Sundquist et al., 2004) although one study has shown that rural residing individuals report fewer mental health concerns than urban residing individuals but the speculation as to why this was found is left open (Weeks et al., 2004).

The physical health disparities associated with rural versus urban location, are factors that are each associated with poorer cognitive aging outcomes (Cassarino & Setti, 2015; Cramm et al., 2013; Saenz et al., 2018), and may reflect partly unique rural-urban pathways by which cognitive functioning may be influenced by rural-urban living. Literature examining the extent to which cognitive health disparities exist in rural versus urban areas is sparse. However, what research there is indicates an association between rurality and diminished cognitive performance in the domains of verbal learning, verbal fluency, verbal memory, orientation, and attention (Saenz et al., 2018; Weden et al., 2018), as well as increased rates of dementia (Harris et al., 2016; Russ, Batty, Hearnshaw, Fenton, & Starr, 2012; Weden et al., 2018).

Geographic location has been found to influence activity engagement which may play a mediating or moderating role in contributing to rural-urban disparities. For example, urban residing individuals have been found to be more physically active than rural residing individuals which may contribute to fewer negative health outcomes such as hypertension (Deng & Paul, 2018; Eberhardt & Pamuk, 2004; Harris et al., 2016; Patterson et al., 2004; Sampaio, Ito, & Carvalho Sampaio, 2013; Singh & Siahpush, 2014; Trivedi et al., 2015; Wilcox et al., 2000), whereas rural individuals have been found to have denser social networks than urban residing individuals which may contribute to fewer mental health concerns and increased wellbeing (Sørensen, 2012).

Other ways that researchers have begun to investigate differences in rural and urban communities is through social capital. Simply put, social capital is a measure of cohesion, reciprocity and engagement members have with their community that help to facilitate the community's efficiency (Putnam, 2000). Some studies have begun to evaluate the difference in the types of activity engagement across rural and urban communities in relation to the area's level of social capital (Beaudoin & Thorson, 2004; Onyx & Bullen, 2000; Sampson, 1988; Sørensen, 2012, 2016). However, to the best of our knowledge, very few studies (none using a sample from the United States) have evaluated the association between social capital and cognitive performance.

With the known physical and cognitive health disparities challenging rural Americans, it is important to consider the pathways by which the environment may be affecting cognitive performance and contributing to these disparities. Previous literature has noted lower educational attainment is often found in rural residing individuals and speculate that this lower educational attainment may partially explain the cognitive disparities seen in rural areas (Saenz et al., 2018; Weden et al., 2018). It has also been suggested that urban areas provide more cognitively stimulating occupations thus acting as a self-selection process which leads individuals with greater cognitive abilities to move from rural areas to urban areas that provide more and better job opportunities, while those with lower cognitive abilities remain in rural areas (Cassarino & Setti, 2015; Saenz et al., 2018). Much like animal models that have suggested that richer environments contribute to fewer signs of brain deterioration and better cognitive performance (Berardi et al., 2007; Harati et al., 2011; Jankowsky et al., 2005), some have suggested the visual and auditory complexity of urban environments may provide a type of "brain training" or essentially brain exercise, which could explain the greater cognitive performance typically seen in urban environments (Cassarino & Setti, 2015). Studies do show, however, that there may be potential benefits to rural living to some specific domains of cognition such as attention (De Fockert et al., 2011). For example, in one study rural individuals were better able to ignore distractors and focus on a target point when compared to urban residing individuals (De Fockert et al., 2011); a potential explanation for this disparity comes from the nature of urban environments, in which individuals are exposed to unrelenting sensory input. Indeed, others have argued that persistent stimulation may result in depleted attentional capacity in urban residing individuals (Kaplan, 1995). That said, most of the differences observed to date have favored those in urban locales across broad domains.

Defining Rural & Urban

How to define areas as rural or urban has long been a topic of debate among researchers. We provide an overview of quantitative measure of "rural" and "rurality", distinguishing between discrete measures derived from threshold-based typologies, and continuous measures. We begin by presenting a selection of classifications developed and employed in the United States and juxtapose these with an example of a continuous measure of rurality, the Index of Relative Rurality (IRR) (Inagami et al., 2016; Waldorf & Ayoung, 2015; Waldorf, 2006), that is based on four dimensions: population size, density, percentage of urban residents, and the distance to the closest metropolitan area.

US Census Urban/Rural Distinction

The US Census Bureau (USCB) dichotomizes areas as either rural or urban based on a set of characteristics (Bureau, 2010). The USCB classifies an urban area as a neighboring area of census blocks with a population density of minimally 1,000 people per square mile and a total population of 2,500 or more (Bureau, 2010). From this definition, the USCB further dichotomizes urban areas into two categories, urbanized areas, and urban clusters. To be considered an urbanized area, the area must have at minimum 50,000 residents, whereas areas with 2,500 to 49,999 residents would be considered an urban cluster (Bureau, 2010; Waldorf & Ayoung, 2015; Waldorf, 2006). All other areas that do not fit these criteria are considered rural (Bureau, 2010; Waldorf, 2006). The problem with this kind of dichotomy is that areas with 49,999 residents may not be vastly different from an area with 50,101 residents for example; whereas it would be placed in the same category as an area that is vastly different, having only 2,510 residents.

Core Based Statistical Areas (CBSA)

Similar to the U.S. Census, the Office of Management and Budget (OMB) dichotomizes areas as either rural or urban but emphasizes commuter traffic to define urban areas. Once a CBSA is defined, it is further dichotomized into either metropolitan statistical areas (MSA) or micropolitan statistical areas (MiSA). Much like the U.S. Census' threshold criteria for defining urbanized areas and urban clusters, MSA's consist of 50,000 or more residents in contributing cities where as MiSA's consist of more than 10,000 but fewer than 50,000 residents in contributing cities (Bureau, 2003b; Bureau & OMB, 2003; Waldorf & Ayoung, 2015). Any counties that do not fall into either the metropolitan or micropolitan are called non-core counties and are considered rural. A major problem with this type of classification is that counties that are primarily rural, could be considered urban based on commuter flows. Additionally, many counties could have a substantial number of urban residents, but the number falls just below the threshold to be considered a micropolitan area and is thus grouped with counties that are mostly rural (Bureau, 2003b; Bureau & OMB, 2003; Waldorf & Ayoung, 2015).

Rural-Urban Continuum Code (RUCC)

The rural-urban continuum codes (RUCC) is calculated at the county level and uses the above-mentioned categorization techniques to place counties into one of nine ordinal categories based on urbanicity (1 to 3) or rurality (4 to 9) (USDA, 2013). This is executed with a three-step method. The first step is to determine if the county belongs to a metropolitan statistical area or if it is a non-metropolitan area. In the second step, metropolitan areas are further sub-divided and assigned a numerical value associated with one of three categories numbered 1, 2 or 3 which are distinguished by the population size of the metro area (USDA, 2013). In the third step, non-metro areas are then sub-divided and assigned a numerical value associated with one of six categories numbered 4 through 9 and are distinguished by the size of the urban population and the distance to the nearest metro area (USDA, 2013). Similar to the metro/non-metro coding scheme, counties that are vastly different geographically may be grouped into similar categories, while counties that are very similar geographically could be grouped into very different categories.

Rural-Urban Commuting Area Codes (RUCA)

The Rural-Urban Commuting Area (RUCA) codes are calculated on the census tract level and are based on population density, urbanization, and commuting patterns. Using these features, the RUCA codes assign a number (1-10) to each census tract categorizing tracts into various levels of metropolitan, micropolitan, small towns, and rural commuting areas (USDA, 2010). The codes can be further delineated based on secondary commuting flows (USDA, 2010). This helps address the problem of inappropriately dichotomizing the placement of the tract as rural or urban; but because this is a categorical variable, it is subject to the same problems with setting thresholds for categorical placements of rurality or urbanicity. To appropriately evaluate rurality or urbanicity, research must move away from categorical definitions to continuous measurement.

Index of Relative Rurality (IRR)

Few studies have evaluated differences in rural and urban classification systems (Inagami et al., 2016; Waldorf, 2006; Waldorf & Ayoung, 2015). Waldorf (2006, 2015) discusses differences in current classification systems while proposing the pros and cons of each system and recommending the Index of Relative Rurality or the IRR (described in further detail below) as the best method. The IRR combines population size, population density, percentage of urban population, and distance to the nearest urban area (Metropolitan/Micropolitan Statistical Area) to create a continuous measure of rurality that is on a bounded scale ranging from 0 representing the most urban areas, to 1 representing the most rural areas (Inagami et al., 2016; Waldorf, 2006; Waldorf & Ayoung, 2015).

Calculating the IRR is a relatively simple process once the contributing variables have been collected. To begin, measures of population, population density, and percent of urban individuals must be collected from the U.S. Census for the geographic scale of interest. For example, if the scale of analysis is at the county level, the county's population, population density, and percent urban must be obtained. Population and population density are typically very skewed so these two variables must be log transformed to normalize their skewed distributions (Waldorf, 2006; Waldorf & Ayoung, 2015). Next, the distance to the nearest metro area must be calculated. The distance can be from the participants address to the nearest major city, or from the centroid of the county/zip code/tract to the nearest major city. Next all four variables must be put into compatible scales before combining them (Waldorf, 2006; Waldorf & Ayoung, 2015). Note that three of the variables that comprise the IRR are negatively related to rurality (population, population density, and percent urban) whereas distance to major cities is positively related to rurality (Waldorf, 2006; Waldorf & Ayoung, 2015). To rescale positively related variables, the variable (i.e. population) is subtracted from the max observation (i.e. max population in the sample) and divided by the maximum observation minus the minimum observation (i.e. minimum population in the sample) to put the variables on a scale bounded from 0 to 1 (Waldorf, 2006; Waldorf & Ayoung, 2015). For the distance measure, the same process is performed but the resulting division is subtracted from one which reverses the direction to be in line with the other three variables (Waldorf, 2006; Waldorf & Ayoung, 2015). To link the four variables, take the unweighted average (Waldorf, 2006; Waldorf & Ayoung, 2015). Note, formulas for the creation of the IRR are provided in Chapter 2.

Being a continuous measure of rurality, the IRR offers several advantages that the aforementioned categorization methods cannot address. First, although the IRR was developed for analysis at the county level, the composition of the measure allows for application to any geographic scale (Waldorf, 2006; Waldorf & Ayoung, 2015). Many studies from a broad range of fields have utilized the IRR at the county level for their analyses (Barber, 2013; De Montis et al., 2012; Gallardo & Scammahorn, 2011; Heflin & Miller, 2012; Kaza, 2013; Lambert et al., 2010; Mammen et al., 2011; Stewart & Lambert, 2008), while others have adapted the IRR to the zip code (Hubach et al., 2014; Inagami et al., 2016). To the best of our knowledge, this will be the first study to adapt the IRR at the census tract level. Adapting the IRR to the census tract level will allow us to leverage a more proximal measure of the participant's environment. Second, the composition of the IRR makes it sensitive to changes in any of the comprising variables (Waldorf, 2006; Waldorf & Ayoung, 2015). In the aforementioned categorization methods of rurality, it is possible that there would have to be substantial changes in the contributing variables before an area would pass the threshold into the next category. For example, using the population thresholds described above, an area with population of 2,500 would have to significantly grow to a population of 50,000 or more before passing the threshold into the next category of urbanicity. With the continuous measure of rurality however, even small changes in any of the contributing variables would reflect change in the IRR score, making it much more sensitive to the complex nature of rurality. Because of this sensitivity, the third benefit of the IRR is that it is useful for studying changes in the environment over time (Waldorf, 2006; Waldorf & Ayoung, 2015). Publicly available census data can allow researchers to develop IRR scores going backward in time. This could allow for developmental researchers to "reconstruct" aspects of the environment that the participant was previously exposed to if the researcher can obtain address histories.

These benefits make the Index of Relative Rurality a valuable, yet underutilized tool, particularly for developmental psychologist as it allows the ability to develop and empirically test targeted ecological hypotheses about the interplay between the individual and their contextual environment. Further research is needed to better understand how using this tool may inform our models of contexts, environments, and cognition, and strengthen ecological-developmental research in the field.

Activity Engagement

The literature evaluating leisure time activity engagement, or those activities that we do in our non-working hours, has been well studied (Bennett et al., 2006; Chan et al., 2018a; Gow et al., 2017; Hoang et al., 2016; Karp et al., 2006; Scarmeas et al., 2001; Sofi et al., 2011; Taaffe et al., 2008; Wang et al., 2002a, 2017a; Wilson et al., 2013a). A small but growing literature has begun to examine the differences in activity engagement across rural and urban residing individuals.

When examining physical activity and engagement differences across rural and urban individuals, previous literature has begun to show the importance of understanding the relationship between activity engagement and geographic location. Prior research has well demonstrated that rural residing individuals engage in significantly less physical activities than their urban residing counterparts (Deng & Paul, 2018; Eberhardt & Pamuk, 2004; Patterson et al., 2004; Sampaio et al., 2013; Sanderson et al., 2002; Singh & Siahpush, 2014; Trivedi et al., 2015; Wilcox et al., 2000; Yankeelov et al., 2015). An interesting finding, however, is that rural individuals have also been shown to have significantly more barriers in their environment which hinder activity engagement (Aronson & Oman, 2004; Eyler & Vest, 2002; Salvo et al., 2018; Sanderson et al., 2002, 2002; Wilcox et al., 2000). These environmental barriers have been reported to include features of a more rural environment, such as uneven or nonexistent sidewalks and the absence street lights (Eyler & Vest, 2002; Salvo et al., 2018; Sanderson et al., 2002; Wilcox et al., 2000; Yankeelov et al., 2015), distance to, cost of, or lack of exercise facilities (Eyler & Vest, 2002; Sanderson et al., 2002; Wilcox et al., 2000), and small roads with heavy commercial vehicle traffic (Salvo et al., 2018). Alternatively, environmental traits that are often associated with urban living have been found to increase physical activity. These environmental features include high residential density, higher land-use mix (i.e. residential, commercial, public areas, etc.), higher street connectivity, and shorter distances to destinations (Cohen et al., 2007; Handy et al., 2002; Michael et al., 2006; Saelens & Handy, 2008). These environmental barriers that are hindering physical activity engagement, as well as the environmental benefits that encourage physical activity contextualize the need to better understand the relationship between the environmental context and activity engagement.

Similarly, social activity engagement has been shown to differ significantly across rural and urban individuals as well. One study evaluating social engagement in a sample of older adults found that rural individuals were less socially engaged compared to urban individuals, especially in activities such as eating out, meeting friends, or going to exercise groups (Vogelsang, 2016). Vogelsang (2016) suggests that being in a rural environment would require greater travel for individuals to engage in these activities, contributing to the lessened engagement but acknowledges that most of the sample in this study were still driving so distance may not be as important as initially considered. Other geographic differences in social activity engagement include the suggestions that the social network in rural areas differs from that in urban areas, such that the relationships between the members of a social network for rural individuals are stronger, more developed, and more deeply connected, as compared to social networks in urban areas which consist of more acquaintances, are less developed, and are less strongly connected (Paúl et al., 2003; Sørensen, 2012; Wanless et al., 2010; Ziersch et al., 2009). Further, rural individuals have been shown to engage in more community activities (Onyx & Bullen, 2000; Sørensen, 2012; Ziersch et al., 2009). Urban residing individuals on the other hand have been found to report more social participation (Meng & Chen, 2014; Vogelsang, 2016), and likely have greater access to resources that allow for social engagement such as restaurants, theaters, parks, etc. (Clarke et al., 2011; Vogelsang, 2016). Other studies which have evaluated social activities which contribute to social capital have and found that rural individuals show significantly more participation in neighborhood and community events, while urban individuals are more proactive in social context, meaning they are more likely to reach out to social networks for information or resources when needed (Onyx & Bullen, 2000; Wanless et al., 2010). While there may be geographic differences in the types of social activity individuals engage in, studies have shown that regardless of rurality or urbanicity, social activity engagement is an important predictor for cognitive performance and late life quality of life (Barnes et al., 2004; Bassuk et al., 1999; Bennett et al., 2006; Bot et al., 2016; Ertel et al., 2008; Holtzman et al., 2004; Kelly et al., 2017; Krueger et al., 2009; Litwin & Stoeckel, 2015; Salthouse et al., 2002; Sampaio et al., 2013).

These studies provide examples of how the environment may influence activity engagement with downstream influences on physical and cognitive health. It is important to also consider that individuals can also select into environments that support their activity interests, as well as, the likely reciprocal interacting affects between activity engagement and the environment (Laidley et al., 2019). In summary, rural individuals seem to face more barriers hindering their engagement in physical activity but have higher quality social networks, whereas urban residing individuals typically have more opportunities for physical activity engagement (e.g. gyms, street connectivity, etc.) and have more social engagement. Additionally, the social activity engagement literature suggests that the types of social activity reported are different for rural and urban residing individuals, which may differentially influence cognitive health. Further research is warranted to examine the geographic differences in how individuals spend their leisure time, how the amount of time spent on activity engagement varies geographically, and potential selection effects based on genetic similarities.

Social Capital

Many conceptualizations of social capital exist within the literature, contributing to the lack of an operational definition of the term. Depending upon academic domain, the creation, composition, and utility, of social capital differs. For example, researchers in the field of ecology often conceptualize social capital as a network of resources that can be employed for personal economic growth (i.e. "it's not what you know, but who you know") (De Carolis et al., 2009; De Carolis & Saparito, 2006; Nahapiet & Ghoshal, 1998). Alternatively, researchers in the social sciences conceptualize social capital as a network of resources whereby members of said network have high reciprocity for one another (i.e. "you scratch my back and I'll scratch yours"). What follows is a brief synopsis of the differing conceptualizations of social capital from the leading theorist in the field of social capital, i.e., Bourdieu, Lin, Coleman, and Putnam, how we will incorporate social capital into this dissertation.

Bourdieu: Resources Linked to Social Networks

Bourdieu is considered a pioneer in the field of Social Capital, introducing the concept in 1979 (Bourdieu & Richardson, 1986). Primarily interested in how social structures lead to unequal opportunities for status attainment, Bourdieu emphasized economic capital, defined as material goods exchanged for monetary profits, as the root of both cultural and social capital. In defining these terms, Bourdieu described cultural capital as having three sub forms. The first sub form described is the embodied state, or the habits, skills, and dispositions developed from the interactions with others in the culture. The second sub form is the objectified state or the actual cultural goods that are a product of the members of that culture, while the third sub form is the institutionalized state or the educational attainment of the individual. Bourdieu contrasts economic and cultural capital (including the sub forms of cultural capital) with social capital, which he poses is embedded within the networks of social relationships (Bourdieu & Richardson, 1986). The amount of social capital that an individual possess depends on two factors: 1) the size of the individuals social network that can be mobilized when needed and 2) the amount of total capital (economic, cultural, and social) the individual is perceived to have from others in the network (Bourdieu & Richardson, 1986). Moreover, Bourdieu proposed that social capital is produced by the conversion of these three forms of capital. For example, economic capital can be converted to social capital through investments in local businesses, cultural capital can be converted to social capital through the social connections that are established and maintained through formal schooling. In turn, social capital can be converted to economic capital through the goods and services produced, and be converted to cultural capital through the benefits of being associated with prestigious groups (Bourdieu & Richardson, 1986). While Bourdieu thoroughly described the forms of capital, he did not specify how these forms could be measured.

Lin: Resources Rooted in Social Networks

Lin's theory of Social capital draws on classical theories of capital and is defined as "resources embedded in a social structure that are accessed and/or mobilized in purposive actions" (Lin, 1999, p. 29). Lin differentiated two types of social capital: contact resources and network resources (Lin, 1999). Contact resources are defined as those resources from network members that an individual would mobilize on their own, while network resources are the resources available from network members to whom the individual has access.

Unlike Bourdieu; Lin and colleagues developed a method for measurement of the two types of social capital (Lin, 1982; Lin, Nan & Dumin, 1986). To measure network resources participants can complete the position generator task. The position generator task asks an individual to identify individuals within their social network who fit into a 30-item list of occupations. This list of occupations provides a representative sample of occupational positions that are salient in society and vary in occupational prestige (Van der Gaag et al., 2008). For example, a participant could identify their friend Jana who is a lawyer (high occupational prestige), their acquaintance Kelsey who is the director at her at work (medium-high occupational prestige), their family member Juan who is a postman (medium-low occupational prestige), and their neighbor Jeremy who is a construction worker (low occupational prestige). Three social capital indices are calculated from this position generator (Van der Gaag et al., 2008). The first index is *extensity* or the total number of positions in which an individual could identify at least one contact (Van der Gaag et al., 2008). The second index is *upper reachability* or the highest prestige score of the occupations to which the individual has access (Van der Gaag et al., 2008). The third index is *range,* measures the difference between the highest and lowest occupational prestige scores to which the individual has access to determine the range of access to those with varying occupational prestige (Van der Gaag et al., 2008).

To measure contact resources, participants can complete the resource generator which asks participants to identify contacts associated with a fixed list of concrete social resources across multiple life domains such as help when the individual is ill, help when needing to borrow something, or help during major life events, etc. (Snidjers, 1999; Van der Gaag et al., 2008). Social capital is thought to be the sum score of access to all types of resources with those having greater access to resources being deemed to have higher social capital.

Coleman: Social & Structural Resources

Coleman's theory of social capital criticized economists for prioritizing individualistic self-interests as a factor contributing to the development of social capital. Instead, Coleman further developed the ideas of Bourdieu and Lin by prioritizing the necessity for social interdependence for the development of an individuals' social capital. Coleman achieves this by defining social capital by its function, stating "It is not a single entity, but a variety of different entities having two characteristics in common: They all consist of some aspect of a social structure and they facilitate certain actions of individuals who are within that structure." (Coleman, 1990). Coleman carefully and purposefully developed his definition of social capital to be vague, as he was unsure how to appropriately determine the value of social capital as a quantifiable concept (Song et al., 2013). While his definition was intentionally broad, Coleman does provide six types of social capital (albeit, with no methods for measurement) that satisfy his definition's two characteristics (that they occur inherently in the social structure and facilitate functions within the social structure).

Interestingly, Coleman posed that social capital functioned in both positive and negative directions as well as at both individual and collective levels (Song et al., 2013). Coleman described five macro-level conditions which could work to raise and lower social capital in an area (Coleman, 1990). Three of the five macro-level conditions were though to raise social capital: maintenance of social relationships, encouraging altruistic behaviors, and trustworthiness (Coleman, 1990). The last two conditions were thought to lower social capital: higher independence and failing social relationships. Additionally, Coleman argued that in contrast to other forms of capital that can only be privately owned; social capital is a property of the social structure stating that social capital not only benefits those who contribute to it within a community, but all the members of the community as a whole (Coleman, 1990).

Putnam: Helping Features of Social Organization

Putnam describes social capital as "social networks and the norms of reciprocity and trustworthiness that arise from them" (Putnam, 2000, p. 19.). Putnam poses that social networks are composed of the growth and sustainment of formal and informal social connections. Formal social connections include membership or participation in political, educational, and/or religious organizations and activities, as well as relationships with those in the workplace (Putnam, 2000). Alternatively, informal social connections are those which include participation with friends, family, and neighbors in informal leisure activities (Putnam, 2000). Putnam, similar to Coleman, supports the idea that social capital is both a "private good" and a "public good", and proposes that social capital is an inherent property of the social structure. Essentially when individuals engage in helpful behaviors, they too will receive help from others when needed (Putnam, 2000; Song et al., 2013).

Putnam 2000 describes that there are two subtypes of social capital, which he terms bonding and bridging. Bonding social capital refers to greater connections between members of a group, whereas bridging social capital refers to the greater connections to others outside of the group to obtain goods or services not available within the group. One study used a longitudinal sample of older individuals living in Japan to evaluate the association between bonding and bridging social capital on cognitive performance (Murayama et al., 2013). Due to the ethnic heterogeneity in the study region bonding social capital was measured by perceived homogeneity within the area (how similar the participant feels to others) in their social networks performance (Murayama et al., 2013). Alternatively, bridging social capital was evaluated through perceptions of heterogeneity (how dis-similar participants felt to others) in their social networks performance (Murayama et al., 2013). This study found support for individuals who had strong perceived heterogeneous networks or strong social networks with individuals who were ethnically different, were associated with less cognitive decline at follow up than individuals who had weak homogenous networks or weak social networks with individuals who were ethnically similar performance (Murayama et al., 2013).

An additional article by this research team was recently published (2018) which evaluated social capital's association with subjective symptoms of dementia in older Japanese individuals (Murayama et al., 2018). This study found evidence for individuals with denser neighborhood networks to be less likely to have subjective dementia symptoms for women only (Murayama et al., 2018). Because of the limited number of studies, further research investigating the associations between social capital and cognitive performance is greatly warranted.

This dissertation most closely aligns with the theoretical conceptualization of social capital proposed by Putnam in that social capital is a public and private good that supports the well-being of the members of the community (Putnam, 2000). Putnam developed a social capital index which could be used to assess the amount of social capital in each state (Putnam, 2000). This index was later developed for analysis at the county level by combining factors that Putnam and other have suggested contribute to social capital (Northeast Regional Center for Rural Development, 2019; Rupasingha et al., 2006). The county level social capital index considers the number of local membership organizations, as well as measures of community participation such as voter turnout and census response rates to create a continuous scale of social capital (Northeast Regional Center for Rural Development, 2019; Rupasingha et al., 2006). This county level measure of social capital as well as individual level facets of social capital such as social support, social networks and perceived support will be used in this dissertation to evaluate geographic differences in social capital and social capital's associations with activity engagement and physical health.

Purpose and Research Aims

The primary purpose of this dissertation is to examine implications for rural or urban living on activity engagement and cognitive performance using participants who are at the cusp of midlife. This dissertation will also examine the relationship between social capital to activity engagement and cognitive performance across rural and urban residing individuals. A conceptual model for the full dissertation can be found in Figure 1. In brief, the conceptual model proposes moderators and mediators of cognitive performance focusing on adults on the verge of midlife, suggesting that social capital may mediate the relationship between activity engagement and cognitive performance.

Moreover, rurality is viewed as serving a moderator of these associations given that prior work suggests geographic differences in activity engagement and social capital.

This dissertation will evaluate features of the conceptual model in three studies. Study 1 will replicate and expand upon previous literature by adapting the Index of Relative Rurality to the census tract level or IRRtract (a level of analysis not previously done). Study 1 will use data from the US Census to develop the IRRtract for each census tract and each county in which our participants reside to understand if valuable information is gained by evaluating participants on a more proximal scale (census tract) as compared to a more distal scale (county). Study 1 will use the proximal measure of rurality (IRRtract to evaluate geographic differences in the type of activity engagement (i.e. quality of activity engagement)) and the amount of time spend on leisure time activities (i.e. quantity of activity engagement). Referring to the conceptual model for this dissertation (Figure 1), Study 1 evaluates the relationships between activity engagement and IRR (i.e. the blue boxes). Using the IRR created in Study 1, Study 2 of the dissertation will examine geographic differences in social capital and its related facets such as social support. Additionally, Study 2 will examine social capital's association to geographic differences in physical health (not shown in conceptual model), as it may be salient to cognitive differences if rural disparities in health are likewise observed. Referring to Figure 1, Study 2 evaluates the relationship between social capital and IRR (i.e. the red boxes). Study 3 will build upon Studies 1 and 2 and use the IRR to evaluate geographic differences in cognitive performance across rural and urban residing individuals while controlling for contributing variables such as activity engagement and other covariates (i.e. educational attainment, occupational attainment, etc.). Referring to Figure 1, this would be the split blue and red box to the purple box. Study 3 will additionally evaluate the relationship between social capital and cognitive performance, a relationship that has not been previously evaluated. Referring to Figure 1, this would be the b path. Moreover, Study 3 will examine the role social capital may play as a mediator between activity engagement and cognitive performance. Referring to Figure 1, this would be the a and b paths. Last, Study 3 will address the full conceptual model presented in Figure 1 and evaluate whether the associations between activity engagement, social capital, and cognitive performance are moderated by extent of rurality/urbanization.

This model will be applied to data collected in the ongoing Colorado Adoption/Twin Study of Lifespan behavioral development and cognitive aging (CATSLife) (Wadsworth et al., 2019a, 2019b). CATSLife leverages rich two samples from foundational longitudinal studies of twins and adoptees to evaluate etiologies of individual differences on behavioral development and cognitive aging. As described in subsequent chapters, the CATSLife participants are approaching midlife, now on average 33 years, an ideal sample to test spatial and behavioral factors important to cognitive functioning. Midlife is a critical period in human development. Midlife often requires individuals to balance many roles (e.g. work and family), become a bridge between previous and successive generations (i.e. the link between aging parents and adult children), and is the link between early life and aging (Infurna et al., 2020). Despite mid-life's critical role the lifespan, the available literature concerning this developmental period is lacking, particularly with respect to cognition (Infurna et al., 2020). Although the literature concerning mid-life is lacking, there are interesting findings beginning to surface suggesting that developmental periods leading up to midlife may be important as well. Longitudinal studies such as Add Health have evaluated similarly aged individuals as CATSLife (24-34) demonstrating that there are geographic differences in cardiovascular health that can already be identified at this relatively early point in the lifespan (Lawrence et al., 2017). Another study which utilized the same sample but at a later point in the lifespan (32-42), has similarly found geographic differences but with respect to inflammatory biomarkers (Cole et al., 2020). Because CATSLife participants are in the developmental period prior to the transition to midlife, it provides a unique opportunity to contribute an understudied period of adult development. Moreover, the sibling structure in CATSLife makes it possible to evaluate evidence of similarity between siblings with respect to geospatial features and behaviors and thus to address possibly selectivity in spatial-behavioral associations, although longitudinal designs would of course be stronger.

Aims & Research Questions

Aim 1: Adapt the IRRcounty to the census tract level (IRRtract), to create a method for examining rurality at a finer geographic scale.

Research Question 1a: What knowledge is gained from examining variables (e.g. activity engagement) on geographic area that is more proximal to the participants daily life (IRRtract) compared to a larger geographic area that is more distal to the participants daily life (IRRcounty)?

Research Question 1b: How does leisure time activity engagement differ qualitatively (i.e. types of activity) and quantitively (i.e. hours per week) across rural and urban residing individuals for each domain of activity engagement (i.e. cognitive, physical, social)?

Aim 2: *Examine social capital and its facets such as social support across rural and urban residing individuals.*

Research Question 2a: How does social capital and its facets, such as social support, differ across rural and urban residing individuals?

Research Question 2b: How does social capital and its facets relate to physical health differences between rural and urban residing individuals?

Aim 3. *Examine how activity engagement and social capital influence cognitive performance in mid-life and how it differs across rural and urban residing individuals.*

Research Question 3a. Are there significant differences cognitive performance for rural and urban residing individuals when controlling for relevant covariates, such as educational attainment and occupational complexity?

Research Question 3b. What is the association between activity engagement, as mediated by social capital, on cognitive performance when controlling for relevant covariates?

Research Question 3c. Do the associations between activity engagement, as mediated by social capital, on cognitive performance differ for rural and urban residing individuals?

References

Aronson, R. E., & Oman, R. F. (2004). Views on Exercise and Physical Activity Among Rural-Dwelling Senior Citizens. *The Journal of Rural Health*, *20*(1), 76–79. https://doi.org/10.1111/j.1748-0361.2004.tb00010.x

Barber, C. E. (2013). Perceptions of Aging-Friendly Community Characteristics: Does County Rurality Make a Difference? *Online Journal of Rural Research & Policy*, *8*(2). https://doi.org/10.4148/ojrrp.v8i2.1944

Barnes, L. L., De Leon, C. M., Wilson, R. S., Bienias, J. L., & Evans, D. A. (2004). Social resources and cognitive decline in a population of older African Americans and whites. *Neurology*, *63*(12), 2322–2326.

Bassuk, S. S., Glass, T. A., & Berkman, L. F. (1999). Social disengagement and incident cognitive decline in community-dwelling elderly persons. *Annals of Internal Medicine*, *131*(3), 165–173.

Beaudoin, C. E., & Thorson, E. (2004). Social Capital in Rural and Urban Communities: Testing Differences in Media Effects and Models. *Journalism & Mass Communication Quarterly*, *81*(2), 378–399. https://doi.org/10.1177/107769900408100210

Befort, C. A., Nazir, N., & Perri, M. G. (2012). Prevalence of obesity among adults from rural and urban areas of the United States: Findings from NHANES (2005-2008). *The Journal of Rural Health*, *28*(4), 392–397.

Behringer, B., Friedell, G. H., Dorgan, K. A., Hutson, S. P., Naney, C., Phillips, A., & Cantrell, E. (2007). Understanding the challenges of reducing cancer in Appalachia: Addressing a place-based health disparity population. *Californian Journal of Health Promotion*, *5*, 40–49.

Bennett, D. A., Schneider, J. A., Tang, Y., Arnold, S. E., & Wilson, R. S. (2006). The effect of social networks on the relation between Alzheimer's disease pathology and level of cognitive function in old people: A longitudinal cohort study. *The Lancet Neurology*, *5*(5), 406–412.

Berardi, N., Braschi, C., Capsoni, S., Cattaneo, A., & Maffei, L. (2007). Environmental enrichment delays the onset of memory deficits and reduces neuropathological hallmarks in a mouse model of Alzheimer-like neurodegeneration. *Journal of Alzheimer's Disease*, *11*(3), 359–370.

Bot, S. D., Mackenbach, J. D., Nijpels, G., & Lakerveld, J. (2016). Association between Social Network Characteristics and Lifestyle Behaviours in Adults at Risk of

Diabetes and Cardiovascular Disease. *PLOS ONE*, *11*(10), e0165041. https://doi.org/10.1371/journal.pone.0165041

Bourdieu, P., & Richardson, J. G. (1986). The forms of capital. In *Handbook of Theory and Research for the Sociology of Education.* (pp. 241–258). Westport: Greenwood Press.

Beaudoin, C. E., & Thorson, E. (2004). Social Capital in Rural and Urban Communities: Testing Differences in Media Effects and Models. *Journalism & Mass Communication Quarterly*, *81*(2), 378–399. https://doi.org/10.1177/107769900408100210

Bronfenbrenner, U., & Ceci, S. J. (1994). Nature-nuture reconceptualized in developmental perspective: A bioecological model. *Psychological Review*, *101*(4), 568–586. https://doi.org/10.1037/0033-295X.101.4.568

Bureau, U. C. (2003). *Core-Based Statistical Areas*. The United States Census Bureau. https://www.census.gov/topics/housing/housing-patterns/about/core-based-statistical-areas.html

Bureau, U. C. (2010). *2010 Census Urban and Rural Classification and Urban Area Criteria*. The United States Census Bureau. https://www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural/2010-urban-rural.html

Cassarino, M., & Setti, A. (2015). Environment as 'Brain Training': A review of geographical and physical environmental influences on cognitive ageing. *Ageing Research Reviews*, *23*, 167–182. https://doi.org/10.1016/j.arr.2015.06.003

Chan, T., Parisi, J. M., Moored, K. D., & Carlson, M. C. (2018b). Variety of Enriching Early Life Activities Linked to Late Life Cognitive Functioning in Urban Community-Dwelling African Americans. *The Journals of Gerontology: Series B*.

Clark, A. (1999). An embodied cognitive science? *Trends in Cognitive Sciences*, *3*(9), 345–351. https://doi.org/10.1016/S1364-6613(99)01361-3

Clarke, P. J., Ailshire, J. A., House, J. S., Morenoff, J. D., King, K., Melendez, R., & Langa, K. M. (2012). Cognitive function in the community setting: The neighbourhood as a source of 'cognitive reserve'? *J Epidemiol Community Health*, *66*(8), 730–736.

Cohen, D. A., McKenzie, T. L., Sehgal, A., Williamson, S., Golinelli, D., & Lurie, N. (2007). Contribution of public parks to physical activity. *American Journal of Public Health*, *97*(3), 509–514.

Cole, S. W., Shanahan, M. J., Gaydosh, L., & Harris, K. M. (2020). Population-based RNA profiling in Add Health finds social disparities in inflammatory and antiviral gene regulation to emerge by young adulthood. *Proceedings of the National Academy of Sciences*, *117*(9), 4601–4608.

Coleman, J. (1990). *Foundations of social theory. Cambridge, MA: Belknap Press of Harvard University Press*.

Cramm, J. M., van Dijk, H. M., & Nieboer, A. P. (2013). The Importance of Neighborhood Social Cohesion and Social Capital for the Well Being of Older Adults in the Community. *The Gerontologist*, *53*(1), 142–152. https://doi.org/10.1093/geront/gns052

De Carolis, D. M., Litzky, B. E., & Eddleston, K. A. (2009). Why Networks Enhance the Progress of New Venture Creation: The Influence of Social Capital and Cognition. *Entrepreneurship Theory and Practice*, *33*(2), 527–545. https://doi.org/10.1111/j.1540-6520.2009.00302.x

De Carolis, D. M., & Saparito, P. (2006). Social Capital, Cognition, and Entrepreneurial Opportunities: A Theoretical Framework. *Entrepreneurship Theory and Practice*, *30*(1), 41–56. https://doi.org/10.1111/j.1540-6520.2006.00109.x

De Fockert, J. W., Caparos, S., Linnell, K. J., & Davidoff, J. (2011). Reduced distractibility in a remote culture. *PLoS One*, *6*(10), e26337.

De Montis, A., Caschili, S., & Trogu, D. (2012, June 13). *Accessibility, Rurality and Remoteness: An Investigation on the Island of Sardinia, Italy. In Planning Support Tools: Policy Analysis, Implementation and Evaluation.* Proceedings of the Seventh International Conference on Informatics and Urban and Regional Planning INPUT2012: 155.

Deng, Y., & Paul, D. R. (2018). The Relationships Between Depressive Symptoms, Functional Health Status, Physical Activity, and the Availability of Recreational Facilities: A Rural-Urban Comparison in Middle-Aged and Older Chinese Adults. *International Journal of Behavioral Medicine*, *25*(3), 322–330. https://doi.org/10.1007/s12529-018-9714-3

Eberhardt, M. S., & Pamuk, E. R. (2004). The Importance of Place of Residence: Examining Health in Rural and Nonrural Areas. *American Journal of Public Health*, *94*(10), 1682–1686. https://doi.org/10.2105/AJPH.94.10.1682

Ertel, K. A., Glymour, M. M., & Berkman, L. F. (2008). Effects of social integration on preserving memory function in a nationally representative US elderly population. *American Journal of Public Health*, *98*(7), 1215–1220.

Eyler, A. A., & Vest, J. R. (2002). Environmental and Policy Factors Related to Physical Activity in Rural White Women. *Women & Health*, *36*(2), 109–119. https://doi.org/10.1300/J013v36n02_08

Gallardo, R., & Scammahorn, R. (2011). Determinants of innovative versus non-innovative entrepreneurs in three southern states. *Review of Regional Studies*, *41*(2, 3), 103–117.

Gatz, M., Prescott, C. A., & Pedersen, N. L. (2006). Lifestyle risk and delaying factors. *Alzheimer Disease & Associated Disorders*, *20*, S84–S88.

Glymour, M. M., & Manly, J. J. (2008). Lifecourse social conditions and racial and ethnic patterns of cognitive aging. *Neuropsychology Review*, *18*(3), 223–254.

Gow, A. J., Pattie, A., & Deary, I. J. (2017). Lifecourse Activity Participation From Early, Mid, and Later Adulthood as Determinants of Cognitive Aging: The Lothian Birth Cohort 1921. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *72*(1), 25–37. https://doi.org/10.1093/geronb/gbw124

Handy, S. L., Boarnet, M. G., Ewing, R., & Killingsworth, R. E. (2002). How the built environment affects physical activity: Views from urban planning. *American Journal of Preventive Medicine*, *23*(2), 64–73.

Harati, H., Majchrzak, M., Cosquer, B., Galani, R., Kelche, C., Cassel, J.-C., & Barbelivien, A. (2011). Attention and memory in aged rats: Impact of lifelong environmental enrichment. *Neurobiology of Aging*, *32*(4), 718–736.

Harris, J. K., Beatty, K., Leider, J. P., Knudson, A., Anderson, B. L., & Meit, M. (2016). The Double Disparity Facing Rural Local Health Departments. *Annual Review of Public Health*, *37*(1), 167–184. https://doi.org/10.1146/annurev-publhealth-031914-122755

Heflin, C., & Miller, K. (2012). The geography of need: Identifying human service needs in rural America. *Journal of Family Social Work*, *15*(5), 359–374.

Hoang, T. D., Reis, J., Zhu, N., Jacobs, D. R., Launer, L. J., Whitmer, R. A., Sidney, S., & Yaffe, K. (2016). Effect of early adult patterns of physical activity and television viewing on midlife cognitive function. *JAMA Psychiatry*, *73*(1), 73–79.

Holtzman, R. E., Rebok, G. W., Saczynski, J. S., Kouzis, A. C., Wilcox Doyle, K., & Eaton, W. W. (2004). Social network characteristics and cognition in middle-aged and older adults. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *59*(6), P278–P284.

Hubach, R. D., Dodge, B., Cola, T., Battani, P. R., & Reece, M. (2014). *Assessing the Sexual Health Needs of Men Who Have Sex with Men (MSM) Residing in Rural and Mixed Rural Areas*. The Health Education Monograph Series, 31(2), 33-39.

Inagami, S., Gao, S., Karimi, H., Shendge, M. M., Probst, J. C., & Stone, R. A. (2016). Adapting the Index of Relative Rurality (IRR) to Estimate Rurality at the ZIP Code Level: A Rural Classification System in Health Services Research: Adapting the Index of Relative Rurality. *The Journal of Rural Health*, *32*(2), 219–227. https://doi.org/10.1111/jrh.12148

Infurna, F. J., Gerstorf, D., & Lachman, M. E. (2020). Midlife in the 2020s: Opportunities and challenges. *American Psychologist*, *75*(4), 470–485. https://doi.org/10.1037/amp0000591

Jankowsky, J. L., Melnikova, T., Fadale, D. J., Xu, G. M., Slunt, H. H., Gonzales, V., Younkin, L. H., Younkin, S. G., Borchelt, D. R., & Savonenko, A. V. (2005). Environmental enrichment mitigates cognitive deficits in a mouse model of Alzheimer's disease. *Journal of Neuroscience*, *25*(21), 5217–5224.

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, *15*(3), 169–182.

Karp, A., Paillard-Borg, S., Wang, H.-X., Silverstein, M., Winblad, B., & Fratiglioni, L. (2006). Mental, physical and social components in leisure activities equally contribute to decrease dementia risk. *Dementia and Geriatric Cognitive Disorders*, *21*(2), 65–73.

Kaza, N. (2013). The changing urban landscape of the continental United States. *Landscape and Urban Planning*, *110*, 74–86. https://doi.org/10.1016/j.landurbplan.2012.10.015

Kelly, M. E., Duff, H., Kelly, S., McHugh Power, J. E., Brennan, S., Lawlor, B. A., & Loughrey, D. G. (2017). The impact of social activities, social networks, social support and social relationships on the cognitive functioning of healthy older adults: A systematic review. *Systematic Reviews*, *6*(1), 259. https://doi.org/10.1186/s13643-017-0632-2

Krabbendam, L., & Van Os, J. (2005). Schizophrenia and urbanicity: A major environmental influence—conditional on genetic risk. *Schizophrenia Bulletin*, *31*(4), 795–799.

Krueger, K. R., Wilson, R. S., Kamenetsky, J. M., Barnes, L. L., Bienias, J. L., & Bennett, D. A. (2009). Social engagement and cognitive function in old age. *Experimental Aging Research*, *35*(1), 45–60.

Laidley, T., Vinneau, J., & Boardman, J. D. (2019). Individual and Social Genomic Contributions to Educational and Neighborhood Attainments: Geography, Selection, and Stratification in the United States. *Sociological Science*, *6*, 580–608. https://doi.org/10.15195/v6.a22

Lambert, D. M., Wilcox, M. D., Clark, C. D., Murphy, B., & Park, W. M. (2010). Is growth in the health sector correlated with later-life migration? In *Progress in Spatial Analysis* (pp. 381–403). Springer.

Lawrence, E., Hummer, R. A., & Harris, K. M. (2017). The cardiovascular health of young adults: Disparities along the urban-rural continuum. *The Annals of the American Academy of Political and Social Science*, *672*(1), 257–281.

Lin, N. (1999). Building a Network Theory of Social Capital. In N. Lin, R. Cook, & S. Burt, (Eds.), *Social Capital: Theory and Research.* Aldine de Gruyter.

Lin, N. (2002a). *Social Capital: A Theory of Social Structure and Action*. Cambridge University Press.

Lin, N. (1982). Social Resources and Instrumental Action. In P. V. Marsden & N. Lin (Eds.), *Social Structure and Network Analysis.* (pp. 131–145). Sage. https://scholar.google.com/scholar_lookup?title=Social%20resources%20and%20instrumental%20action&author=N.%20Lin&pages=131-145&publication_year=1982

Lin, Nan, & Dumin, M. (1986). Access to occupations through social ties. *Social Networks*, *8*(4), 365–385.

Litwin, H., & Stoeckel, K. J. (2015). Social Network, Activity Participation, and Cognition: A Complex Relationship. *Research on Aging*, *38*(1), 76–97. https://doi.org/10.1177/0164027515581422

Mainous, A. G., & Kohrs, F. P. (1995). A comparison of health status between rural and urban adults. *Journal of Community Health*, *20*(5), 423–431.

Mammen, S., Lawrence, F. C., Marie, P. S., Berry, A. A., & Knight, S. E. (2011). The earned income tax credit and rural families: Differences between non-participants and participants. *Journal of Family and Economic Issues*, *32*(3), 461–472.

Martin, M., & Zimprich, D. (2005). Cognitive development in midlife. *Middle Adulthood: A Lifespan Perspective*, 179–206.

Meng, T., & Chen, H. (2014). A multilevel analysis of social capital and self-rated health: Evidence from China. *Health & Place*, *27*, 38–44. https://doi.org/10.1016/j.healthplace.2014.01.009

Michael, Y. L., Green, M. K., & Farquhar, S. A. (2006). Neighborhood design and active aging. *Health & Place*, *12*(4), 734–740.

Murayama, H., Sugiyama, M., Inagaki, H., Okamura, T., Miyamae, F., Ura, C., Edahiro, A., Motokawa, K., & Awata, S. (2018). Is community social capital associated with subjective symptoms of dementia among older people? A cross-sectional study in Japan: Social capital and dementia symptoms. *Geriatrics & Gerontology International*. https://doi.org/10.1111/ggi.13519

Nahapiet, J., & Ghoshal, S. (1998). Social Capital, Intellectual Capital, and the Organizational Advantage. *The Academy of Management Review*, *23*(2), 242–266. JSTOR. https://doi.org/10.2307/259373

Northeast Regional Center for Rural Development, S. C. V. for 2014. (2019). *Social Capital Variables for 2014 (Northeast Regional Center for Rural Development)*. Northeast Regional Center for Rural Development (Penn State University). https://aese.psu.edu/nercrd/community/social-capital-resources/social-capital-variables-for-2014

Onyx, J., & Bullen, P. (2000). Measuring Social Capital in Five Communities. *The Journal of Applied Behavioral Science*, *36*(1), 23–42. https://doi.org/10.1177/0021886300361002

Patterson, P. D., Moore, C. G., Probst, J. C., & Shinogle, J. A. (2004). Obesity and Physical Inactivity in Rural America. *The Journal of Rural Health*, *20*(2), 151–159. https://doi.org/10.1111/j.1748-0361.2004.tb00022.x

Paúl, C., Fonseca, A. M., Martín, I., & Amado, J. (2003). Psychosocial profile of rural and urban elders in Portugal. *European Psychologist*, *8*(3), 160.

Peen, J., Schoevers, R. A., Beekman, A. T., & Dekker, J. (2010). The current status of urban-rural differences in psychiatric disorders. *Acta Psychiatrica Scandinavica*, *121*(2), 84–93. https://doi.org/10.1111/j.1600-0447.2009.01438.x

Putnam, R. D. (2000). Bowling alone: The Collapse and Revival of American Community. In *Bowling alone: The Collapse and Revival of American Community*. Simon & Schuster.

Richards, M., & Wadsworth, M. (2004). Long term effects of early adversity on cognitive function. *Archives of Disease in Childhood*, *89*(10), 922–927.

Romans, S., Cohen, M., & Forte, T. (2011). Rates of depression and anxiety in urban and rural Canada. *Social Psychiatry and Psychiatric Epidemiology*, *46*(7), 567–575.

Rupasingha, A., Goetz, S. J., & Freshwater, D. (2006). The production of social capital in US counties. *The Journal of Socio-Economics*, *35*(1), 83–101. https://doi.org/doi:10.1016/j.socec.2005.11.001

Russ, T. C., Batty, G. D., Hearnshaw, G. F., Fenton, C., & Starr, J. M. (2012). Geographical variation in dementia: Systematic review with meta-analysis. *International Journal of Epidemiology*, *41*(4), 1012–1032. https://doi.org/10.1093/ije/dys103

Saelens, B. E., & Handy, S. L. (2008). Built environment correlates of walking: A review. *Medicine and Science in Sports and Exercise*, *40*(7 Suppl), S550.

Saenz, J. L., Downer, B., Garcia, M. A., & Wong, R. (2018). Cognition and Context: Rural–Urban Differences in Cognitive Aging Among Older Mexican Adults. *Journal of Aging and Health*, *30*(6), 965–986. https://doi.org/10.1177/0898264317703560

Sallis, J. F., Bowles, H. R., Bauman, A., Ainsworth, B. E., Bull, F. C., Craig, C. L., Sjöström, M., De Bourdeaudhuij, I., Lefevre, J., Matsudo, V., Matsudo, S., Macfarlane, D. J., Gomez, L. F., Inoue, S., Murase, N., Volbekiene, V., McLean, G., Carr, H., Heggebo, L. K., … Bergman, P. (2009). Neighborhood Environments and Physical Activity Among Adults in 11 Countries. *American Journal of Preventive Medicine*, *36*(6), 484–490. https://doi.org/10.1016/j.amepre.2009.01.031

Salthouse, T. A. (2009). When does age-related cognitive decline begin? *Neurobiology of Aging*, *30*(4), 507–514.

Salthouse, T. A., Berish, D. E., & Miles, J. D. (2002). The role of cognitive stimulation on the relations between age and cognitive functioning. *Psychology and Aging*, *17*(4), 548–557. https://doi.org/10.1037/0882-7974.17.4.548

Salvo, G., Lashewicz, B. M., Doyle-Baker, P. K., & McCormack, G. R. (2018). Neighbourhood Built Environment Influences on Physical Activity among Adults: A Systematized Review of Qualitative Evidence. *International Journal of Environmental Research and Public Health*, *15*(5), 897. https://doi.org/10.3390/ijerph15050897

Sampaio, P. Y. S., Ito, E., & Carvalho Sampaio, R. A. (2013). The association of activity and participation with quality of life between Japanese older adults living in rural and urban areas. *Journal of Clinical Gerontology and Geriatrics*, *4*(2), 51–56. https://doi.org/10.1016/j.jcgg.2012.11.004

Sampson, R. J. (1988). Local Friendship Ties and Community Attachment in Mass Society: A Multilevel Systemic Model. *American Sociological Review*, *53*(5), 766–779. https://doi.org/10.2307/2095822

Sanderson, B., Littleton, M., & Pulley, L. V. (2002). Environmental, Policy, and Cultural Factors Related to Physical Activity Among Rural, African American Women. *Women & Health*, *36*(2), 73–88. https://doi.org/10.1300/J013v36n02_06

Scarmeas, N., Levy, G., Tang, M.-X., Manly, J., & Stern, Y. (2001). Influence of leisure activity on the incidence of Alzheimer's disease. *Neurology*, *57*(12), 2236–2242.

Singh, G. K., & Siahpush, M. (2014). Widening Rural–Urban Disparities in Life Expectancy, U.S., 1969–2009. *American Journal of Preventive Medicine*, *46*(2), e19–e29. https://doi.org/10.1016/j.amepre.2013.10.017

Smith, K. B., Humphreys, J. S., & Wilson, M. G. (2008). Addressing the health disadvantage of rural populations: How does epidemiological evidence inform rural health policies and research? *Australian Journal of Rural Health*, *16*(2), 56–66. https://doi.org/doi: 10.1111/j.1440-1584.2008.00953.x

Snidjers, T. A. B. (1999). Prologue to the measurement of social capital. *La Revue Tocqueville, 20(01).*

Sofi, F., Valecchi, D., Bacci, D., Abbate, R., Gensini, G. F., Casini, A., & Macchi, C. (2011). Physical activity and risk of cognitive decline: A meta-analysis of prospective studies. *Journal of Internal Medicine*, *269*(1), 107–117.

Song, L., Son, J., & Lin, N. (2013). *Social capital and health* (W. C. Cockerham, Ed.). Springer.

Sørensen, J. F. L. (2012). Testing the Hypothesis of Higher Social Capital in Rural Areas: The Case of Denmark. *Regional Studies*, *46*(7), 873–891. https://doi.org/10.1080/00343404.2012.669471

Sørensen, J. F. L. (2016). Rural–Urban Differences in Bonding and Bridging Social Capital. *Regional Studies*, *50*(3), 391–410. https://doi.org/10.1080/00343404.2014.918945

Stewart, L. A., & Lambert, D. M. (2008). *Factors determining corn-based ethanol plant site selection, 2000-2007.* (No. 812-2016-52579).

Sundquist, K., Frank, G., & Sundquist, J. A. N. (2004). Urbanisation and incidence of psychosis and depression: Follow-up study of 4.4 million women and men in Sweden. *The British Journal of Psychiatry*, *184*(4), 293–298.

Taaffe, D. R., Irie, F., Masaki, K. H., Abbott, R. D., Petrovitch, H., Ross, G. W., & White, L. R. (2008). Physical activity, physical function, and incident dementia in elderly men: The Honolulu–Asia Aging Study. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *63*(5), 529–535.

Trivedi, T., Liu, J., Probst, J., Merchant, A., Jones, S., & Martin, A. (2015). Obesity and obesity-related behaviors among rural and urban adults in the USA. *Rural Remote Health*, *15*(4), 11.

USDA, E. (2010). *USDA ERS - Rural-Urban Commuting Area Codes*. Rural-Urban Commuting Area Codes. https://www.ers.usda.gov/data-products/rural-urban-commuting-area-codes/

USDA, E. (2013). *USDA ERS - Rural-Urban Continuum Codes*. https://www.ers.usda.gov/data-products/rural-urban-continuum-codes/

Van der Gaag, M., Snijders, T. A., & Flap, H. D. (2008). *Position generator measures and their relationship to other social capital measures* (Nan Lin & B. Erickson H., Eds.). Oxford University Press USA.

Vogelsang, E. M. (2016). Older adult social participation and its relationship with health: Rural-urban differences. *Health & Place*, *42*, 111–119. https://doi.org/10.1016/j.healthplace.2016.09.010

Wadsworth, S. J., Corley, R. P., Munoz, E., Trubenstein, B. P., Knaap, E., DeFries, J. C., Plomin, R., Reynolds, C. A., & The CATSLife Team. (2019a). CATSLife: A Study of Lifespan Behavioral Development and Cognitive Functioning. *Twin Research and Human Genetics*, *22*(6), 695–706. https://doi.org/10.1017/thg.2019.49

Wadsworth, S. J., Corley, R. P., Munoz, E., Trubenstein, B. P., Knaap, E., DeFries, J. C., Plomin, R., Reynolds, C. A., & The CATSLife Team. (2019b). CATSLife: A Study of Lifespan Behavioral Development and Cognitive Functioning – Corrigendum. *Twin Research and Human Genetics*, *22*(6), 829–829. https://doi.org/10.1017/thg.2019.126

Wahl, H.-W., Iwarsson, S., & Oswald, F. (2012). Aging well and the environment: Toward an integrative model and research agenda for the future. *The Gerontologist*, *52*(3), 306–316.

Waldorf, B. (2006). *A Continuous Multi-Dimensional Measure of Rurality: Moving Beyond Threshold Measures*. Selected Paper, Annual Meetings of the Association of Agricultural Economics, Long Beach, CA, July 2006.

Waldorf, B., & Ayoung, K. (2015). *Defining And Measuring Rurality in the US: From Typologies to Continuous Indices*. 26. https://doi.org/doi:10.4231/R7959FS8

Wang, H.-X., Karp, A., Winblad, B., & Fratiglioni, L. (2002b). Late-Life Engagement in Social and Leisure Activities Is Associated with a Decreased Risk of Dementia: A Longitudinal Study from the Kungsholmen Project. *American Journal of Epidemiology*, *155*(12), 1081–1087. https://doi.org/10.1093/aje/155.12.1081

Wang, H.-X., MacDonald, S. W., Dekhtyar, S., & Fratiglioni, L. (2017a). Association of lifelong exposure to cognitive reserve-enhancing factors with dementia risk: A community-based cohort study. *PLoS Medicine*, *14*(3), e1002251.

Wanless, D., Mitchell, B. A., & Wister, A. V. (2010). Social determinants of health for older women in Canada: Does rural–urban residency matter? *Canadian Journal on Aging/La Revue Canadienne Du Vieillissement*, *29*(2), 233–247.

Weden, M. M., Shih, R. A., Kabeto, M. U., & Langa, K. M. (2018). Secular Trends in Dementia and Cognitive Impairment of U.S. Rural and Urban Older Adults. *American Journal of Preventive Medicine*, *54*(2), 164–172. https://doi.org/10.1016/j.amepre.2017.10.021

Weeks, W. B., Kazis, L. E., Shen, Y., Cong, Z., Ren, X. S., Miller, D., Lee, A., & Perlin, J. B. (2004). Differences in health-related quality of life in rural and urban veterans. *American Journal of Public Health*, *94*(10), 1762–1767. https://doi.org/10.2105/AJPH.94.10.1762

Wen, M., Browning, C. R., & Cagney, K. A. (2003). Poverty, affluence, and income inequality: Neighborhood economic structure and its implications for health. *Social Science & Medicine*, *57*(5), 843–860. https://doi.org/10.1016/S0277-9536(02)00457-4

Wen, M., Fan, J. X., Kowaleski-Jones, L., & Wan, N. (2018). Rural–urban disparities in obesity prevalence among working age adults in the United States: Exploring the mechanisms. *American Journal of Health Promotion*, *32*(2), 400–408. https://doi.org/DOI: 10.1177/0890117116689488

Wilcox, S., Castro, C., King, A., Housemann, R., & Brownson, R. (2000). Determinants of leisure time physical activity in rural compared with urban older and ethnically diverse women in the United States. *Journal of Epidemiology & Community Health*, *54*(9), 667–672. https://doi.org/10.1136/jech.54.9.667

Wilson, Robert S., Boyle, P. A., Yu, L., Barnes, L. L., Schneider, J. A., & Bennett, D. A. (2013a). Life-span cognitive activity, neuropathologic burden, and cognitive aging. *Neurology*, 10–1212.

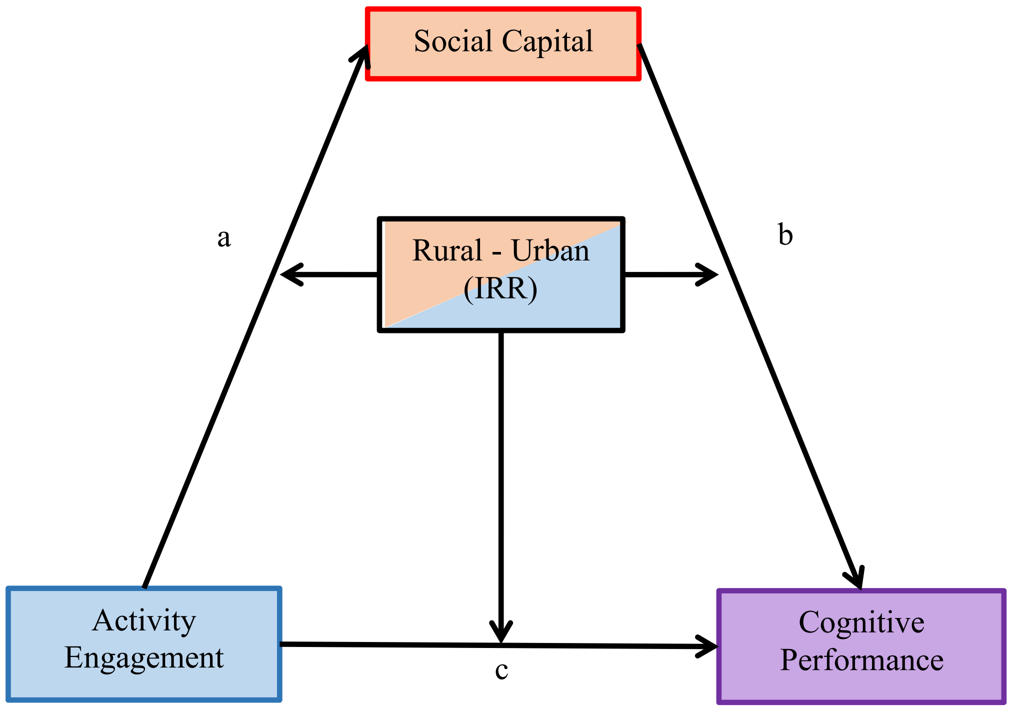
Wu, Y.-T., Prina, A. M., & Brayne, C. (2015). The association between community environment and cognitive function: A systematic review. *Social Psychiatry and Psychiatric Epidemiology*, *50*(3), 351–362. https://doi.org/10.1007/s00127-014-0945-6

Wu, Y.-T., Prina, A. M., Jones, A., Matthews, F. E., & Brayne, C. (2017). The Built Environment and Cognitive Disorders: Results From the Cognitive Function and Ageing Study II. *American Journal of Preventive Medicine*, *53*(1), 25–32. https://doi.org/10.1016/j.amepre.2016.11.020

Yankeelov, P. A., Faul, A. C., D'Ambrosio, J. G., Collins, W. L., & Gordon, B. (2015). "Another Day in Paradise": A Photovoice Journey of Rural Older Adults Living With Diabetes. *Journal of Applied Gerontology*, *34*(2), 199–218. https://doi.org/10.1177/0733464813493136

Ziersch, A. M., Baum, F., Darmawan, I. G. N., Kavanagh, A. M., & Bentley, R. J. (2009). Social capital and health in rural and urban communities in South Australia. *Australian and New Zealand Journal of Public Health*, *33*(1), 7–16. https://doi.org/10.1111/j.1753-6405.2009.00332.x

Figure 1.1: Conceptual Model of Dissertation



Chapter Two:

Evaluating Geographic Differences in Activity Engagement using the Index of Relative Rurality

Introduction

Understanding the context of a participant's environment is crucial for examining factors that influence behaviors impacting health and cognitive functioning (Cassarino & Setti, 2015; Clark, 1999; Gibson, 1991). The importance of context is not a new idea as ecological models have proposed that human development is the result of the interplay between human behavior and the contextual environment (Bronfenbrenner, 1979; Bronfenbrenner & Ceci, 1994; Canter & Craik, 1981). An individual's environment may afford or hinder engagement in any number of health behaviors (Aronson & Oman, 2004; Deng & Paul, 2018; Eyler & Vest, 2002; Sanderson et al., 2002; Wilcox et al., 2000; Yankeelov et al., 2015). For example, neighborhoods with sidewalks, streetlights and low crime would afford residents increased opportunity to engage in physical activity outside of the home and around the neighborhood (Sallis et al., 2009; Sanderson et al., 2002). Alternatively, neighborhoods with high crime or inadequate lighting would discourage resident's physical activity outside of the home (Sallis et al., 2009; Sanderson et al., 2002). Rural and urban neighborhoods may fundamentally differ in affordances (Matz et al., 2015; Parks et al., 2003; Salvo et al., 2018; Sanderson et al., 2002; Wen et al., 2018; Wu, Prina, Jones, Matthews, et al., 2017; Yankeelov et al., 2015). How to effectively define and distinguish between rurality and urbanicity has been a long-standing question in the social sciences, but the ability to do so may provide important information about individuals' patterns of activity engagement and health within neighborhoods. Developing a proximal measure of rurality/urbanicity will provide an index that is likely to be closely associated with individuals' perceived environments and health-related behaviors such as activity engagement.

Policy makers and researchers have developed seemingly unsatisfactory methods that attempt to distinguish rural areas from urban areas. While each of these previous methods define rural and urban areas differently, they share the common question, "Is this area rural or urban?" Often-used approaches dichotomize areas as rural or urban or categorize areas into levels of urbanicity based on pre-determined "thresholds" of a single variable or combination of variables (i.e. population, population density, distance to nearest metropolitan area, commuting patterns, etc.) (Bureau, 2003, 2010; USDA, 2010, 2013; Waldorf, 2006; Waldorf & Ayoung, 2015). This dichotomous and categorical coding can be problematic when trying to understand a participant's proximal environment due to misrepresentation of small areas based on large area data. Rather than considering rurality or urbanicity as a dichotomy, we adopt and extend the Index or Relative Rurality (IRR) which evaluates rurality or urbanicity on a continuum from 0 to 1 with 0 being the most urban areas and 1 being the most rural (Inagami et al., 2016; Waldorf, 2006; Waldorf & Ayoung, 2015).

Index of Relative Rurality (IRR)

The IRR is the only continuous measure of rurality and combines population size, population density, percent of urban population and remoteness (distance to nearest Metropolitan/Micropolitan Statistical Area) (Inagami et al., 2016; Waldorf, 2006;

Waldorf & Ayoung, 2015). The IRR measures an area's relative rurality using basic dimensions of environmental qualities and scores the area on a bounded scale ranging from 0 (completely urban) to 1 (completely rural) (Inagami et al., 2016; Waldorf, 2006; Waldorf & Ayoung, 2015).

Using the IRR offers many advantages that are unavailable in other measurements of rurality and urbanicity. The first is that the measure of rurality is not confined to one spatial scale (Inagami et al., 2016; Waldorf, 2006; Waldorf & Ayoung, 2015). Many of the categorical coding schemes can only be applied to the county or tract level. When using the IRR, the scale of rurality can be applied to larger areas such as states, or groups of counties, or to smaller areas such as zip codes (Inagami et al., 2016), townships or census tracts (Waldorf, 2006; Waldorf & Ayoung, 2015). Previous work on IRR has applied this scale at the county level (Waldorf, 2006; Waldorf & Ayoung, 2015) and to the zip code level (Inagami et al., 2016). Despite its adaptably to multiple geographic scales, to the best of our knowledge, this will be the first study to adapt the IRR to a scale as small as the census tract. Assessing rurality at the tract level allows for a more proximal measure of the participants environment. The second benefit of using the IRR is that it is very sensitive to small changes in any of the defining variables making it responsive to the multi-faceted nature of rurality (Waldorf, 2006; Waldorf & Ayoung, 2015). When using dichotomous or categorical coding methods, in many cases, there would have to be substantial changes in the contributing variables (e.g. population) to cross the threshold for moving into the next category of urbanicity or rurality (Waldorf, 2006; Waldorf & Ayoung, 2015). When using the IRR however, the combination of variables traditionally used to classify rurality (i.e. population, population density, percent urban, and remoteness) are combined and scaled onto a continuum rather than a categorical measure allowing for even slight changes in any of the contributing variables to be reflected in the IRR score. The third benefit of the IRR is that the measure of rurality becomes a measure that can be used for studying changes in rurality over time (Waldorf, 2006; Waldorf & Ayoung, 2015). Due to the sensitivity of the IRR, with available data (Waldorf, 2006), it is possible to evaluate small changes in rurality across time making it a beneficial tool for developmental psychologists.

Activity Engagement

Leisure time activity engagement has been well studied (Bennett et al., 2006; Chan et al., 2018a; Chen et al., 2020; Gow et al., 2017; Hoang et al., 2016; Karp et al., 2006; Phansikar & Mullen, 2019; Queen et al., 2019; Scarmeas et al., 2001; Sharifian et al., 2020; Sofi et al., 2011; Taaffe et al., 2008; Wang et al., 2002a, 2017a; Wilson et al., 2013a). Although there are many ways to characterize activity engagement, Schaie, Willis, Knight, Levey, & Park (2016) characterize leisure activities as those activities which are for emotional and/or aesthetic enjoyment (e.g. gardening or hobbies), relaxation (e.g. reading or playing card games), companionship (e.g. visiting with friends/family), religious observances/affiliation (e.g. attending services), and/or physical well-being (e.g. physical exercise) (Schaie et al., 2016). Most often, however, activities are discussed vis-à-vis domains of cognitive, social, or physical engagement. Cognitive activity engagement or participating in activities such as reading, doing crossword puzzles or playing strategic card/board games, has been associated with cognitive performance benefits (Lee et al., 2019; Scarmeas et al., 2001; Wilson et al., 2013a). Similarly, physical activity engagement or participation in activities such as walking/jogging, weight training, swimming or other physically strenuous acts have been associated with cognitive performance benefits (Hoang et al., 2016; Marttinen et al., 2020; Mueller et al., 2020; Paluska & Schwenk, 2000; Sofi et al., 2011; Taaffe et al., 2008). Likewise, engagement in social activities or having better social networks have been shown to offer cognitive performance benefits (Barnes et al., 2004; Bennett et al., 2006; Ertel et al., 2008; Kelly, Duff, Kelly, McHugh Power, et al., 2017; Krueger et al., 2009; Kuiper et al., 2015, 2016; Tang et al., 2020; Wang et al., 2017). It is important, however, to consider the differences in activity engagement (amount of time spent, types of activities engaged in, etc.) observed between rural and urban communities.

Considering physical activity engagement, it may seem reasonable to make assumptions that individuals living in more rural or agricultural areas may be engaging in significantly more physical activity as a product of their occupation, but the available research would not support this assumption. In fact, the literature evaluating geographic differences in physical activity engagement finds that rural individuals, age 18 and older, engage in less leisure time physical activity than urban individuals (Deng & Paul, 2018; Eberhardt & Pamuk, 2004; Patterson et al., 2004; Reis et al., 2004; Sampaio et al., 2013; Trivedi et al., 2015; Weaver et al., 2013; Wilcox et al., 2000). Recently, two studies evaluating physical activity have found no differences between rural and urban residing individuals (Fan et al., 2014; Robertson et al., 2018) and one study has shown that rural individuals engage in more physical activity than urban individuals, albeit this study was examining physical activity of four year olds (Suherman et al., 2020). This mixture of findings may suggest that geographic differences in leisure time physical activity are not universally found.

There are potential environmental barriers and environmental supports that may contribute to the observed differences in physical activity engagement. One study evaluated the barriers in the environment that hindered engagement in physical activity for older rural individuals (Aronson & Oman, 2004). The lack of indoor facilities, extreme weather conditions, stray dogs, traffic, lack of sidewalks, uneven walking surface, and crime were all reported as barriers to engagement in physical activity (Aronson & Oman, 2004). Additional studies have found similar results with major barriers to physical activity engagement for rural individuals being: small roads with large commercial vehicle traffic (Salvo et al., 2018), care taking or family responsibilities (Eyler & Vest, 2002; Sanderson et al., 2002), lack of sidewalks/street, lights, or uneven walking surfaces (Eyler & Vest, 2002; Sanderson et al., 2002; Wilcox et al., 2000; Yankeelov et al., 2015), lack of social support (Eyler & Vest, 2002; Sanderson et al., 2002; Wilcox et al., 2000), distance to and cost of fitness facilities (Eyler & Vest, 2002; Sanderson et al., 2002; Wilcox et al., 2000), inadequate weather conditions (Eyler & Vest, 2002; Sanderson et al., 2002; Yankeelov et al., 2015) and crime or unsafe area (Eyler & Vest, 2002; Sanderson et al., 2002; Tang et al., 2020).

The environment does not provide only barriers to activity engagement but may provide encouragement or support for physical activity engagement. A recent study evaluated how recreational facilities in the environment affected physical activity engagement (Deng & Paul, 2018). This study found that when there were more recreational facilities in the environment, urban individuals but not rural individuals reported engaging in more physical activity (Deng & Paul, 2018). Additionally, this study found that urban individuals are not only reporting greater physical activity engagement, but these individuals reported greater functional capacity (doing household chores, cooking hot meals, managing money, etc.) and reported significantly fewer depressive symptoms than rural residing individuals (Deng & Paul, 2018).

When considering social engagement, one may assume that because there are more people and more opportunities for social engagement in urban areas, urban residents may report greater social activity engagement and greater social support. Previous work on the geographic differences in social activity and social support provides mixed results. While some studies find that those in urban areas report lower sense of belonging to their communities, deprived social groups, and lower social support (Romans et al., 2011; Romans et al., 1992; Romans-Clarkson et al., 1990), other studies have found that those in urban areas report greater social participation (Meng & Chen, 2014; Vogelsang, 2016). Still, other work finds no differences in social engagement across rural and urban individuals (Levasseur et al., 2015; Therrien & Desrosiers, 2010).

Similar to physical activities, there may be environmental barriers in rural areas that hinder social engagement, such as the distance to areas for social activity (Vogelsang, 2016). Availability of, and transportation to, social engagement opportunities such as restaurants, community centers, and libraries are greater in urban areas, areas which could be hindering social activity engagement for rural residing individuals (Clarke et al., 2011; Vogelsang, 2016). In fact, one study found that having a driver's license and means of transportation for rural individual was significantly associated with higher social participation (Levasseur et al., 2015). Alternatively, there may be benefits of living in rural areas that support social activity engagement. Many studies have proposed that while rural residing individuals may have smaller social networks, the network of rural individuals are denser and of greater intensity (i.e. rural networks are more developed or of better quality) than those in urban areas whose networks include more acquaintances (Beggs et al., 1996; Sørensen, 2012; Wirth, 1938; Ziersch et al., 2009).

Previous literature suggests that engagement in leisure time activities may show geographic differences, but previous research often considers distal levels of analysis by contrasting results from areas that represent extremely rural and extremely urban, typically as defined by census reports (Aronson & Oman, 2004; Deng & Paul, 2018; Eyler & Vest, 2002; Matz et al., 2015; Sampaio et al., 2013; Sanderson et al., 2002; Trivedi et al., 2015). To expand on previous literature, this study aims to adapt the IRRcounty measure to the census tract level (IRRtract), a level of analysis that has not been conducted previously. This adaptation will allow us to evaluate participants on a finer geographic scale, which could provide a more accurate representation of participant's proximal environment. Additionally, to the best of our knowledge, only one other research group has begun to investigate the relationship between activity engagement (i.e., physical activity) and IRRzip (Huffman & Amireault, 2019); but this work is ongoing and not yet available. Thus, the first research question for this study asks what knowledge is gained from examining rurality variables on a finer geographic scale (IRRtract) compared to a larger geographic scale (IRRcounty)? Activity engagement will be examined at the county level (IRRcounty) and at census tract level (IRRtract) to determine if using a finer geographic scale provides information about the participants living environment that is not captured on a larger geographic scale. The second research question for this study asks how leisure time activity engagement differs quantitatively (i.e. hours per week) and qualitatively (i.e. types of activity) and across rural and urban residing individuals for each domain of activity engagement (i.e. cognitive, physical, social)?

Method

Participants

Participants are from the ongoing Colorado Adoption/Twin Study of Lifespan behavioral development and cognitive aging (Wadsworth et al., 2019a, 2019b), which has combined two parent studies: the Colorado Adoption Project (CAP) begun in 1977 (Plomin & DeFries, 1983; Rhea, Bricker, et al., 2013a) and the Longitudinal Twin Study (LTS) begun in 1985 (Rhea, Gross, et al., 2013). As of May 31, 2019, 1155 individuals were tested as part of CATSLife, including 500 CAP individuals and 655 LTS individuals. The total sample ranged in age from 28.06 to 49.33 years (Mage = 33.02, SD=4.90). Gender demographics are 53.59% female. In terms of race and ethnicity, 92.04% report as white, and 5.97% report as Hispanic. See Table 1.1 for demographics by sample.

The present study included participants into the analysis sample if two criteria were met. First, participants must have completed the online survey portion of the CATSLife data collection (*N*=1153). Second, participants must reside within the United States with coded geospatial indices for geographic analysis (*N*=1139). This resulted in a primary analysis sample of 1131 participants. Qualitative ratings of hobbies, described below, were available for a subset of 978 CATSLife participants tested through July 30, 2018 (36 month of testing).

Measures

Geocoding

Geospatial data was linked to participant addresses using five sources: (1) US Department of Agriculture's (USDA's) Economic Research Service (ERS) Rural/Urban Continuum Codes (RUCC); (2) USDA's ERS Rural/Urban Commuting Areas (RUCA) data; (3) US Census Bureau's 2010 Census Urban List Records Layout data; (4) US Census Bureau's 2000 to 2010 Census Tract Population Change data; and (5) US Census Bureau's Principal cities of metropolitan and micropolitan statistical areas (MMSA) data. Original address information was retained at the Institute for Behavioral Genetics (IBG) at University of Colorado, Boulder where participant addresses along with random, non-participant US addresses to maintain participant confidentiality were converted to latitude and longitude using the U.S. Census Bureau's Batch Address Geocoder (Bureau, US Census). For those whose addresses could not be converted to latitude and longitude using the U.S. Census Bureau's Address Geocoder, addresses along with random, non-participant US addresses were entered into Google Maps to obtain the latitude and longitude of the residence (N=85). Participant's random token IDs and latitude/longitude coordinates along with a set of randomly interspersed addresses from other sources were passed to the Biobehavioral Research Lab at University of California, Riverside (UCR). All latitude and longitude were then plotted, using ArcGIS version 10.6.1, on top of a "layer" representing the counties of the United States which was projected using North American Datum 1983 (ESRI, 2018; US Department of Commerce, 2018). Centroids for both the census tract as well as the county were then plotted on the "layer" by identifying the geographic center of each county and tract polygon and their associated geographic coordinates. Each set of coordinates were linked with the county and tract in which they fell, assigning the appropriate GEOID to each participant using ArcGIS 10.6.1 (ESRI, 2018). A GEOID is an 11 digit number assigned by the US Census Bureau where the first two numbers indicate the state, the next three numbers indicate the county, and the last six numbers indicate the census tract (Bureau, 2020). This variable then allows for merging with the RUCC, RUCA, county, and tract level demographic data. Lastly, the latitude and longitude of the metropolitan and micropolitan statistical areas (MMSA) were plotted on the North American Datum layer along with the geocoded address and centroids of counties and tracts. Distances from the address and from the centroids to the nearest MMSA were measured in miles. After census and mapping variables were calculated, the data file was returned to IBG with the random token ID whereupon IBG removed all latitude and longitude coordinates, as well as all randomly interspersed addresses, and linked back to participant study IDs to return to UCR a reduced dataset for calculation of IRR variables.

Index of Relative Rurality. The county level IRR (IRRcounty) consists of four dimensions of rurality identified as: population size, population density, urbanicity (a measure of population density based on small areas & defined by the U.S. Census as the percent of the population living in urban area) and remoteness or distance to nearest metropolitan area (Inagami et al., 2016; Waldorf, 2006; Waldorf & Ayoung, 2015). When adapting the IRRcounty to the IRR for zip code level analysis (IRRzip), previous literature has included 3 of the 4 dimensions of rurality: population size, population density, and remoteness measured by the distance from the centroid of the zip code to the nearest MMSA (Inagami et al., 2016). The Inagami et al., 2016 study did not include the measure of urbanicity as their data only provided the zip code associated with the participants residence (Inagami et al., 2016). The current study adapted the IRRcounty & IRRzip for analysis at the census tract level (IRRtract) and returned to the 4 dimensions of rurality used with the IRRcounty.

In addition to measuring the distance from the centroid of the county and census tract to the nearest MMSA as done when evaluating IRRzip, this study measured distance from the participant's home address (which was converted to latitude and longitude) to the nearest MMSA for a more accurate representation of remoteness. Distance from the centroid of the county as well as the centroid of the census tract to the nearest MMSA, were strongly correlated with the distance from the participant's own latitude-longitude to the nearest MMSA (r = 0.69 and r = 0.99, respectively). This supports the findings of (Inagami et al., 2016) and indicates that county and census tract centroids could be used a proxy measure when precise addresses information is not available. Distance correlations are shown in Table 1.2. More details of the sources and measurements of population size, population density, urbanicity, and remoteness are detailed below.

The specific measures used in the current study to calculate the IRRcounty and IRRtract scales included census data to determine population size and density for each county and census tract. Participant's addresses were linked with the associated county level and census tract level population, population density, and urbanization (the percent of urban residing individuals in the area as determined by the US Census). Population and population density were log transformed to account for their skewed distributions (Inagami et al., 2016; Waldorf, 2006; Waldorf & Ayoung, 2015). Remoteness was operationalized as the distance (in miles) from the participants home address (latitude/longitude) to the city associated with the nearest MMSA. To calculate remoteness, a base layer representing the counties within the United States which was projected in North American Datum (US Department of Commerce, 2018) was first imported into ArcGIS version 10.6 (ESRI, 2018). Participant latitude-longitude points and the latitude and longitude points for the MMSA's were then displayed over the US counties layer and the distance from the participant's latitude-longitude to the latitude and longitude of the nearest city associated with the MMSA was measured in miles. Following the previous work of Waldorf & Kim (2015) when calculating IRR, population and population density were transformed to deal with the skewed nature of these data (Waldorf & Ayoung, 2015). This was done using both a Base 10 transformation as well as a natural log transformation as previous literature did not specify the type of transformation used (Inagami et al., 2016; Waldorf, 2006; Waldorf & Ayoung, 2015).

Ultimately the transformation type did not have any meaningful effects on the outcome of the data and natural log transformed variables are described in this paper.

The variables that comprise the IRR are measured on different scales so they must be rescaled to ensure compatibility across the four dimensions (Inagami et al., 2016; Waldorf, 2006; Waldorf & Ayoung, 2015). Three of the variables that comprise the IRR are negatively related to rurality and are considered Type I variables. Type I variables include population, population density and percent urban (Inagami et al., 2016; Waldorf, 2006; Waldorf & Ayoung, 2015). The fourth variable that comprises the IRR (distance to nearest MMSA) is positively related to rurality and is considered a Type 2 variable (Inagami et al., 2016; Waldorf, 2006; Waldorf & Ayoung, 2015). For Type I variables the following formula was used (Inagami et al., 2016; Waldorf, 2006; Waldorf & Ayoung, 2015):

$$\boldsymbol{X_i \rightarrow \frac{X_{max} - X_i}{X_{max} - X_{min}} \in [0, 1]} \qquad [1]$$

For the Type II variable, the following formula was used (Inagami et al., 2016; Waldorf, 2006; Waldorf & Ayoung, 2015):

$$\boldsymbol{X_i \rightarrow 1 - \frac{X_{max} - X_i}{X_{max} - X_{min}} \in [0, 1]} \qquad [2]$$

Using these formulae, the resulting four dimensions were bounded to range from 0 (completely urban) to 1 (completely rural) creating an index that is independent of the units of measurement (Inagami et al., 2016; Waldorf, 2006; Waldorf & Ayoung, 2015). Due to the lack of theoretical guidance available in the literature to determine if the dimensions of rurality each contribute equally, and to replicate previous work, this study used the unweighted average of the bounded four dimension so that no dimension of rurality contributes more than any other to the IRR calculations (Inagami et al., 2016; Waldorf, 2006; Waldorf & Ayoung, 2015). As the distance of the centroid of the census tract to the nearest MMSA was nearly perfectly correlated with the distance from the participant's own address/latitude-longitude (r=0.99, p<.0001), we calculated IRRtract using the distance from the participant's own address to the nearest MMSA. Moreover, in order to differentiate IRRcounty from IRRtract we calculated IRRcounty using the distance from the centroid of the county to the nearest MMSA. See Table 1.2 for correlations of distance to MMSA.

IRR was correlated with both RUCC and RUCA measures to confirm the measurements of IRR. RUCC was moderately correlated with IRRtract (r=0.51, N=1139, $p < .0001$) and highly correlated with IRRcounty (r=.74, N=1139, $p < .0001$). RUCA was correlated moderately high with IRRtract (r=0.63, N=1139, $p < .0001$) and with IRRcounty (r=0.68, N=1139, $p < .0001$). Descriptive statistics for IRRcounty and IRRtract as well as variables used to comprise IRR are presented in Table 1.3.

Activity Engagement Scale

A 20-item activity engagement scale measured the frequency of engagement in a list of several leisure time activities (adapted from (Jessor & Jessor, 1977), and used in prior assessments of CAP and LTS (Haberstick et al., 2014)). Example activity items include items such as "Working out as part of a personal exercise program?", "Going out with friends or dating?" and "Doing things with your family?" The item "how many hours per week do you spend doing activities with a pet" was added at the CATSLife assessment. All items were rescaled to capture hours of engagement in each week for each of the items. Items were rescaled in hour units such that 0 = None, 1 = 1 hour a week, 2.5 = 2-3 hours a week, 4.5 = 4-5 hours a week, 6.5 = 6-7 hours a week, to 8 = 8 or more hours a week as in prior work (Haberstick et al., 2014)). All recoded activity items were then summed to create a score of total hours of activity engagement per week. Descriptives for the recoded items as well as the total number of hours per week spent on activity engagement are shown in Table 1.4.

In creating summary measures of 5 activity domains of engagement, we were informed by prior principal component work in earlier assessments of CAP and LTS (Haberstick et al., 2014) and otherwise applied rational placement of items based on similar activities, e.g., putative cognitive activities reported in Stern & Munn (2010). Four items "sitting around with friends", "talking on the phone", "doing things with a club" and "going out with friends or dating" comprise the social activity domain. Five items "taking part in an organized sport or recreation program", "working out as part of a personal exercise program (like running or biking)", "playing pickup games like basketball, touch football, etc.", "practicing different physical activities (like shooting baskets or working on dance routines)", and "doing activities with a pet" comprise the physical activity domain. Three items "doing things with your family", "taking care of younger family members", and "doing household chores" comprise the family activity domain. Four items "just sitting and listening to music", "just sitting and doing nothing", "watching tv" and "using a computer/tablet/phone for fun" comprise the sedentary activity domain. Three items “reading for fun”, “spending time on a hobby” and “playing a musical instrument” comprise the cognitive activity domain. A total hours of activity engagement domain was also calculated by summing the total number of hours of engagement for all 19 items. Mean hours of activity engagement per week (HPW) for social activities was 6.78 (SD=4.00), mean HPW physical activities was 6.54 (SD=4.74), mean HPW family activities 10.78 (SD=7.08), mean HPW sedentary activity 11.88 (SD=5.85), mean HPW cognitive activity 4.65 (SD=3.79), mean HPW total leisure time engagement 40.63 (SD=11.93). Descriptives for individual activity items for activity domains are shown in Table 1.4. The skew of the HPW domain and total scores ranged from 0.31 to 1.29, with all but HWP cognitive activity under 1.0. (see supplemental Table ST1.1 in Appendix 1).

Open Ended Activity Engagement Coding. Twelve corresponding open-ended items pertaining to activity engagement were included in the CATSLife assessment to further probe the qualities of the activities that persons reported hours of engagement. For the current analysis, we coded two of the open-ended questions “What club(s) do you belong to?” and “What hobby(ies) do you do?”, and applied coding systems to evaluate the qualitative differences in engagement in clubs and hobbies across rural and urban residing individuals. Each entry for clubs and hobbies was coded using a blind dual entry technique by having a team of research assistants follow the rating system. Each club/hobby that was provided from the participant was coded in multiple ways. For a full description of all coding techniques, see Appendix 1.

The coding scheme used in the analyses described in this paper was as follows. Each club/hobby was rated to indicate the degree to which the club/hobby was cognitive, social, or physical. Specific coding instructions read: "Each type of club [hobby] may have varying levels of demand with cognitive, social and physical types of engagement. Indicate the level of demand for each club in each of these domains by selecting from the provided options below." Raters provided a value based on the following instructions: "Rate how cognitively, socially, and physically demanding you feel each club [hobby] is on a 5-point scale where:1 = absolutely no cognitive demand (sleeping), no social demand (home alone), no physical demands (meditation); 2 = some cognitive, social, or physical demands; 3 = moderate cognitive demand (reading newspaper), moderate social demand (visiting with a friend), moderate physical demands (hiking); 4 = a lot of cognitive, social, or physical demands; 5 = high cognitive demand (completing a tax form), high social demand (dinner party), high physical demands (competitive kayaking). The overall coding scheme, rating scale scheme, and cognitive examples were informed by prior work evaluating the multifaceted properties of activity engagement (Salthouse et al., 2002; Wang et al., 2002a). The examples selected for no, moderate, and high physical demand were selected from activities that were described as such in the 2011 Compendium of Physical Activities (Ainsworth et al., 2000). An example of the rater sheet with instructions and consensus rating descriptions are shown in Appendix 1.

Between the first and second entry of the dual entry coding of clubs, raters were compared with each other in terms of absolute agreement and the extent to which they were within 1 scale point. For cognitive ratings there was 32.1% absolute agreement but

82.5% were within 1 scale point. For social ratings, there was 33.6% absolute agreement, with 65.7% agreement within 1 scale point. For physical ratings there was 40.9% absolute agreement and 85.4% agreement within 1 scale point. Between the first and second rating of the dual entry coding of hobbies, raters had a 45.1% absolute agreement, and 88.5% within 1 scale point for cognitive ratings. For social ratings, there was 39.9% absolute agreement and 92.7% within 1 scale point. For physical ratings, there was 45.2% absolute agreement and 91.7% within 1 scale point.

To handle disagreement in the cognitive, social, and physical ratings of each club [hobby], consensus meetings were held using a separate set of raters. Consensus raters were shown what values previous raters had assigned for each club [hobby] as well as the instructions provided to the raters (described above) and made decisions for final scale assignment based on the criteria described in Appendix 1. Between the raw coding from original raters (which included first and second entry) and the final consensus coding of clubs, cognitive ratings were 44.1% in absolute agreement with the consensus assignment and 92.5% within 1 point, social ratings were 35.2% in absolute agreement with the consensus assignment and 80.1% within 1 point, and physical ratings were 38.4% in absolute agreement with the consensus assignment and 85.4% within 1 point. Between the dual entry and consensus coding of hobbies, cognitive ratings were 50.3% in absolute agreement with the final consensus coding and 94.2% within 1 point, social ratings were 53.3% in absolute agreement with the final consensus coding and 93.1% within 1 point, and physical ratings were 41.6% in absolute agreement with the final consensus coding and 92.6% within 1 point.

For the N= 978 participants tested through the 36th month, 968 had available reports on hours of engagement in hobbies and IRR data. Of the 702 who reported at least 1 or more hours of hobby engagement, 592 individuals provided descriptions. The average number of hobbies reported of the 592 reporting hobbies was 2.20 hobbies (SD=1.48; Min=1, Max=12), and of the N=968 total subsample was 1.35 hobbies (SD=1.58; Min=0, Max=12). The descriptives of the number of hobbies and the geometric means (geomeans) of the rated hobbies provided for the N=592 are shown in Table 1.4, with respect to cognitive, social and physical ratings.

Statistical Analysis

Multilevel models were fitted using PROC Mixed in SAS 9.4 (SAS Institute Inc., Cary, NC) to evaluate the associations of rurality at both the tract and county levels with hours per week of activity engagement accounting for sex, age (centered at age 33 years), project (CAP or LTS), adoption status, parental status, and ethnicity. IRR variables were centered on their respective means (IRRcounty=.25, IRRtract=.24). The models accounted for differential sibling relatedness both between (σ^2_{BW}) and within (σ^2_{WI}) sibships by estimating separate random effects for those in adoptive, control, or twin families (dizygotic, DZ; monozygotic, MZ). Sibling similarity for all activity domains was measured by calculating intraclass correlations (ICCs) by taking σ^2_{BW} over the sum of σ^2_{BW} and σ^2_{WI} for each family type (adoptive, control, DZ, and MZ). To evaluate spatial clustering in separate multilevel models, a variable named Alternative FIPS was created. Because 61.9% of the sample population lived within Colorado their full FIPS identifier was used to cluster by county whereas those living outside of Colorado were clustered by state identifiers. The models accounted for clustering between (σ^2_{BW}) and within (σ^2_{WI}) Alternative FIPS identifiers.

Full-information maximum-likelihood was used. Model fit criteria included standard fit indices including: the chi-square difference test ($\Delta\chi^2$) also termed the likelihood ratio test (LRT) for nested models. Practical fit indices were also calculated such as: the Akaike Information Criterion (AIC) which indexes the extent to which the observed covariance matrix differs from the predicted covariance matrix and lowest possible values are preferred between nested models (Beal, 2007; Burnham & Anderson, 2002); and the Bayesian Information Criterion (BIC) which is similar to the AIC but imposes a greater penalty for complex models, again with lowest possible values being preferred (Beal, 2007; Raftery, 1995a).

Results

Descriptive Statistics

The mean IRRcounty was 0.25 (SD=0.10) while the mean IRRtract was 0.24 (SD=0.10), indicating that overall, the participants are living in areas that are more urban than rural. Pearson correlation coefficients indicated strong associations of IRRtract with IRRcounty (r=0.66, p=<0.0001).

Pearson correlation coefficients of HPW activity engagement with IRR variables (N=1127) were partialed for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), race (0=non-White, 1=White) and Hispanic ethnicity (0=non-Hispanic, 1=Hispanic). Small to negligible associations were observed for social activity with IRR at the county level (r= -0.09, p=

0.002) but not at the tract level (r= -0.04, p= 0.18). Small associations were observed for family activity both at the county level (r= 0.12, p< 0.0001) and at the tract level (r= 0.09, p= 0.002). Small to negligible associations were observed for sedentary activity at the tract level (r= -0.08, p= 0.01) but not at the county level (r= -0.03, p= 0.34). These associations led to further analysis using multilevel models to address family and spatial dependencies.

Pearson correlation coefficients partialed for covariates (N=1127) indicated no significant associations of physical activity with IRR at both the county level (r= 0.02, p= 0.58) and at the tract level (r= -0.01, p= 0.80), cognitive activity at both the county level (r= -0.004, p= 0.90) and at the tract level (r= 0.02; p= 0.58), and total activity with IRR at both the county level (r= 0.01, p= 0.78) and at the tract level (r= -0.01, p= 0.70). As there were no significant associations with these activity domains, we report only the sibling and spatial clustering for physical, cognitive, and total activity engagement.

Primary analyses focused on using the raw scaling of HPW of activity engagement as outcomes. In support, we note that correlations with IRR indices and unadjusted HPW activity engagement, as well as square-root transformed HPW activity engagement, were nearly identical (see supplemental Table ST1.1 in Appendix 1).

IRR and Quantitative Activities

IRR and Social Activities.

Similarities in total hours per week spent on social activities were evaluated within and between families in the study regardless of their geographic location, adjusting for sociodemographic covariates as a baseline model (Model 0) prior to comparing geographic associations with social activity. Table 1.5 shows fixed and random effects parameters of Model 0. ICCs calculated from the random effects were small across all sibling types, ranging from 0.09 among control participants to 0.23 among DZ siblings (see supplemental Table ST1.2). Next, including IRR at both the tract and county levels as covariates (Model 1) was significant and showed improved fit over Model 0 [$\Delta\chi 2$ (2) = 15.7, p= 3.90E+04] (see Table 1.5, where IRRcounty uniquely contributed to Social activities (B= -5.38, SE= 1.50, p= 0.0004) but IRRtract did not (B= 1.53, SE= 1.51, p= 0.31) (shown in Table 1.5). The ICCs tended to be somewhat smaller but more consistent across sibling types after inclusion of the IRR covariates (.09 - .20), suggesting a small association of IRR attributes with sibling similarity (see Supplemental Table ST1.2 in Appendix 1).

Sensitivity analyses were run extending Model 1 above to consider the 60 individuals from 30 sibships who were living together at the time of testing (Model 2). Entering living together status as a covariate was not significant (p= 0.17) and did not improve model fit over Model 1 [$\Delta\chi 2$ (1) = 1.9, p= 1.68E-01] (see Table 1.5). ICCs calculated from the random effects were consistent with Model 1, ranging from .09 to .20 (see Supplemental Table ST1.2 in Appendix 1). Model 3 for Social Activity excluded 30 individuals who were members of sibling pairs living together at the time of testing; parameter estimates did not show notable change from Model 1 particularly for the IRR covariates (see Table 1.5), suggesting that these siblings did not appreciably influence IRR association. IRRcounty remained a unique contributor to Social activities (B= -5.23, SE= 1.51, p= 0.0006) and likewise IRRtract did not (B= 1.12, SE= 1.53 p= 0.47). ICCs calculated from the random effects were similarly small across all sibling types, ranging from .10 to .21 (see Supplemental Table ST1.2).

Models were then run to account for spatial but not sibling clustering, adjusting for socio-demographic covariates (Model 4). Table 1.7 shows parameter estimates and fit statistics of Model 4 for social activities. The consideration of spatial clustering in the random effects suggested that only .042 or 4.2% of the total variance in social activities was attributable to spatial clustering. Model 5 for Social Activity included IRR at both the tract and county levels as a covariate in the model while controlling for spatial clustering. Including IRR at both the tract and county levels as covariates in model 5 was not significant as a set [$\Delta\chi 2$ (2) = 5.4; *p*= 6.72E-02] or individually (both *p's* > .06). The spatial clustering after including the IRR covariate was .033 or 3.3%. In considering Models 4 and 5, spatial clustering effects were very small; hence, sibling clustering was most appropriate to include in models of social activity as we were otherwise were unable to include both levels of clustering in a single model due to limited degrees of freedom.

Based on Model 2 the effect size difference comparing observed IRR values in our samples, suggests a large effect size in the hours per week spent on social activity when considering a very urban county (IRRcounty=.10) to a moderately rural county (IRRcounty=.70). The differences in the expected hours per week spent on social activity of representative IRR values denoting Rural vs Urban was 4.42 - 7.66 = -3.24 hours, a Cohen's *d* equivalent of -.81, where individuals in a moderately rural county report 3.24 fewer hours of social activity engagement than those in a very urban county, adjusting for all covariates.

IRR and Family Activity.

Similarities in total hours per week spent on family activities were evaluated within and between families in the study regardless of their geographic location, adjusting for sociodemographic covariates (Model 0) as a baseline model to compare geographic associations with family activity. Table 1.7 shows fixed and random effects parameters of Model 0. ICCs calculated from the random effects were negligible to small across all sibling types, ranging from .00 among adopted siblings to .23 among DZ siblings (see supplemental Table ST1.2 in Appendix 1). Including IRR at both the tract and county levels as covariates was significant and showed improved fit [$\Delta\chi 2$ (2) = 21.8, p= 1.85E-05] (see Table 1.7), where IRRcounty uniquely contributed to Family activities (B= 7.39, SE= 2.56, p= 0.004) but IRRtract did not (B= 2.35, SE= 2.60, p= 0.37). The ICCs tended to be somewhat smaller after inclusion of the IRR covariates (0.00-0.19), suggesting a small association of IRR attributes with sibling similarity (see Supplemental Table ST1.2 in Appendix 1).

Sensitivity analyses were run extending Model 1 above to consider the 60 individuals from 30 sibships who were living together at the time of testing (Model 2). Entering living together status as a covariate was not significant (p= 0.17) and did not improve model fit [$\Delta\chi 2$ (1) = 1.8, p= 1.80E-01] (see Table 1.7). ICCs calculated from the random effects were small across all sibling types, ranging from .00 to .19 (see Supplementary Table ST1.2). Model 3 for Family Activity excluded the 30 individuals who were living together at the time of testing where parameter estimates did show change from Model 1 particularly for the IRR covariates. Note that the regression weights for county dropped slightly but were in the same direction and weights for tract increase when excluding these live together participants for IRRcounty (B= 7.72, SE= 2.60, p= 0.0031) and for IRRtract (B= 2.24, SE= 2.64, p= 0.40) (see Table 1.7). ICCs calculated from the random effects were small across all sibling types, ranging from .00 to .16 (see Supplemental Table ST1.2 in Appendix 1).

Model 4 accounted for spatial but not sibling clustering and adjusted for socio-demographic covariates. Table 1.8 shows parameter estimates and fit statistics of Model 4 for family activities. The consideration of spatial clustering in the random effects suggested that only .017 or 1.7% of the total variance in family activities was attributable to spatial clustering. Model 5 for Family Activity included IRR at both the tract and county levels as a covariate in the model while controlling for spatial clustering. Including IRR at both the tract and county levels as covariates in model 5 was significant and improved model fit [$\Delta\chi 2$ (2) = 21.0, p= 2.75E-05] (shown in Table 1.8) where IRRcounty uniquely contributed to Family activities (B= 7.37, SE= 2.64, p= 0.0053) but IRRtract did not (B= 2.69, SE= 2.62, p= 0.30). The model parameters for Model 5 is shown in Table 1.8. The spatial clustering after including the IRR covariate was .006 or 0.6%. In considering Models 4 and 5, given that spatial clustering effects were very small, accounting for sibling clustering was sufficient.

Based on Model 2 the effect size difference comparing observed IRR values in our samples, suggests a moderate effect size in the hours per week spent on family activity when considering a very urban county (IRRcounty=.10) to a moderately rural county (IRRcounty=.70). The differences in the expected hours per week spent on family activity of representative IRR values denoting Rural vs Urban was 12.44-7.97 = 4.47 hours a Cohen's *d* equivalent of 0.63. Hence, individuals in a moderately rural county report spending about 4.5 more hours per week on family activity engagement than individuals in a very urban county, adjusting for all covariates.

IRR and Sedentary Activity.

Model 0 for Sedentary Activity evaluated similarities in total hours per week spent on sedentary activities within and between families in the study regardless of their geographic location, adjusting for sociodemographic covariates and serves as a baseline model to compare geographic associations with sedentary activity. Table 1.9 shows fixed and random effects parameters of Model 0. ICCs calculated from the random effects were small across all sibling types, ranging from .14 for adopted and DZ participants to .24 for MZ siblings (see supplemental Table ST1.2 in Appendix 1). Including IRR at both the tract and county levels as covariates was significant and showed improved fit [$\Delta\chi2$ (2) = 9.2, p= 1.01E-02] (see Table 1.9), where IRRcounty did not uniquely contribute to Sedentary activities (B= 2.22, SE= 2.24, p= 0.32) but IRRtract did (B= -6.35, SE= 2.26, p= 0.0052). Parameter Estimates for Model 1 are shown in Table 1.9. The ICCs tended to be similar after inclusion of the IRR covariates (.13 - .25), suggesting no association of IRR attributes with sibling similarity (see Supplemental Table ST1.2 in Appendix 1).

Sensitivity analyses were run extending Model 1 above to consider the 60 individuals from 30 sibships who were living together at the time of testing (Model 2). Entering living together status as a covariate was not significant (*p*= 0.65) and did not improve model fit [$\Delta\chi2$ (1) = 0.2, *p*= 6.55E-01] (see Table 1.9). ICCs calculated from the random effects were small across all sibling types, ranging from .12 for DZ siblings to .25 for MZ siblings (see Supplemental Table ST1.2 in Appendix 1). Model 3 for Sedentary Activity excluded the 30 individuals who were living together at the time of testing where parameter estimates showed small change from Model 1 particularly for the IRR covariates: IRRcounty (B= 2.00, SE= 2.28, *p*= 0.38); IRRtract (B= -6.19, SE= 2.32, *p*= 0.0081) (see Table 1.9). ICCs calculated from the random effects were small across all sibling types, ranging from .10 to .22 (see Supplemental Table ST1.2 in Appendix 1).

Model 4 accounted for spatial but not sibling clustering and adjusted for socio-demographic covariates. Table 1.10 shows parameter estimates and fit statistics of Model 4 for sedentary activities. The consideration of spatial clustering in the random effects suggested that only 0 or 0% of the total variance in sedentary activities was attributable to spatial clustering. Model 5 for Sedentary Activity included IRR at both the tract and county levels as a covariate in the model while controlling for spatial clustering and improved model fit [$\Delta\chi2$ (2) = 8.7, *p*= 1.29E-02] (see Table 1.10). Including IRR at both the tract and county levels as covariates in model 5 was not significant at the county level (B= 2.03, SE= 2.25, *p*= 0.37) but was significant at the tract level (B= -6.14, SE= 2.28, *p*= 0.0072) shown in Table 1.10. The spatial clustering after including the IRR covariate was 0 or 0%. In considering Models 4 and 5, given that spatial clustering effects were at zero, accounting for sibling clustering was sufficient.

Based on Model 2 the effect size difference comparing observed IRR values in our samples, suggests a moderate effect size in the hours per week spent on sedentary activity when considering a very urban county (IRRcounty=.10) to a moderately rural county (IRRcounty=.70). The differences in the expected hours per week spent on family activity of representative IRR values denoting Rural vs Urban was 10.01-13.83 = -3.82, a Cohen's *d* equivalent of -0.65. Hence, individuals in a moderately rural tract report spending 3.82 fewer hours per week on sedentary activity engagement than individuals in an urban tract.

IRR and Physical Activity.

Due to the lack of significant correlations between physical activity and IRR variables noted above, only baseline multi-level models are detailed here. Similarities in total hours per week spent on physical activities were examined within and between families in the study regardless of their geographic location, adjusting for sociodemographic covariates as a baseline model (Model 0). Table 1.11 shows fixed and random effects parameters of Models 0. ICCs calculated from the random effects were negligible to moderate across all sibling types, ranging from .00 in control siblings to .34 among MZ siblings (see Supplemental Table ST1.2 in Appendix 1).

Model 4 accounted for spatial but not sibling clustering and adjusted for socio-demographic covariates. Table 1.12 shows parameter estimates and fit statistics for physical activities. The consideration of spatial clustering in the random effects suggested that only .014 or 1.4% of the total variance in physical activities was attributable to spatial clustering.

IRR and Cognitive Activity.

Due to the lack of significant correlations between cognitive activity and IRR variables noted above, only baseline multi-level models are detailed here. Model 0 for

Cognitive Activity evaluated similarities in total hours per week spent on cognitive activities within and between families in the study regardless of their geographic location, adjusting for sociodemographic covariates. Table 1.11 shows fixed and random effects parameters of Model 0. ICCs calculated from the random effects were negligible to moderate across all sibling types, ranging from .05 in adopted siblings to .34 among MZ siblings (see Supplemental Table ST1.2 in Appendix 1).

Model 4 accounted for spatial but not sibling clustering and adjusted for socio-demographic covariates. Table 1.12 shows parameter estimates and fit statistics for cognitive activities. The consideration of spatial clustering in the random effects suggested that only .022 or 2.2% of the total variance in cognitive activities was attributable to spatial clustering.

IRR and Total Activity.

Due to the lack of significant correlations between total activity and IRR variables noted above, only baseline multi-level models are detailed here. Model 0 for Total Activity evaluated similarities in total hours per week spent on Total activities within and between families in the study regardless of their geographic location, adjusting for sociodemographic covariates. Table 1.11 shows fixed and random effects parameters of Model 0. ICCs calculated from the random effects were small across all sibling types, ranging from .00 for adopted siblings to 0.15 for control siblings (see Supplemental Table ST1.2 in Appendix 1).

Model 4 accounted for spatial but not sibling clustering and adjusted for socio-demographic covariates. Table 1.12 shows parameter estimates and fit statistics for Total activities. The consideration of spatial clustering in the random effects suggested that only .0004 or 0.04% of the total variance in Total activities was attributable to spatial clustering.

IRR and Qualitative Activities

We considered the ratings of qualitative entries of clubs and hobbies to further probe the nature of these activities. For self-reported engagement in clubs, there were relatively few entries across the sample and when removing those who submitted a club that was duplicated as a hobby, the sample size became too low to estimate in models (N=93) and were not evaluated further.

For self-reported engagement in hobbies we considered data from the subsample of 968 respondents. There were 266 who reported no hours of engagement in a hobby. There were 592 participants who provided one or more descriptions of hobbies out of 702 participants who reported that they engaged in a hobby at 1 or more hours per week. Thus, there were 110 participants who reported that they engaged in a hobby at 1 or more hours per week, but did not describe their hobbies. We compared the 110 persons who reported one or more hours per week on hobby engagement but did not specify hobbies to the 592 persons that provided descriptions. Using simple t-tests and chi-square comparisons, there were no significant differences on any demographic covariates (female, age, project) or IRRtract or IRRcounty measures ($p \geq .73$). However, as verified in a multi-level model where sibling structure was accounted for, those who did not report a hobby but reported hours per week spent on hobbies tended to report fewer hours of engagement (B=-0.64, SE=0.22, p=0.0034) than those who reported hobbies.

The geomean patterns for hobby ratings indicated higher mean cognitive rating values (M= 2.57, SD= 0.64) than physical hobby ratings (M= 1.83, SD= 0.78) or social hobby ratings (M= 1.69, SD= 0.76) (see Table 1.4). Partial correlations were run between cognitive, social, and physical hobby ratings with IRR at the tract and county levels (partialed for gender, age, parental status, project (0=CAP, 1=LTS), adoption status, Hispanic and White ethnicity). No significant associations were found between physical hobby ratings and IRR at the county level (r= 0.05, p= 0.20) or at the tract level (r= -0.03, p= 0.55). Additionally, no significant associations were found between social hobby ratings and IRR at either the county level (r= -0.02, p= 0.61) or at the tract level (r= -0.03, p= 0.42). Small but significant associations were observed with cognitive hobby ratings and IRR at the county level (r= -0.10, p= 0.0140) and at the tract level (r= -0.08, p= 0.05).

IRR and Cognitive Hobbies.

Model 0 evaluated similarities in cognitively rated hobby engagement within and between families in the study regardless of their geographic location, adjusting for sociodemographic covariates. Table 1.13 shows fixed and random effects parameters of Models 0-2. ICCs calculated from the random effects were small across all sibling types, ranging from .00 for adopted siblings to 0.37 for MZ pairs (see supplemental Table ST1.2 in Appendix 1). Model 1 included IRR at both the tract and county levels as well as hours per week spent on hobbies and total number of hobbies reported as covariates was significant and showed improved fit [$\Delta\chi2$ (2) = 6.0, p= 4.98E-02] (see Table 1.13), where IRRcounty did not uniquely contribute to cognitively rated hobbies (B= -0.49, SE= 0.32, *p*= 0.13), nor did IRRtract (B= -0.12, SE= 0.32, *p*= 0.71), nor did hours per week on hobbies (B= 0.01, SE= 0.01, *p*= 0.25), but total number of hobbies reported did (B= -0.04, SE= 0.02, *p*= 0. 0207) (see Table 1.13). The ICCs tended to be similar after inclusion of the IRR and hobby covariates (.00 - .37), suggesting no association of IRR attributes with sibling similarity (see supplemental Table ST1.2 in Appendix 1). Given the strong correlation between IRRtract and IRRcounty and that IRRcounty showed the stronger of the two correlations with cognitively rated hobbies, Model 2 removed IRRtract. In Model 2, IRRcounty was significant (B= -0.57, SE= 0.23, *p*= 0.02) and the chi-square difference test was significant over Model 0 and showed improved fit [$\Delta\chi 2$ (1) = 5.9, *p*= 1.51E-02] but Model 2 was not significantly reduced in fit over Model 1 [$\Delta\chi 2$ (1) = 0.1, *p*= 7.52E-01] indicating that IRRtract does not contribute unique information from IRRcounty (see Table 1.13). Adding live together status to the model did not alter these patterns (*p*= .67, results not shown).

Based on Model 2 the effect size difference comparing observed IRR values in our samples, suggests a medium effect size in the rated cognitive demand of hobby engagement when considering a very urban county (IRRcounty=.10) to a moderately rural county (IRRcounty=.70), where the differences in the cognitive demand of hobby engagement of representative IRR values denoting Rural vs Urban was 2.56 – 2.90 = -0.34, a Cohen's *d* equivalent of -0.53. Hence those from a moderately rural county reported engaging in hobbies that were on average less cognitively demanding (between 'some' and 'moderate' cognitive demands) than those from a very urban county who reported engaging in hobbies that were on average moderately cognitively demanding.

Discussion

The present study investigated the utility of using the Index of Relative Rurality (IRR) at two geographic scales as well as the geographic differences in leisure time activity engagement in a sample of adults approaching middle age from the ongoing Colorado Adoption/Twin Study of Lifespan behavioral development and cognitive aging (CATSLife). The IRR was constructed using the same methods as proposed by previous literature to evaluate behavioral variables on both a distal level (i.e. IRRcounty) and a proximal level (i.e. IRRtract), a new level of analysis. Moreover, activity engagement was evaluated through self-report measures both quantitatively (i.e. hours per week) and qualitatively (i.e. types of hobbies). This study sought to understand what knowledge could be gained from examining activity engagement on a geographic scale that more proximal to the participants daily life (i.e. IRRtract) compared to a larger geographic scale that is more distal to the participants daily life (i.e. IRRcounty). We expected to observe geographic differences in both qualitative activity engagement (i.e. type of hobby) measure, as well as quantitative activity engagement (i.e. hours per week).

To evaluate geographic differences in quantitative (i.e. hours per week) activity engagement, a series of multilevel models testing for familial or spatial clustering were evaluated, wherein familial clustering was predominant over spatial clustering and thus may reflect the diverse spread of participants across geographies. Results suggested that social, family, and sedentary activity engagement were associated with relative rurality with variation in the unique contributions of IRR at the county or tract level, albeit that both are strongly corrected. No significant associations were found between IRRcounty or IRRtract and quantitative measures (i.e. hours per week) of physical, cognitive, or overall total activity engagement. However, while the overall analyses of quantitative cognitive activity did not show an association with rurality, geographic differences in qualitative (i.e. self-reported hobby) activity engagement were observed with respect to the cognitive demands of hobbies. In evaluating total hours per week spent on leisure time activity engagement, no geographic differences were observed in total reported engagement. The analysis of total activity engagement was included as a confirmation that the results were not due to reporting biases such that some participants report more activity engagement overall than others and are not driving the results.

Specifically, for social activity engagement, the distal measurement of rurality (IRRcounty) was a significant negative predictor of the total number of hours per week spent on social activities, but not the proximal measure or rurality (IRRtract). Controlling for sociodemographic variables, individuals spent about 3¼ fewer hours per week on social activities if they live in a moderately rural county than individuals living in a highly urban county. Our findings align with some previous research showing that older adults living in rural areas are less likely to engage in social activities (Vogelsang, 2016). Although this finding needs further exploration, it is possible that the barriers present in rural living (primarily distance to places to meet with others) may be impacting social activity engagement (Vogelsang, 2016). Another study found that when examining mean level differences in social participation, individuals living in rural areas engage in less social participation compared to their urban residing counterparts (Meng & Chen, 2014). While we did observe geographic differences for social activity engagement as measured by the number of hours per week spent sitting around with friends, talking on the phone, doing things with a club, and going out with friends or dating; no geographic differences observed for engagement in hobbies in terms of level of social demands suggesting that rural individuals do not seem to be refraining from social activity engagement broadly-speaking. It is possible that rural individuals are engaging in social activities that were not provided as an option in the hours per week scale. Further analysis of the qualitative data may illuminate the differences in the types of social activity engagement that rural and urban individuals report.

For family activity engagement, models indicated that distal IRRcounty measure was a significant positive predictor of the total number of hours per week spent on family activities, but IRRtract did not uniquely predict. Controlling for sociodemographic variables, individuals living in a moderately rural county spent almost 4½ more hours per week on family activities than individuals living in a highly urban county. Our finding is consistent with prior work suggesting that due to the lower opportunity for social engagement in rural areas, engagement with the family becomes an essential source of social engagement (Key, 1961) particularly for aging individuals (Zimmerman et al., 2001, 2003). Other work suggests that individuals in rural areas are more likely to have social exchanges exclusively with family than are urban residing individuals (Hofferth & Iceland, 1998; Key, 1961) and that these close family relationships can provide social support (Elder & Conger, 2014). It is possible that individuals in rural areas offset the lower social engagement opportunities with greater family engagement in rural areas. Moreover, prior research suggests that the children in the home can act as channels into the greater community through engagement in community activities such as sports which then allows parents to meet other parents, thus widening their social network (Offer & Schneider, 2007). More contemporary work is needed with respect to opportunities for social engagement. In rural communities, opportunities for "public" social activity (e.g. membership in organizations) may be lacking relative to "private" social activities with the family, friends and neighbors (Davis et al., 2012)

In evaluating physical activity engagement, results suggested no geographic differences in the number of hours per week spent on physical activities nor in hobby engagement that rated on physical demands. It is surprising that no significant geographic differences were found in physical activity engagement. Previous literature has shown geographic differences in physical activity, such that urban residing individuals report higher levels of physical activity than do rural residing individuals (Deng & Paul, 2018; Eberhardt & Pamuk, 2004; Patterson et al., 2004; Reis et al., 2004; Sampaio et al., 2013; Trivedi et al., 2015; Weaver et al., 2013; Wilcox et al., 2000). However, other studies which have evaluated geographic differences in physical activity have found no differences in physical activity engagement for rural and urban individuals (Fan et al., 2014; Robertson et al., 2018). The lack of findings could be because this study evaluated leisure time physical activity engagement, and did not evaluate occupational physical activity. Previous research suggests that rural residents may have more physically demanding occupations which leads rural individuals to engage in less leisure time physical activity than their urban residing counterparts (Patterson et al., 2004; Robertson et al., 2018). Considering measures of leisure time physical activity along with occupational physical activity could provide a better understanding of the geographic differences in physical activity. In fact, Fan et al., 2014 used accelerometers to measure differences in physical activity for rural and urban individuals. Their findings suggested that urban individuals engaged in more high intensity physical activities while rural individuals engaged in similar amounts of low intensity physical activity but overall had more total physical activity engagement (Fan et al., 2014). Fan et al. (2014) explains that the main contributor to rural individuals engaging in more total physical activity was due to the greater endorsement of household physical activity for rural individuals, which was of lighter intensity but due to the longer engagement with these activities, compensated for the lack of high intensity physical activities.

Additionally, the lack of findings for physical activity engagement could be because this study did not include specific measures of environmental barriers (i.e. presence of sidewalks, streetlights, exercise facilities, etc.) to physical activity engagement in rural residing individuals. Previous research has suggested that rural residing individuals may have more environmental barriers that prevent them from engaging in physical activity (Parks et al., 2003; Salvo et al., 2018; Wilcox et al., 2000). Further coding of the qualitative physical activity measures where participants listed the types of physical activities they practice or exercise that they engage in, could lead to insights in geographic differences of physical activity engagement.

Interestingly, contrary to previous research (Eaton et al., 1994; Wilcox et al., 2000), when evaluating sedentary activity engagement, this study's results suggest that the more rural the tract an individual lives in, the fewer hours per week the individual reported engaging in sedentary activities. Indeed, our results indicate that if individuals live in a moderately rural county they will spend almost 4 fewer hours per week on sedentary activities than individuals in a highly urban tract. However, consistent with our findings, prior work looking at screen time differences in rural and urban residing individuals suggests that rural individuals report fewer screen-time sedentary behaviors than urban residing individuals do (Robertson et al., 2018). This finding has implications for health particularly for urban residing individuals. A 2015 systematic review and meta-analysis finds that compared with lower amount of sedentary activities (measured as less than 4 hours per day spent sitting), individuals who engage in higher amounts of sedentary activities (more than 8 hours per day sitting) are at greater risk for type 2 diabetes and cardiovascular disease (Biswas et al., 2015). These associations were further supported in a meta-analysis the following year (Pandey et al., 2016), while other studies have found associations between more sedentariness and higher rates of depression (Zhai et al., 2015). It is also possible that there may be additional factors than simply sedentary or physical activities that affect these health disparities. Indeed at least one study which evaluated both sedentary and physical activity together suggests that factors such as educational attainment and access to places to purchase healthy foods have associations with physical activity and sedentary activity which has implications for health through the relation to Body Mass Index (Dyck et al., 2020). Further exploration of the potential moderators of sedentary and physical activity engagement is warranted to better understand the relationship between activity engagement and health.

In evaluating cognitive activity engagement, results suggested no geographic differences in the total number of hours per week spent on cognitive activities, but the more rural the county, reported hobbies were rated as less cognitively demanding. This finding is not surprising, as other literature has suggested that those who engage in cognitive activities such as reading or doing crossword puzzles are likely to engage in other cognitively stimulating activities (Wilson et al., 2013) which could include cognitively demanding hobbies. Additionally, prior work suggests that rural residing individuals place lower emphasis on academic achievement and educational experiences, which could relate to rural individuals engaging in less cognitively demanding hobbies (Lampard et al., 2000; Roscigno et al., 2005). Moreover, while studies have found no geographic differences in the number of books in the home, rural children have less exposure to resources supporting cognitive activity engagement such as libraries, and access to computers in the home which could be diminishing their exposure to cognitive activities (Clarke et al., 2017). The finding that rural individuals are less likely to have hobbies that are cognitively engaging may have implications for rural-urban disparities in later cognitive impairment and worse physical health. Prior work has suggested that educational attainment may indirectly affect cognitive performance through engagement in leisure activities as well as through improved health behaviors (Langa et al., 2008, 2017; Weden et al., 2018). As rural individuals place a lower emphasis on educational attainment (Lampard et al., 2000; Roscigno et al., 2005), this may affect cognitive activity engagement for rural residing individuals.

A limitation of this study includes the lack data evaluating environmental barriers. Prior studies suggest that there are different barriers that restrict activity engagement for rural and urban residing individuals. Rural individuals report fewer opportunities for activity engagement such as visiting museums, libraries, and community centers as well as a lack of streetlights and sidewalks (Aronson & Oman, 2004; Eyler & Vest, 2002; Parks et al., 2003; Sanderson et al., 2002; Yankeelov et al., 2015). Urban residing individuals reporting unsafe neighborhoods, fear of injury, and not enough time as barriers to activity engagement (Aronson & Oman, 2004; Parks et al., 2003; Yankeelov et al., 2015).

In considering what can be gained by examining activity engagement at more proximal level of measurement (i.e. IRRtract) versus more distal level of measurement (i.e. IRRcounty), we find that proximal measurement mattered more for evaluating sedentary activities. Unlike other leisure activities, which may facilitate engagement with more distal parts of an individual's environment, sedentariness is a leisure activity that does not necessitate engagement with the distal environment (Kaushal & Rhodes, 2014). When considering typical sedentary activities (watching television, playing on the internet, talking on the phone, etc.), these are activities that are usually done in or close to home (Kaushal & Rhodes, 2014). As Kaushal & Rhodes (2014) point out, individuals receive a higher exposure to the stimuli in the home, compared to the stimuli in the neighborhood or county environment. Their 2014 systematic review evaluated the home environment (i.e. proximal measures) and its relationship to both physical and sedentary behaviors (Kaushal & Rhodes, 2014). A review of 49 studies (20 experimental, 29 observational) suggests that the equipment available in the home can support both physical activity (e.g. treadmills, elliptical, exercise bike, etc.), as well as sedentary activities (e.g. cell phones, televisions, laptops/tablets, etc.). This systematic review describes how the location of sedentary equipment (measured as televisions in bedrooms) can influence the amount of sedentary behavior (Kaushal & Rhodes, 2014). Overall, seven studies included in this review had measures of sedentary behavior and televisions present in bedrooms and found that individuals with television in the bedroom engaged in more frequent sedentary behaviors with large effect sizes ranging from d=7.2 to d=11.16 (Kaushal & Rhodes, 2014). Importantly, Kaushal & Rhodes (2014) describe how we have autonomy in our decisions of what type of equipment we have in our home which can influence our sedentary or physical activity engagement. Collectively, these findings suggest that interventions aimed at reducing sedentary behavior should be implemented at the most proximal level (i.e. the home) to be most effective. In fact, a randomized control trial which evaluated use of in-home exercise equipment, showed that the group which received a treadmill demonstrated greater adherence to their physical activity regimen compared to the group who did not receive a treadmill (Jakicic et al., 1999). Comparatively, several studies have demonstrated that providing exercise DVDs may be a more economically friendly option and effective means for providing equipment that facilitates physical activity engagement (Khalil et al., 2012; Moore et al., 2009; Vestergaard et al., 2008).

Unlike sedentary activities, the distal measurement (IRRcounty) was more important for evaluating social activity engagement. Considering social activities typically described in the literature such as joining a social club, going out to dinner, or visiting friends, these activities are often performed outside of the individual's proximal environment (i.e. their census tract). In fact, there is a rich literature which details how a community (i.e. more distal than census tract) is essential for social activity engagement (Arai & Pedlar, 2003; Dyck et al., 2020; Fan & Khattak, 2009; Mannarini & Fedi, 2009). Arai & Pedlar (2003) describe the community as 'the creation of space for individuals to come together' (p. 199). Under this perspective, it is possible that opportunities for social activities are more readily available at the county level as compared to a smaller geographic area such as a census tract (Arai & Pedlar, 2003). Indeed, prior work describes how activities for social engagement often come in the form of attending sporting events and going to church or theaters which are often located away from the individuals home and require some amount travel to participate in (Arai & Pedlar, 2003; Zhang, 2005). These findings support the finding that individuals more distal environment may be more important when considering social activity engagement.

Both distal and proximal measures were important for evaluating engagement in family activities but the distal county-level measure was slightly more informative. Family engagement is obviously proximal to the individual; it makes sense that the affordances at the proximal level of analysis would be informative. However, the distal level affordances may be informative when considering activities done with the family such as going to a zoo or museum. An interesting study similarly grounded in ecological theory evaluated family activity engagement through both the exosystem-level (the distal environment that the individual participates with but does not directly influence such as county level policies) and the microsystem-level (the immediate environment that the individual directly engages with such as family, siblings, and peers) (Churchill et al., 2007). This study points out the lacking research in evaluating exosystem-level influences on activity engagement, highlighting the detail that it is likely due to the fact that an individual family does not influence what resources available in the environment for family activity engagement, but are directly influenced by the availability (or lack thereof) of resources available in the environment for family activity engagement (Churchill et al., 2007). In evaluating what rural families do for fun this study identifies two subcategories of family activities which included stay-at-home activities and going out activities (Churchill et al., 2007). The associations we observed for family activities at the tract level are likely attributable to stay at home activities such as spending time together, playing games or playing outside (Churchill et al., 2007). The associations we observe for family activities at the county level are likely attributable to the going out activities described in the Churchill et al. (2007) study such as going shopping, outdoor activities such as camping or hiking, and children's participation in organized sports. All of the going out activities are more closely aligned with the exosystem or distal county level resources available to families.

In future work, potential neighborhood level barriers affecting participation in activity engagement, such as measures of the participants perceived neighborhood quality and characteristics ought to be considered, including neighborhood safety and access to recreational facilities such as parks, walking trails, and sidewalks. Additionally, future work will evaluate self-reported engagement in clubs and hobbies that were coded into more than just cognitive, social, and physical domains. When coding the qualitative measures, raters coded the reported activities into one of eight activity domains that were informed by prior literature (Flatt et al., 2015; Stebbins, 2015). These activity domains included things such as: Making & Tinkering Relaxation, Passive entertainment vs. Active entertainment, Creative, and Casual Volunteering / Altruism. Further distinguishing between activity engagement domains may provide interesting differences in rural and urban activity engagement patterns. Moreover, further distinguishing activity domains may provide insight to future work examining the implications for activity engagement on later life cognitive performance. For example, studies have found that engagement in volunteer or altruistic activities may help to improve or buffer risks of declines in memory and cognitive functioning in later life (Carlson et al., 2008; Griep et al., 2017; Infurna et al., 2020). Other studies have suggested that engagement in creative activities can bolster problem solving abilities and memory performance in older adults (Cohen, 2006; Fisher & Specht, 1999).

The present findings expand on understanding of geospatial factors associated with activity engagement with implications regarding sedentariness and health particularly for those residing in relatively more urban locales, which tended to report greater hours of such activities. Irrespective of locale, sedentariness has been associated with increased risk of type 2 diabetes, cardiovascular disease, and depression (Biswas et al., 2015; Pandey et al., 2016; Zhai et al., 2015). That said, further explorations of physical activity engagement, particularly type of physical activity engagement is needed to unpack the otherwise null findings in the present study. Furthermore, this study suggests that while there were no geographic differences in hours of cognitive activity engagement, qualitative measures of hobbies did support geographic differences in the level of cognitive demands of hobbies. This finding has implications regarding the risk of cognitive impairment for individuals living in areas that are more rural, particularly for aging populations (Saenz et al., 2018; Weden et al., 2018). As prior work suggests that engagement in cognitive activities may improve late-life cognition (Langa et al., 2008, 2017; Verghese et al., 2003; Weden et al., 2018), our findings suggest that tailoring interventions to individuals, and communities, in increasingly rural locales may be advisable.

References

Ainsworth, B. E., Haskell, W. L., Whitt, M. C., Irwin, M. L., Swartz, A. M., Strath, S. J., O. Brien, W. L., Bassett, D. R., Schmitz, K. H., Emplaincourt, P. O., Jacobs, D. R., & Leon, A. S. (2000). Compendium of Physical Activities: An update of activity codes and MET intensities: *Medicine & Science in Sports & Exercise*, *32*(Supplement), S498–S516. https://doi.org/10.1097/00005768-200009001-00009

Arai, S., & Pedlar, A. (2003). Moving beyond individualism in leisure theory: A critical analysis of concepts of community and social engagement. *Leisure Studies*, *22*(3), 185–202. https://doi.org/10.1080/026143603200075489

Aronson, R. E., & Oman, R. F. (2004). Views on Exercise and Physical Activity Among Rural-Dwelling Senior Citizens. *The Journal of Rural Health*, *20*(1), 76–79. https://doi.org/10.1111/j.1748-0361.2004.tb00010.x

Barnes, L. L., De Leon, C. M., Wilson, R. S., Bienias, J. L., & Evans, D. A. (2004). Social resources and cognitive decline in a population of older African Americans and whites. *Neurology*, *63*(12), 2322–2326.

Beal, D. J. (2007). Information criteria methods in SAS for multiple linear regression models. *15th Annual SouthEast SAS Users Group (SESUG) Proceedings, South Carolina, Paper SA05*.

Beggs, J. J., Haines, V. A., & Hurlbert, J. S. (1996). Revisiting the Rural-Urban Contrast: Personal Networks in Nonmetropolitan and Metropolitan Settings1. *Rural Sociology*, *61*(2), 306–325. https://doi.org/10.1111/j.1549-0831.1996.tb00622.x

Bennett, D. A., Schneider, J. A., Tang, Y., Arnold, S. E., & Wilson, R. S. (2006). The effect of social networks on the relation between Alzheimer's disease pathology and level of cognitive function in old people: A longitudinal cohort study. *The Lancet Neurology*, *5*(5), 406–412.

Biswas, A., Oh, P. I., Faulkner, G. E., Bajaj, R. R., Silver, M. A., Mitchell, M. S., & Alter, D. A. (2015). Sedentary Time and Its Association With Risk for Disease Incidence, Mortality, and Hospitalization in Adults. *Annals of Internal Medicine*, *162*(2), 123–132. https://doi.org/10.7326/M14-1651

Bronfenbrenner, U. (1979). *The Ecology of Human Development*. Harvard University Press.

Bronfenbrenner, U., & Ceci, S. J. (1994). Nature-nuture reconceptualized in developmental perspective: A bioecological model. *Psychological Review*, *101*(4), 568–586. https://doi.org/10.1037/0033-295X.101.4.568

Bureau, U. C. (n.d.). *Welcome to Geocoder*. Retrieved June 4, 2020, from https://geocoding.geo.census.gov/geocoder/locations/addressbatch?form

Bureau, U. C. (2003). *Core-Based Statistical Areas*. The United States Census Bureau. https://www.census.gov/topics/housing/housing-patterns/about/core-based-statistical-areas.html

Bureau, U. C. (2010). *2010 Census Urban and Rural Classification and Urban Area Criteria*. The United States Census Bureau. https://www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural/2010-urban-rural.html

Bureau, U. C. (2020). *Understanding Geographic Identifiers (GEOIDs)*. The United States Census Bureau. https://www.census.gov/programs-surveys/geography/guidance/geo-identifiers.html

Burnham, K. P., & Anderson, D. R. (2002). A practical information-theoretic approach. *Model Selection and Multimodel Inference, 2nd Ed. Springer, New York*, *2*.

Canter, D. V., & Craik, K. H. (1981). Environmental psychology. *Journal of Environmental Psychology*, *1*(1), 1–11. https://doi.org/10.1016/S0272-4944(81)80013-8

Carlson, M. C., Saczynski, J. S., Rebok, G. W., Seeman, T., Glass, T. A., McGill, S., Tielsch, J., Frick, K. D., Hill, J., & Fried, L. P. (2008). Exploring the Effects of an "Everyday" Activity Program on Executive Function and Memory in Older Adults: Experience Corps®. *The Gerontologist*, *48*(6), 793–801. https://doi.org/10.1093/geront/48.6.793

Cassarino, M., & Setti, A. (2015). Environment as 'Brain Training': A review of geographical and physical environmental influences on cognitive ageing. *Ageing Research Reviews*, *23*, 167–182. https://doi.org/10.1016/j.arr.2015.06.003

Chan, T., Parisi, J. M., Moored, K. D., & Carlson, M. C. (2018). Variety of Enriching Early Life Activities Linked to Late Life Cognitive Functioning in Urban Community-Dwelling African Americans. *The Journals of Gerontology: Series B*.

Chen, S.-T., Hyun, J., Graefe, A. R., Mowen, A. J., Almeida, D. M., & Sliwinski, M. J. (2020). The Influence of Leisure Engagement on Daily Emotional Well-Being. *Leisure Sciences*, *0*(0), 1–18. https://doi.org/10.1080/01490400.2020.1757537

Churchill, S. L., Clark, V. L. P., Prochaska-Cue, K., Creswell, J. W., & Ontai-Grzebik, L. (2007). How Rural Low-Income Families Have Fun: A Grounded Theory Study. *Journal of Leisure Research*, *39*(2), 271–294. https://doi.org/10.1080/00222216.2007.11950108

Clark, (1999). An embodied cognitive science? *Trends in Cognitive Sciences*, *3*(9), 345–351.

Clarke, B. L., Koziol, N. A., & Sheridan, S. M. (2017). The Effects of Rurality on Parents' Engagement in Children's Early Literacy. In G. C. Nugent, G. M. Kunz, S. M. Sheridan, T. A. Glover, & L. L. Knoche (Eds.), *Rural Education Research in the United States: State of the Science and Emerging Directions* (pp. 231–250). Springer International Publishing. https://doi.org/10.1007/978-3-319-42940-3_12

Clarke, P. J., Ailshire, J. A., House, J. S., Morenoff, J. D., King, K., Melendez, R., & Langa, K. M. (2011). Cognitive function in the community setting: The neighbourhood as a source of 'cognitive reserve'? *Journal of Epidemiology & Community Health*, jech–2010.

Cohen, G. (2006). Research on Creativity and Aging: The Positive Impact of the Arts on Health and Illness. *Generations*, *30*(1), 7–15.

Davis, S., Crothers, N., Grant, J., Young, S., & Smith, K. (2012). Being involved in the country: Productive ageing in different types of rural communities. *Journal of Rural Studies*, *28*(4), 338–346.

Deng, Y., & Paul, D. R. (2018). The Relationships Between Depressive Symptoms, Functional Health Status, Physical Activity, and the Availability of Recreational Facilities: A Rural-Urban Comparison in Middle-Aged and Older Chinese Adults. *International Journal of Behavioral Medicine*, *25*(3), 322–330. https://doi.org/10.1007/s12529-018-9714-3

Dyck, D. V., Barnett, A., Cauwenberg, J. V., Zhang, C. J. P., Sit, C. H. P., & Cerin, E. (2020). Main and interacting effects of physical activity and sedentary time on older adults' BMI: The moderating roles of socio-demographic and environmental attributes. *PLOS ONE*, *15*(7), e0235833. https://doi.org/10.1371/journal.pone.0235833

Eaton, C. B., Nafziger, A. N., Strogatz, D. S., & Pearson, T. A. (1994). Self-reported physical activity in a rural county: A New York county health census. *American Journal of Public Health*, *84*(1), 29–32. https://doi.org/10.2105/AJPH.84.1.29

Eberhardt, M. S., & Pamuk, E. R. (2004). The Importance of Place of Residence: Examining Health in Rural and Nonrural Areas. *American Journal of Public Health*, *94*(10), 1682–1686. https://doi.org/10.2105/AJPH.94.10.1682

Elder Jr, G. H., & Conger, R. D. (2014). *Children of the land: Adversity and success in rural America*. University of Chicago Press.

Ertel, K. A., Glymour, M. M., & Berkman, L. F. (2008). Effects of social integration on preserving memory function in a nationally representative US elderly population. *American Journal of Public Health*, *98*(7), 1215–1220.

ESRI. (2018). *ArcMap* (10.6.1) [Computer software]. http://desktop.arcgis.com/en/arcmap/

Eyler, A. A., & Vest, J. R. (2002). Environmental and Policy Factors Related to Physical Activity in Rural White Women. *Women & Health*, *36*(2), 109–119. https://doi.org/10.1300/J013v36n02_08

Fan, J. X., Wen, M., & Kowaleski-Jones, L. (2014). Rural–Urban Differences in Objective and Subjective Measures of Physical Activity: Findings From the National Health and Nutrition Examination Survey (NHANES) 2003–2006. *Preventing Chronic Disease*, *11*. https://doi.org/10.5888/pcd11.140189

Fan, Y., & Khattak, A. J. (2009). Does urban form matter in solo and joint activity engagement? *Landscape and Urban Planning*, *92*(3), 199–209. https://doi.org/10.1016/j.landurbplan.2009.05.006

Fisher, B. J., & Specht, D. K. (1999). Successful Aging And Creativity In Later Life. *Journal of Aging Studies*, *13*(4), 457–472. https://doi.org/10.1016/S0890-4065(99)00021-3

Flatt, J. D., Hughes, T. F., Documét, P. I., Lingler, J. H., Trauth, J. M., & Albert, S. M. (2015). A Qualitative Study on the Types and Purposes of Social Activities in Late Life. *Activities, Adaptation & Aging*, *39*(2), 109–132. https://doi.org/10.1080/01924788.2015.1024485

Gibson, E. J. (1991). *The ecological approach: A foundation for environmental psychology.*

Gow, A. J., Pattie, A., & Deary, I. J. (2017). Lifecourse Activity Participation From Early, Mid, and Later Adulthood as Determinants of Cognitive Aging: The Lothian Birth Cohort 1921. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *72*(1), 25–37. https://doi.org/10.1093/geronb/gbw124

Griep, Y., Hanson, L. M., Vantilborgh, T., Janssens, L., Jones, S. K., & Hyde, M. (2017). Can volunteering in later life reduce the risk of dementia? A 5-year longitudinal study among volunteering and non-volunteering retired seniors. *PLoS One*, *12*(3), e0173885.

Haberstick, B. C., Zeiger, J. S., & Corley, R. P. (2014). Genetic and environmental influences on the allocation of adolescent leisure time activities. *BioMed Research International*, *2014*.

Harris, J. K., Beatty, K., Leider, J. P., Knudson, A., Anderson, B. L., & Meit, M. (2016). The Double Disparity Facing Rural Local Health Departments. *Annual Review of Public Health*, *37*(1), 167–184. https://doi.org/10.1146/annurev-publhealth-031914-122755

Hoang, T. D., Reis, J., Zhu, N., Jacobs, D. R., Launer, L. J., Whitmer, R. A., Sidney, S., & Yaffe, K. (2016). Effect of early adult patterns of physical activity and television viewing on midlife cognitive function. *JAMA Psychiatry*, *73*(1), 73–79.

Hofferth, S. L., & Iceland, J. (1998). Social Capital in Rural and Urban Communities1. *Rural Sociology*, *63*(4), 574–598. https://doi.org/10.1111/j.1549-0831.1998.tb00693.x

Huffman, M. K., & Amireault, S. (2019). INDEX OF RELATIVE RURALITY AS A PREDICTOR OF PHYSICAL ACTIVITY CORRELATES FOR OLDER ADULTS. *Innovation in Aging*, *3*(Supplement_1), S521–S521. https://doi.org/10.1093/geroni/igz038.1920

Inagami, S., Gao, S., Karimi, H., Shendge, M. M., Probst, J. C., & Stone, R. A. (2016). Adapting the Index of Relative Rurality (IRR) to Estimate Rurality at the ZIP Code Level: A Rural Classification System in Health Services Research: Adapting the Index of Relative Rurality. *The Journal of Rural Health*, *32*(2), 219–227. https://doi.org/10.1111/jrh.12148

Infurna, F. J., Gerstorf, D., & Lachman, M. E. (2020). Midlife in the 2020s: Opportunities and challenges. *American Psychologist*, *75*(4), 470–485. https://doi.org/10.1037/amp0000591

Jakicic, J. M., Winters, C., Lang, W., & Wing, R. R. (1999). Effects of Intermittent Exercise and Use of Home Exercise Equipment on Adherence, Weight Loss, and Fitness in Overweight Women: A Randomized Trial. *JAMA*, *282*(16), 1554–1560. https://doi.org/10.1001/jama.282.16.1554

Jessor, R., & Jessor, S. L. (1977). *Problem behavior and psychosocial development: A longitudinal study of youth.*

Karp, A., Paillard-Borg, S., Wang, H.-X., Silverstein, M., Winblad, B., & Fratiglioni, L. (2006). Mental, physical and social components in leisure activities equally contribute to decrease dementia risk. *Dementia and Geriatric Cognitive Disorders*, *21*(2), 65–73.

Kaushal, N., & Rhodes, R. E. (2014). The home physical environment and its relationship with physical activity and sedentary behavior: A systematic review. *Preventive Medicine*, *67*, 221–237. https://doi.org/10.1016/j.ypmed.2014.07.026

Kelly, M. E., Duff, H., Kelly, S., McHugh Power, J. E., Brennan, S., Lawlor, B. A., & Loughrey, D. G. (2017). The impact of social activities, social networks, social support and social relationships on the cognitive functioning of healthy older adults: A systematic review. *Systematic Reviews*, *6*(1), 259. https://doi.org/10.1186/s13643-017-0632-2

Key, W. H. (1961). Rural-Urban Differences and the Family. *The Sociological Quarterly*, *2*(1), 49–56. https://doi.org/10.1111/j.1533-8525.1961.tb01484.x

Khalil, H., Quinn, L., van Deursen, R., Martin, R., Rosser, A., & Busse, M. (2012). Adherence to Use of a Home-Based Exercise DVD in People With Huntington Disease: Participants' Perspectives. *Physical Therapy*, *92*(1), 69–82. https://doi.org/10.2522/ptj.20100438

Krueger, K. R., Wilson, R. S., Kamenetsky, J. M., Barnes, L. L., Bienias, J. L., & Bennett, D. A. (2009). Social engagement and cognitive function in old age. *Experimental Aging Research*, *35*(1), 45–60.

Kuiper, J. S., Zuidersma, M., Voshaar, R. C. O., Zuidema, S. U., van den Heuvel, E. R., Stolk, R. P., & Smidt, N. (2015). Social relationships and risk of dementia: A systematic review and meta-analysis of longitudinal cohort studies. *Ageing Research Reviews*, *22*, 39–57.

Kuiper, J. S., Zuidersma, M., Zuidema, S. U., Burgerhof, J. G., Stolk, R. P., Oude Voshaar, R. C., & Smidt, N. (2016). Social relationships and cognitive decline: A systematic review and meta-analysis of longitudinal cohort studies. *International Journal of Epidemiology*, *45*(4), 1169–1206.

Lampard, J. E., Voigt, M., & Bornstein, M. H. (2000). Urban and rural parenting. *Parenthood in America: An Encyclopedia*, *2*, 442–444.

Langa, K. M., Larson, E. B., Crimmins, E. M., Faul, J. D., Levine, D. A., Kabeto, M. U., & Weir, D. R. (2017). A comparison of the prevalence of dementia in the United States in 2000 and 2012. *JAMA Internal Medicine*, *177*(1), 51–58.

Langa, K. M., Larson, E. B., Karlawish, J. H., Cutler, D. M., Kabeto, M. U., Kim, S. Y., & Rosen, A. B. (2008). Trends in the prevalence and mortality of cognitive impairment in the United States: Is there evidence of a compression of cognitive morbidity? *Alzheimer's & Dementia*, *4*(2), 134–144.

Lee, Y., Chi, I., & Palinkas, L. A. (2019). Retirement, Leisure Activity Engagement, and Cognition Among Older Adults in the United States. *Journal of Aging and Health*, *31*(7), 1212–1234. https://doi.org/10.1177/0898264318767030

Levasseur, M., Cohen, A. A., Dubois, M.-F., Généreux, M., Richard, L., Therrien, F.-H., & Payette, H. (2015). Environmental Factors Associated With Social Participation of Older Adults Living in Metropolitan, Urban, and Rural Areas: The NuAge Study. *American Journal of Public Health*, *105*(8), 1718–1725. https://doi.org/10.2105/AJPH.2014.302415

Mannarini, T., & Fedi, A. (2009). Multiple senses of community: The experience and meaning of community. *Journal of Community Psychology*, *37*(2), 211–227. https://doi.org/10.1002/jcop.20289

Marttinen, R., Simon, M., Phillips, S., & Fredrick, R. N. (2020). Latina Elementary School Girls' Experiences in an Urban After-School Physical Education and Literacy Program. *Journal of Teaching in Physical Education*, *1*(aop), 1–10. https://doi.org/10.1123/jtpe.2019-0211

Matz, C. J., Stieb, D. M., & Brion, O. (2015). Urban-rural differences in daily time-activity patterns, occupational activity and housing characteristics. *Environmental Health*, *14*(1). https://doi.org/10.1186/s12940-015-0075-y

Meng, T., & Chen, H. (2014). A multilevel analysis of social capital and self-rated health: Evidence from China. *Health & Place*, *27*, 38–44. https://doi.org/10.1016/j.healthplace.2014.01.009

Moore, J., Fiddler, H., Seymour, J., Grant, A., Jolley, C., Johnson, L., & Moxham, J. (2009). Effect of a home exercise video programme in patients with chronic obstructive pulmonary disease. *Journal of Rehabilitation Medicine*, *41*(3), 195–200. https://doi.org/10.2340/16501977-0308

Mueller, K. D., Norton, D., Koscik, R. L., Morris, M. C., Jonaitis, E. M., Clark, L. R., Fields, T., Allison, S., Berman, S., Kraning, S., Zuelsdorff, M., Okonkwo, O., Chin, N., Carlsson, C. M., Bendlin, B. B., Hermann, B. P., & Johnson, S. C. (2020). Self-reported health behaviors and longitudinal cognitive performance in late middle age: Results from the Wisconsin Registry for Alzheimer's Prevention. *PLOS ONE*, *15*(4), e0221985. https://doi.org/10.1371/journal.pone.0221985

Offer, S., & Schneider, B. (2007). Children's Role in Generating Social Capital. *Social Forces*, *85*(3), 1125–1142. JSTOR.

Paluska, S. A., & Schwenk, T. L. (2000). Physical activity and mental health. *Sports Medicine*, *29*(3), 167–180.

Pandey, A., Salahuddin, U., Garg, S., Ayers, C., Kulinski, J., Anand, V., Mayo, H., Kumbhani, D. J., de Lemos, J., & Berry, J. D. (2016). Continuous dose-response association between sedentary time and risk for cardiovascular disease: A meta-analysis. *JAMA Cardiology*, *1*(5), 575–583.

Parks, S. E., Housemann, R. A., & Brownson, R. C. (2003). Differential correlates of physical activity in urban and rural adults of various socioeconomic backgrounds in the United States. *Journal of Epidemiology & Community Health*, *57*(1), 29–35. https://doi.org/10.1136/jech.57.1.29

Patterson, P. D., Moore, C. G., Probst, J. C., & Shinogle, J. A. (2004). Obesity and Physical Inactivity in Rural America. *The Journal of Rural Health*, *20*(2), 151–159. https://doi.org/10.1111/j.1748-0361.2004.tb00022.x

Phansikar, M., & Mullen, S. P. (2019). Exploring Active Travel and Leisure-Time Physical Activity Relationships With Cognition Among Older Adults. *Journal of Aging and Physical Activity*, *1*(aop), 1–8. https://doi.org/10.1123/japa.2019-0125

Plomin, R., & DeFries, J. C. (1983). The Colorado adoption project. *Child Development*, 276–289.

Queen, T. L., Butner, J., Berg, C. A., & Smith, J. (2019). Activity Engagement Among Older Adult Spousal Caregivers. *The Journals of Gerontology: Series B*, *74*(7), 1278–1282. https://doi.org/10.1093/geronb/gbx106

Raftery, A. E. (1995). Bayesian Model Selection in Social Research. *Sociological Methodology*, *25*, 111–163. https://doi.org/10.2307/271063

Reis, J. P., Bowles, H. R., Ainsworth, B. E., Dubose, K. D., Smith, S., & Laditka, J. N. (2004). Nonoccupational physical activity by degree of urbanization and U.S. geographic region. *Medicine and Science in Sports and Exercise*, *36*(12), 2093—2098. https://doi.org/10.1249/01.mss.0000147589.98744.85

Rhea, S.-A., Bricker, J. B., Wadsworth, S. J., & Corley, R. P. (2013). The Colorado Adoption Project. *Twin Research and Human Genetics*, *16*(01), 358–365. https://doi.org/10.1017/thg.2012.109

Rhea, S.-A., Gross, A. A., Haberstick, B. C., & Corley, R. P. (2013). Colorado Twin Registry—An Update. *Twin Research and Human Genetics : The Official Journal of the International Society for Twin Studies*, *16*(1). https://doi.org/10.1017/thg.2012.93

Robertson, M. C., Song, J., Taylor, W. C., Durand, C. P., & Basen-Engquist, K. M. (2018). Urban-Rural Differences in Aerobic Physical Activity, Muscle Strengthening Exercise, and Screen-Time Sedentary Behavior: Urban-Rural Differences in Physical Activity. *The Journal of Rural Health*, *00*, 1–10. https://doi.org/10.1111/jrh.12295

Romans, S., Cohen, M., & Forte, T. (2011). Rates of depression and anxiety in urban and rural Canada. *Social Psychiatry and Psychiatric Epidemiology*, *46*(7), 567–575.

Romans, S. E., Walton, V. A., Herbison, G. P., & Mullen, P. E. (1992). Social Networks and Psychiatric Morbidity in New Zealand Women. *Australian and New Zealand Journal of Psychiatry*, *26*(3), 485–492. https://doi.org/10.3109/00048679209072075

Romans-Clarkson, S., E., Walton, V., A., Herbison, P., & Mullen, P. (1990). *Psychiatric Morbidity among Women in Urban and Rural New Zealand: Psycho-social Correlates - ProQuest*. https://search.proquest.com/openview/253655a5b652cd8eb52b9cb15d33e3cb/1/advanced

Roscigno, V. J., Tomaskovic-Devey, D., & Crowley, M. (2005). Education and the Inequalities of Place. *Social Forces*, *84*(4), 2121–2146.

Saenz, J. L., Downer, B., Garcia, M. A., & Wong, R. (2018). Cognition and Context: Rural–Urban Differences in Cognitive Aging Among Older Mexican Adults. *Journal of Aging and Health*, *30*(6), 965–986. https://doi.org/10.1177/0898264317703560

Sallis, J. F., Bowles, H. R., Bauman, A., Ainsworth, B. E., Bull, F. C., Craig, C. L., Sjöström, M., De Bourdeaudhuij, I., Lefevre, J., Matsudo, V., Matsudo, S., Macfarlane, D. J., Gomez, L. F., Inoue, S., Murase, N., Volbekiene, V., McLean, G., Carr, H., Heggebo, L. K., … Bergman, P. (2009). Neighborhood Environments and Physical Activity Among Adults in 11 Countries. *American Journal of Preventive Medicine*, *36*(6), 484–490. https://doi.org/10.1016/j.amepre.2009.01.031

Salthouse, T. A., Berish, D. E., & Miles, J. D. (2002). The role of cognitive stimulation on the relations between age and cognitive functioning. *Psychology and Aging*, *17*(4), 548–557. https://doi.org/10.1037/0882-7974.17.4.548

Salvo, G., Lashewicz, B. M., Doyle-Baker, P. K., & McCormack, G. R. (2018). Neighbourhood Built Environment Influences on Physical Activity among Adults: A Systematized Review of Qualitative Evidence. *International Journal of Environmental Research and Public Health*, *15*(5), 897. https://doi.org/10.3390/ijerph15050897

Sampaio, P. Y. S., Ito, E., & Carvalho Sampaio, R. A. (2013). The association of activity and participation with quality of life between Japanese older adults living in rural and urban areas. *Journal of Clinical Gerontology and Geriatrics*, *4*(2), 51–56. https://doi.org/10.1016/j.jcgg.2012.11.004

Sanderson, B., Littleton, M., & Pulley, L. V. (2002). Environmental, Policy, and Cultural Factors Related to Physical Activity Among Rural, African American Women. *Women & Health*, *36*(2), 73–88. https://doi.org/10.1300/J013v36n02_06

Scarmeas, N., Levy, G., Tang, M.-X., Manly, J., & Stern, Y. (2001). Influence of leisure activity on the incidence of Alzheimer's disease. *Neurology*, *57*(12), 2236–2242.

Schaie, K. W., Willis, S. L., Knight, B. G., Levy, B., & Park, D. C. (Eds.). (2016). *Handbook of the Psychology of Aging* (7 edition). Academic Press.

Sharifian, N., Gu, Y., Manly, J. J., Schupf, N., Mayeux, R., Brickman, A. M., & Zahodne, L. B. (2020). Linking depressive symptoms and cognitive functioning: The mediating role of leisure activity. *Neuropsychology*, *34*(1), 107–115. https://doi.org/10.1037/neu0000595

Sofi, F., Valecchi, D., Bacci, D., Abbate, R., Gensini, G. F., Casini, A., & Macchi, C. (2011). Physical activity and risk of cognitive decline: A meta-analysis of prospective studies. *Journal of Internal Medicine*, *269*(1), 107–117.

Sørensen, J. F. L. (2012). Testing the Hypothesis of Higher Social Capital in Rural Areas: The Case of Denmark. *Regional Studies*, *46*(7), 873–891. https://doi.org/10.1080/00343404.2012.669471

Stebbins, R. A. (2015). *Between Work and Leisure: The Common Ground of Two Separate Worlds*. Transaction Publishers.

Stern, C., & Munn, Z. (2010). Cognitive leisure activities and their role in preventing dementia: A systematic review. *International Journal of Evidence-Based Healthcare*, *8*(1), 2–17. https://doi.org/10.1111/j.1744-1609.2010.00150.x

Suherman, A., Jajat, Rahayu, N. I., Sultoni, K., Risma, R., & Agust, K. (2020). *Early Childhood Physical Activity and Sedentary Behavior in Indonesia: Objectively Measure Using Accelerometer*. 426–428. https://doi.org/10.2991/ahsr.k.200214.114

Taaffe, D. R., Irie, F., Masaki, K. H., Abbott, R. D., Petrovitch, H., Ross, G. W., & White, L. R. (2008). Physical activity, physical function, and incident dementia in elderly men: The Honolulu–Asia Aging Study. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *63*(5), 529–535.

Tang, F., Zhang, W., Chi, I., Li, M., & Dong, X. Q. (2020). Importance of Activity Engagement and Neighborhood to Cognitive Function Among Older Chinese Americans. *Research on Aging*, 0164027520917064. https://doi.org/10.1177/0164027520917064

Therrien, F.-H., & Desrosiers, J. (2010). Participation of metropolitan, urban and rural community-dwelling older adults. *Archives of Gerontology and Geriatrics*, *51*(3), e52–e56. https://doi.org/10.1016/j.archger.2009.11.017

Trivedi, T., Liu, J., Probst, J., Merchant, A., Jones, S., & Martin, A. (2015). Obesity and obesity-related behaviors among rural and urban adults in the USA. *Rural Remote Health*, *15*(4), 11.

US Department of Commerce, N. O. and A. A. (2018). *North American Datum of 1983 (NAD 83)—Horizontal and Geometric Datums—Datums—National Geodetic Survey*. https://www.ngs.noaa.gov/datums/horizontal/north-american-datum-1983.shtml

USDA, E. (2010). *USDA ERS - Rural-Urban Commuting Area Codes*. Rural-Urban Commuting Area Codes. https://www.ers.usda.gov/data-products/rural-urban-commuting-area-codes/

USDA, E. (2013). *USDA ERS - Rural-Urban Continuum Codes*. https://www.ers.usda.gov/data-products/rural-urban-continuum-codes/

Verghese, J., Lipton, R. B., Katz, M. J., Hall, C. B., Derby, C. A., Kuslansky, G., Ambrose, A. F., Sliwinski, M., & Buschke, H. (2003). Leisure activities and the risk of dementia in the elderly. *New England Journal of Medicine*, *348*(25), 2508–2516.

Vestergaard, S., Kronborg, C., & Puggaard, L. (2008). Home-based video exercise intervention for community-dwelling frail older women: A randomized controlled trial. *Aging Clinical and Experimental Research*, *20*(5), 479–486. https://doi.org/10.1007/BF03325155

Vogelsang, E. M. (2016). Older adult social participation and its relationship with health: Rural-urban differences. *Health & Place*, *42*, 111–119. https://doi.org/10.1016/j.healthplace.2016.09.010

Wadsworth, S. J., Corley, R. P., Munoz, E., Trubenstein, B. P., Knaap, E., DeFries, J. C., Plomin, R., Reynolds, C. A., & The CATSLife Team. (2019a). CATSLife: A Study of Lifespan Behavioral Development and Cognitive Functioning. *Twin Research and Human Genetics*, *22*(6), 695–706. https://doi.org/10.1017/thg.2019.49

Wadsworth, S. J., Corley, R. P., Munoz, E., Trubenstein, B. P., Knaap, E., DeFries, J. C., Plomin, R., Reynolds, C. A., & The CATSLife Team. (2019b). CATSLife: A Study of Lifespan Behavioral Development and Cognitive Functioning – Corrigendum. *Twin Research and Human Genetics*, *22*(6), 829–829. https://doi.org/10.1017/thg.2019.126

Waldorf, B. (2006). *A Continuous Multi-Dimensional Measure of Rurality: Moving Beyond Threshold Measures*. Selected Paper, Annual Meetings of the Association of Agricultural Economics, Long Beach, CA, July 2006.

Waldorf, B., & Ayoung, K. (2015). *Defining And Measuring Rurality in the US: From Typologies to Continuous Indices*. 26. https://doi.org/doi:10.4231/R7959FS8

Wang, H.-X., Karp, A., Winblad, B., & Fratiglioni, L. (2002). Late-life engagement in social and leisure activities is associated with a decreased risk of dementia: A longitudinal study from the Kungsholmen project. *American Journal of Epidemiology*, *155*(12), 1081–1087.

Wang, H.-X., MacDonald, S. W., Dekhtyar, S., & Fratiglioni, L. (2017). Association of lifelong exposure to cognitive reserve-enhancing factors with dementia risk: A community-based cohort study. *PLoS Medicine*, *14*(3), e1002251.

Weaver, K. E., Palmer, N., Lu, L., Case, L. D., & Geiger, A. M. (2013). Rural–urban differences in health behaviors and implications for health status among US cancer survivors. *Cancer Causes & Control*, *24*(8), 1481–1490. https://doi.org/10.1007/s10552-013-0225-x

Weden, M. M., Shih, R. A., Kabeto, M. U., & Langa, K. M. (2018). Secular Trends in Dementia and Cognitive Impairment of U.S. Rural and Urban Older Adults. *American Journal of Preventive Medicine*, *54*(2), 164–172. https://doi.org/10.1016/j.amepre.2017.10.021

Wen, M., Fan, J. X., Kowaleski-Jones, L., & Wan, N. (2018). Rural–urban disparities in obesity prevalence among working age adults in the United States: Exploring the mechanisms. *American Journal of Health Promotion*, *32*(2), 400–408. https://doi.org/DOI: 10.1177/0890117116689488

Wilcox, S., Castro, C., King, A., Housemann, R., & Brownson, R. (2000). Determinants of leisure time physical activity in rural compared with urban older and ethnically diverse women in the United States. *Journal of Epidemiology & Community Health*, *54*(9), 667–672. https://doi.org/10.1136/jech.54.9.667

Wilson, R. S., Boyle, P. A., Yu, L., Barnes, L. L., Schneider, J. A., & Bennett, D. A. (2013). Life-span cognitive activity, neuropathologic burden, and cognitive aging. *Neurology*, 10–1212.

Wirth, L. (1938). Urbanism as a Way of Life. *American Journal of Sociology*, *44*(1), 1–24. JSTOR.

Wu, Y.-T., Prina, A. M., Jones, A., Matthews, F. E., & Brayne, C. (2017). The Built Environment and Cognitive Disorders: Results From the Cognitive Function and Ageing Study II. *American Journal of Preventive Medicine*, *53*(1), 25–32. https://doi.org/10.1016/j.amepre.2016.11.020

Yankeelov, P. A., Faul, A. C., D'Ambrosio, J. G., Collins, W. L., & Gordon, B. (2015). "Another Day in Paradise": A Photovoice Journey of Rural Older Adults Living With Diabetes. *Journal of Applied Gerontology*, *34*(2), 199–218. https://doi.org/10.1177/0733464813493136

Zhai, L., Zhang, Y., & Zhang, D. (2015). Sedentary behaviour and the risk of depression: A meta-analysis. *British Journal of Sports Medicine*, *49*(11), 705–709.

Zhang, M. (2005). Exploring the relationship between urban form and nonwork travel through time use analysis. *Landscape and Urban Planning*, *73*(2), 244–261. https://doi.org/10.1016/j.landurbplan.2004.11.008

Ziersch, A. M., Baum, F., Darmawan, I. G. N., Kavanagh, A. M., & Bentley, R. J. (2009). Social capital and health in rural and urban communities in South Australia. *Australian and New Zealand Journal of Public Health*, *33*(1), 7–16. https://doi.org/10.1111/j.1753-6405.2009.00332.x

Zimmerman, S., Scott, A. C., Park, N. S., Hall, S. A., Wetherby, M. M., Gruber-Baldini, A. L., & Morgan, L. A. (2003). Social engagement and its relationship to service provision in residential care and assisted living. *Social Work Research*, *27*(1), 6–18. https://doi.org/10.1093/swr/27.1.6

Zimmerman, S., Sloane, P., & Eckert, J. (2001). Emerging issues in residential care/assisted living. *Assisted Living: Needs, Practices, and Policies in Residential Care for the Elderly*, 317–331.

Table 1.1: Sociodemographic Descriptive Statistics

	N	*Range*	*Minimum*	*Maximum*	*Mean*	*SD*	*Variance*
Age	1155	21.28	28.06	49.33	33.02	4.90	24.01
CAP	500	18.32	31.01	49.33	37.98	3.22	10.38
LTS	655	5.848	28.06	33.91	29.24	1.16	1.35
Gender	1155	1	0	1	0.54	0.50	0.25
CAP	500	1	0	1	0.53	0.50	0.25
LTS	655	1	0	1	0.54	0.50	0.25
White	1155	1	0	1	0.92	0.27	0.07
CAP	500	1	0	1	0.93	0.26	0.07
LTS	655	1	0	1	0.92	0.28	0.08
Hispanic	1155	1	0	1	0.06	0.24	0.06
CAP	500	1	0	1	0.01	0.10	0.01
LTS	655	1	0	1	0.10	0.30	0.09

Note: CAP=Colorado Adoption Project; LTS=Longitudinal Twin Study; Gender (male=0, female=1); White (no=0, yes=1); Hispanic (no=0, yes=1).

Table 1.2: Correlations of distance to MMSA

	1.	2.	3.
1. Distance from Participant to MMSA	1		
2. Distance from County Centroid to MMSA	0.690**	1	
3. Distance from Tract Centroid to MMSA	0.987**	0.689**	1

Note. All distances were measured in miles. N=1139; ***p*<0.0001

Table 1.3: Descriptive Statistics for Geographic Measures

Remoteness	*N*	*Min*	*Max*	*Mean*	*SD*	*Variance*
County Centroid	1139	0.02	176.69	16.13	13.81	190.80
CAP	493	0.32	94.44	16.21	13.25	175.61
LTS	646	0.02	176.69	16.08	14.24	202.68
Tract Centroid	1139	0.29	166.70	9.19	10.76	115.81
CAP	493	0.38	104.87	9.87	10.45	109.16
LTS	646	0.29	166.70	8.67	10.97	120.44
Address	1139	0.16	157.26	9.00	10.53	110.85
CAP	493	0.17	98.02	9.69	10.40	108.16
LTS	646	0.16	157.26	8.47	10.60	112.43
Percent Urban	*N*	*Min*	*Max*	*Mean*	*SD*	*Variance*
% Urban County	1139	0	100	89.44	15.72	246.99
CAP	493	0	100	89.55	16.05	257.47
LTS	646	0	100	89.36	15.47	239.36
% Urban Tract	1139	0	100	91.49	23.06	531.67
CAP	493	0	100	90.55	24.96	623.19
LTS	646	0	100	92.20	21.48	461.50
Population Density	*N*	*Min*	*Max*	*Mean*	*SD*	*Variance*
PD County	1139	150.28	2.01E+05	1.69E+04	2.26E+04	5.09E+08
CAP	493	150.28	1.86E+05	1.79E+04	2.35E+04	5.52E+08
LTS	646	228.30	2.01E+05	1.62E+04	2.18E+04	4.76E+08
PD Tract	1139	0.30	4.17E+04	3.57E+02	2.34E+03	5.46E+06
CAP	493	0.55	3.76E+04	4.05E+02	2.42E+03	5.88E+06
LTS	646	0.30	4.17E+04	3.21E+02	2.27E+03	5.14E+06
Population	*N*	*Min*	*Max*	*Mean*	*SD*	*Variance*
Pop County	1139	690	9.82E+06	7.38E+05	1.21E+06	1.46E+12
CAP	493	690	9.82E+06	8.04E+05	1.34E+06	1.79E+12
LTS	646	2801	9.82E+06	6.88E+05	1.10E+06	1.21E+12
Pop Tract	1139	561	2.62E+04	4.86E+03	2.07E+03	4.30E+06
CAP	493	561	2.62E+04	4.85E+03	2.26E+03	5.11E+06
LTS	646	892	1.92E+04	4.87E+03	1.92E+03	3.68E+06
IRR	*N*	*Min*	*Max*	*Mean*	*SD*	*Variance*
IRR_{county}	1139	0.06	0.79	0.25	0.10	0.01
CAP	493	0.06	0.79	0.24	0.11	0.01
LTS	646	0.06	0.77	0.25	0.10	0.01

Table 1.3: Descriptive Statistics for Geographic Measures

IRR (cont.)	*N*	*Min*	*Max*	*Mean*	*SD*	*Variance*
IRR_{tract}	1139	0.05	0.80	0.24	0.10	0.01
CAP	493	0.05	0.80	0.25	0.11	0.01
LTS	646	0.12	0.76	0.24	0.09	0.01
RUCC/A	***N***	***Min***	***Max***	***Mean***	***SD***	***Variance***
RUCC	1139	1	9	1.68	1.25	1.57
CAP	493	1	9	1.68	1.36	1.84
LTS	646	1	9	1.68	1.17	1.37
RUCA	1139	1	10	1.43	1.45	2.09
CAP	493	1	10	1.47	1.62	2.63
LTS	646	1	10	1.40	1.30	1.68

Note. CAP=Colorado Adoption Project; LTS=Longitudinal Twin Study. Remoteness - Centroid denotes the distance (in miles) from the centroid of the county to the nearest metro/micropolitan statistical area, Address denotes the distance (in miles) from the participants address to the nearest metro/micropolitan statistical area. % Urban County = percent of individuals in the county living in an urban area, % Urban Tract = percent of individuals in the census tract living in an urban area. Population Density calculated per square mile. IRRcounty = Index of Relative Rurality for the county with MMSA measured from the centroid of the county; IRRtract = IRR for the census tract with MMSA measured from the participant's address; RUCC=Rural Urban Continuum Codes. RUCA=Rural Urban Commuting Area codes.

Table 1.4: Activity Engagement Domain Descriptive Statistics

	N	*Min*	*Max*	*Mean*	*SD*	*Var.*
Sum Social HPW	1127	0	25	6.77	4.00	15.97
sitting around with friends?	1127	1	6	2.74	1.04	1.08
talking on the phone?	1127	1	6	2.48	1.10	1.21
doing things with a club?	1126	1	6	1.31	0.72	0.52
going out with friends or dating?	1125	1	6	2.67	1.20	1.45
Sum Physical HPW	1127	0	32	6.54	4.74	22.50
taking part in an organized sport or recreation program?	1127	1	6	1.65	1.06	1.12
working out as part of a personal exercise program?	1126	1	6	2.80	1.45	2.09
playing pickup games like basketball, touch football, etc.?	1127	1	6	1.23	0.58	0.33
practicing different physical activities?	1126	1	6	1.63	1.01	1.01
doing activities with a pet?	1079	1	6	2.56	1.47	2.17
Sum Family HPW	1127	0	24	10.78	7.07	49.94
doing things with your family?	1127	1	6	3.77	1.61	2.60
taking care of younger family members?	1127	1	6	2.77	2.23	4.95
doing household chores?	1127	1	6	3.69	1.21	1.47
Sum Sedentary HPW	1127	0	32	11.88	5.86	34.29
just sitting and listening to music?	1127	1	6	2.04	1.12	1.25
just sitting and doing nothing?	1127	1	6	2.39	1.29	1.65
watching tv?	1126	1	6	3.99	1.46	2.13
using a computer/tablet/phone for fun?	1126	1	6	3.84	1.50	2.25
Sum Cognitive HPW	1127	0	24	4.65	3.78	14.32
reading for fun?	1127	1	6	2.45	1.23	1.51
spending time on a hobby?	1127	1	6	2.59	1.40	1.96
playing a musical instrument?	1079	1	6	1.43	0.97	0.94
Sum Total Hours	1127	5	85.5	40.61	11.91	141.73
Number of Hobbies	592	1	12	2.20	1.48	2.18
Cognitively Rated Hobbies	592	1.59	5	2.57	0.64	0.42
Socially Rated Hobbies	592	1	5	1.69	0.76	0.58
Physically Rated Hobbies	592	1	5	1.83	0.78	0.60

Note. HPW=Hours per Week; N's reflect those with available IRR scores. For Number of Hobbies reported, one response was not codable as to cognitive demands but the descriptive statistics were otherwise the same with rounding across domains.

Table 1.5: Social Activity Multilevel models with random effects for siblings.

	Model 0		Model 1		Model 2		Model 3	
Parameters	**B**	**se**	**B**	**se**	**B**	**se**	**B**	**se**
Intercept	**7.01**	0.59	**7.00**	0.58	**6.87**	0.59	**7.07**	0.59
Female	0.19	0.24	0.19	0.24	0.19	0.24	0.14	0.24
Centered Age	-0.03	0.05	-0.02	0.05	-0.02	0.05	-0.02	0.05
Project	**-1.43**	0.51	**-1.50**	0.50	-1.43	0.50	**-1.54**	0.50
Adoption Status	0.58	0.37	0.50	0.36	0.51	0.36	0.53	0.36
Hispanic	*-1.11*	0.64	*-1.14*	0.63	*-1.14*	0.63	**-1.38**	0.63
White	0.25	0.53	0.32	0.53	0.38	0.53	0.28	0.53
Living Together	--	--	--	--	0.81	0.59	--	--
IRRtract	--	--	1.53	1.51	1.47	1.50	1.12	1.53
IRRcounty	--	--	**-5.38**	1.50	**-5.40**	1.50	**-5.23**	1.51
σ^2_{BW} Adopted	**2.82**	1.54	**2.90**	1.46	**2.89**	1.46	**3.04**	1.48
σ^2_{BW} Control	1.14	1.25	1.14	1.25	1.16	1.26	1.37	1.27
σ^2_{BW} DZ	**3.68**	1.33	**3.12**	1.28	**3.11**	1.28	**2.78**	1.33
σ^2_{BW} MZ	*2.33*	1.42	**2.63**	1.45	**2.52**	1.44	1.64	1.46
σ^2_{WI} Adopted	**12.53**	1.74	**11.85**	1.65	**11.83**	1.64	**11.73**	1.65
σ^2_{WI} Control	**11.21**	1.53	**11.07**	1.52	**11.07**	1.52	**10.82**	1.50
σ^2_{WI} DZ	**12.14**	1.41	**12.16**	1.41	**12.15**	1.41	**12.50**	1.50
σ^2_{WI} MZ	**14.84**	1.69	**14.92**	1.70	**14.93**	1.70	**15.52**	1.83
Model Fit	**Model 0**		**Model 1**		**Model 2**		**Model3**	
-2 Log Likelihood	6252.0		6236.3		6234.4		6063.8	
AIC	6282.0		6270.3		6270.4		6097.8	
BIC	6349.6		6346.8		6351.4		6174.4	
$\Delta\chi^2$	--		15.7		1.9		--	
df	--		2		1		--	
p	--		3.90E-04		1.68E-01		--	
N individuals	1127		1127		1127		1097	
N sibships	666		666		666		666	

Note. Adjusted for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), race (0=non-White, 1=White) and Hispanic ethnicity (0=non-Hispanic, 1=Hispanic), IRR (mean centered). Bolded parameters are significant $p < .05$; italicized parameters are $p < .10$.

Table 1.6: Social Activity Multilevel models with random effects for spatial clustering.

	Model 4		Model 5	
Parameters	**B**	**se**	**B**	**se**
Intercept	**7.02**	0.58	7.08	0.57
Female	0.24	0.23	0.23	0.23
Centered Age	-0.04	0.05	-0.04	0.05
Project	**-1.54**	0.51	**-1.57**	0.51
Adoption Status	**0.77**	0.37	**0.74**	0.37
Hispanic	**-1.46**	0.58	**-1.46**	0.58
White	0.31	0.50	0.33	0.50
IRRtract	--	--	0.18	1.55
IRRcounty	--	--	*-3.07*	1.64
σ^2_{BW} Spatial Clusters	**0.64**	0.28	**0.50**	0.25
σ^2_{WI} Spatial Clusters	**14.64**	0.63	**14.63**	0.63
Model Fit	**Model 4**		**Model 5**	
-2 Log Likelihood	6252.10		6246.70	
AIC	6270.10		6268.70	
BIC	6291.40		6294.80	
$\Delta\chi 2$	--		5.4	
df	--		2	
p	--		6.72E-02	
N Individuals	1127		1127	
N Spatial Clusters	79		79	

Note. Adjusted for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), race (0=non-White, 1=White) and Hispanic ethnicity (0=non-Hispanic, 1=Hispanic), IRR (mean centered). Bolded parameters are significant $p < .05$; italicized parameters are $p < .10$.

Table 1.7: Family Activity Multilevel models with random effects for siblings.

	Model 0		Model 1		Model 2		Model 3	
Parameters	**B**	**se**	**B**	**se**	**B**	**se**	**B**	**se**
Intercept	**8.75**	1.00	8.85	**0.98**	9.06	1.00	**8.60**	1.01
Female	**2.38**	0.41	2.36	**0.41**	2.35	0.41	**2.41**	0.41
Centered Age	**0.22**	0.09	0.21	**0.09**	0.21	0.09	**0.21**	0.09
Project	**2.39**	0.94	2.47	**0.93**	2.36	0.93	**2.41**	0.94
Adoption Status	-0.70	0.67	-0.69	0.67	-0.71	0.67	-0.66	0.67
Hispanic	1.18	1.03	1.10	1.01	1.10	1.01	1.29	1.03
White	-0.28	0.89	-0.40	0.88	-0.50	0.88	-0.14	0.90
Living Together	--	--	--	--	-1.24	0.91	--	--
IRRtract	--	--	2.35	2.60	2.45	2.60	2.24	2.64
IRRcounty	--	--	**7.39**	2.56	**7.45**	2.56	**7.72**	2.60
σ^2_{BW} Adopted	0.00	.	0.00	.	0.00	.	0.00	.
σ^2_{BW} Control	5.89	5.78	3.69	5.60	3.77	5.61	3.74	5.61
σ^2_{BW} DZ	**9.54**	3.54	**7.48**	3.40	**7.45**	3.40	**6.28**	3.45
σ^2_{BW} MZ	**5.55**	3.35	*5.07*	3.34	*4.80*	3.31	*4.89*	3.54
σ^2_{WI} Adopted	**48.08**	4.47	**48.25**	4.50	**48.22**	4.50	**48.33**	4.51
σ^2_{WI} Control	**46.48**	6.69	**46.72**	6.71	**46.69**	6.70	**46.67**	6.72
σ^2_{WI} DZ	**31.76**	3.71	**32.05**	3.75	**32.07**	3.76	**33.37**	3.99
σ^2_{WI} MZ	**33.36**	3.88	**33.48**	3.90	**33.49**	3.90	**34.95**	4.20
Model Fit	**Model 0**		**Model 1**		**Model 2**		**Model3**	
-2 Log Likelihood	7456.5		7434.7		7432.9		7253.1	
AIC	7484.5		7466.7		7466.9		7285.1	
BIC	7547.5		7538.8		7543.4		7357.1	
$\Delta\chi2$	--		21.8		1.8		--	
df	--		2		1		--	
p	--		1.85E-05		1.80E-01		--	
N individuals	1127		1127		1127		1097	
N sibships	666		666		666		666	

Note. Adjusted for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), race (0=non-White, 1=White) and Hispanic ethnicity (0=non-Hispanic, 1=Hispanic), IRR (mean centered). Bolded parameters are significant $p < .05$; italicized parameters are $p < .10$.

Table 1.8: Family Activity Multilevel models with random effects for spatial clustering.

	Model 4		Model 5	
Parameters	**B**	**se**	**B**	**se**
Intercept	**8.82**	0.98	**8.80**	0.96
Female	**2.35**	0.40	**2.32**	0.39
Centered Age	**0.20**	0.09	**0.19**	0.09
Project	**2.63**	0.88	**2.67**	0.87
Adoption Status	-0.80	0.63	-0.76	0.63
Hispanic	0.92	0.99	0.94	0.99
White	-0.35	0.87	-0.41	0.86
IRRtract	--	--	2.69	2.62
IRRcounty	--	--	**7.37**	2.64
σ^2_{BW} Spatial Clusters	*0.76*	0.52	0.24	0.37
σ^2_{WI} Spatial Clusters	**43.74**	1.87	**43.27**	1.85
Model Fit	**Model 4**		**Model 5**	
-2 Log Likelihood	7470.9		7449.9	
AIC	7488.9		7471.9	
BIC	7510.2		7498.0	
$\Delta\chi 2$	--		21.0	
df	--		2	
p	--		2.75E-05	
N Individuals	1127		1127	
N Spatial Clusters	79		79	

Note. Adjusted for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), race (0=non-White, 1=White) and Hispanic ethnicity (0=non-Hispanic, 1=Hispanic), IRR (mean centered). Bolded parameters are significant $p < .05$; italicized parameters are $p < .10$.

Table 1.9: Sedentary Activity Multilevel models with random effects for siblings.

	Model 0		Model 1		Model 2		Model 3	
Parameters	**B**	**se**	**B**	**se**	**B**	**se**	**B**	**se**
Intercept	**13.06**	0.88	**12.98**	0.88	**12.91**	0.89	**13.03**	0.90
Female	**-1.14**	0.36	**-1.11**	0.36	**-1.10**	0.36	**-1.06**	0.36
Centered Age	0.00	0.08	0.00	0.08	0.00	0.08	0.00	0.08
Project	-0.21	0.77	-0.14	0.77	-0.11	0.77	-0.13	0.77
Adoption Status	*1.08*	0.56	**1.21**	0.57	**1.21**	0.57	**1.15**	0.57
Hispanic	-1.52	0.94	-1.37	0.93	-1.37	0.93	-1.41	0.94
White	-0.58	0.80	-0.56	0.79	-0.53	0.80	-0.66	0.81
Living Together	--	--	--	--	0.39	0.86	--	--
IRRtract	--	--	**-6.35**	2.26	**-6.37**	2.26	**-6.19**	2.32
IRRcounty	--	--	2.22	2.24	2.21	2.24	2.00	2.28
σ^2_{BW} Adopted	*5.35*	3.93	*5.13*	3.95	*5.15*	3.95	*5.38*	3.99
σ^2_{BW} Control	*4.24*	3.26	*4.42*	3.27	*4.45*	3.27	*4.23*	3.26
σ^2_{BW} DZ	*4.87*	3.04	*4.40*	3.01	*4.36*	3.01	3.50	3.18
σ^2_{BW} MZ	**8.29**	2.88	**8.50**	2.87	**8.49**	2.87	**7.53**	3.05
σ^2_{WI} Adopted	**31.56**	4.52	**31.65**	4.55	**31.63**	4.55	**31.51**	4.56
σ^2_{WI} Control	**24.08**	3.60	**23.55**	3.56	**23.54**	3.56	**23.77**	3.59
σ^2_{WI} DZ	**30.31**	3.58	**30.54**	3.60	**30.54**	3.60	**31.25**	3.84
σ^2_{WI} MZ	**25.95**	2.97	**25.45**	2.93	**25.45**	2.93	**27.52**	3.29
Model Fit	**Model 0**		**Model 1**		**Model 2**		**Model 3**	
-2 Log Likelihood	7142.5		7133.3		7133.1		6955.7	
AIC	7172.5		7167.3		7169.1		6989.7	
BIC	7240.0		7243.8		7250.1		7066.2	
$\Delta\chi2$	--		9.2		0.2		--	
df	--		2		1		--	
p	--		1.01E-02		6.55E-01		--	
N individuals	1127		1127		1127		1097	
N sibships	666		666		666		666	

Note. Adjusted for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), race (0=non-White, 1=White) and Hispanic ethnicity (0=non-Hispanic, 1=Hispanic), IRR (mean centered). Bolded parameters are significant $p < .05$; italicized parameters are $p < .10$.

Table 1.10: Sedentary Activity Multilevel models with random effects for spatial clustering.

	Model 4		Model 5	
Parameters	**B**	**se**	**B**	**se**
Intercept	**13.30**	0.84	**13.22**	0.84
Female	**-1.02**	0.35	**-0.98**	0.35
Centered Age	-0.01	0.08	-0.01	0.08
Project	-0.20	0.77	-0.16	0.76
Adoption Status	**1.15**	0.55	**1.27**	0.55
Hispanic	**-1.71**	0.87	*-1.57*	0.87
White	-0.96	0.76	-0.94	0.75
IRRtract	--	--	**-6.14**	2.28
IRRcounty	--	--	2.03	2.25
σ^2_{BW} Spatial Clusters	0.00	.	0.00	.
σ^2_{WI} Spatial Clusters	**33.70**	1.42	**33.44**	1.41
Model Fit	**Model 4**		**Model 5**	
-2 Log Likelihood	7162.6		7153.9	
AIC	7178.6		7173.9	
BIC	7197.5		7197.6	
$\Delta\chi 2$	--		8.7	
df	--		2	
p	--		1.29E-02	
N Individuals	1127		1127	
N Spatial Clusters	79		79	

Note. Adjusted for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), race (0=non-White, 1=White) and Hispanic ethnicity (0=non-Hispanic, 1=Hispanic), IRR (mean centered). Bolded parameters are significant $p < .05$; italicized parameters are $p < .10$.

Table 1.11: Multilevel models with random effects for siblings.

Parameters	Model 0 - Physical		Model 0 - Cognitive		Model 0 - Total	
	B	se	B	se	B	se
Intercept	**5.76**	0.70	**3.92**	0.56	**38.76**	1.76
Female	**-0.57**	0.29	**-0.51**	0.24	0.27	0.71
Centered Age	-0.09	0.06	-0.06	0.05	0.02	0.15
Project	0.23	0.61	*0.97*	0.53	2.05	1.52
Adoption Status	0.04	0.43	-0.42	0.38	0.64	1.10
Hispanic	0.75	0.77	0.20	0.58	-0.82	1.87
White	1.01	0.63	0.68	0.50	0.83	1.59
σ^2_{BW} Adopted	1.94	1.91	0.75	1.42	0.00	.
σ^2_{BW} Control	0.00	.	1.71	1.73	*16.51*	10.84
σ^2_{BW} DZ	2.86	2.26	*1.87*	1.28	7.44	13.89
σ^2_{BW} MZ	**7.01**	1.79	**3.87**	0.96	**19.35**	11.29
σ^2_{WI} Adopted	**18.17**	2.42	**14.01**	1.87	**144.93**	13.37
σ^2_{WI} Control	**20.29**	1.80	**15.43**	2.10	**92.42**	12.57
σ^2_{WI} DZ	**24.29**	2.80	**12.17**	1.48	**155.34**	18.12
σ^2_{WI} MZ	**13.49**	1.56	**7.54**	0.85	**118.50**	13.41
Model Fit	**Model 0 - Physical**		**Model 0 - Cognitive**		**Model 0 - Total**	
-2 Log Likelihood	6662.3		6149.0		8748.8	
AIC	6690.3		6179.0		8776.8	
BIC	6753.3		6246.5		8839.8	
N individuals	1127		1127		1127	
N sibships	666		666		666	

Note. Adjusted for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), race (0=non-White, 1=White) and Hispanic ethnicity (0=non-Hispanic, 1=Hispanic). Bolded parameters are significant $p < .05$; italicized parameters are $p < .10$.

Table 1.12: Multilevel models with random effects for spatial clustering.

	Model 4 - Physical		Model 4 - Cognitive		Model 4 - Total	
Parameters	**B**	**se**	**B**	**se**	**B**	**se**
Intercept	**5.77**	0.69	**4.02**	0.55	**38.71**	1.72
Female	*-0.54*	0.28	**-0.57**	0.22	0.48	0.71
Centered Age	-0.08	0.06	-0.07	0.05	0.02	0.15
Project	0.00	0.62	**1.02**	0.50	1.92	1.56
Adoption Status	0.10	0.45	-0.37	0.35	0.72	1.12
Hispanic	0.73	0.70	0.26	0.56	-1.06	1.77
White	*1.12*	0.61	0.68	0.49	0.83	1.54
σ^2_{BW} Spatial Clusters	0.30	0.35	*0.31*	0.22	0.06	1.10
σ^2_{WI} Spatial Clusters	**21.95**	0.95	**13.87**	0.60	**139.73**	5.98
Model Fit	**Model 4 - Physical**		**Model 4 - Cognitive**		**Model 4 - Total**	
-2 Log Likelihood	6691.6		6179.4		8765.8	
AIC	6709.6		6197.4		8783.8	
BIC	6731.0		6218.7		8805.1	
N Individuals	1127		1127		1127	
N Spatial Clusters	79		79		79	

Note. Adjusted for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), race (0=non-White, 1=White) and Hispanic ethnicity (0=non-Hispanic, 1=Hispanic). Bolded parameters are significant $p < .05$; italicized parameters are $p < .10$.

Table 1.13: Cognitive Rated Hobbies Multilevel models with random effects for siblings.

	Model 0		Model 1		Model 2	
Parameters	**B**	**se**	**B**	**se**	**B**	**se**
Intercept	**2.83**	0.13	**2.81**	0.13	**2.82**	0.13
Female	**-0.15**	0.05	**-0.14**	0.05	**-0.14**	0.05
Centered Age	**-0.03**	0.01	**-0.02**	0.01	**-0.02**	0.01
Project	*0.20*	0.11	*0.19*	0.11	*0.19*	0.11
Adoption Status	-0.02	0.08	*-0.02*	0.08	-0.02	0.08
Hispanic	-0.13	0.13	-0.12	0.13	-0.13	0.13
White	**-0.25**	0.11	**-0.24**	0.11	**-0.24**	0.11
HPW Hobbies	0.02	0.01	0.01	0.01	0.01	0.01
N Hobbies	**-0.04**	0.02	**-0.04**	0.02	**-0.04**	0.02
IRRtract	--	--	-0.12	0.32	--	--
IRRcounty	--	--	-0.49	0.32	**-0.57**	0.23
σ^2_{BW} Adopted	0.00	.	0.00	.	0.00	.
σ^2_{BW} Control	0.00	.	0.00	.	0.00	.
σ^2_{BW} DZ	0.04	0.05	0.03	0.05	0.03	0.05
σ^2_{BW} MZ	**0.16**	0.06	**0.16**	0.06	**0.16**	0.06
σ^2_{WI} Adopted	**0.28**	0.04	**0.28**	0.04	**0.28**	0.04
σ^2_{WI} Control	**0.41**	0.05	**0.41**	0.05	**0.41**	0.05
σ^2_{WI} DZ	**0.38**	0.06	**0.38**	0.06	**0.38**	0.06
σ^2_{WI} MZ	**0.27**	0.05	0.27	0.05	**0.27**	0.05
Model Fit	**Model 0**		**Model 1**		**Model 2**	
-2 Log Likelihood	1116.7		1110.7		1110.8	
AIC	1146.7		1144.7		1142.8	
BIC	1214.2		1221.2		1214.8	
$\Delta\chi2$	**--**		6.0		0.1	
df	**--**		2		1	
p	**--**		4.98E-02		7.52E-01	
N individuals	592		592		592	
N sibships	665		665		665	

Note. Adjusted for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), race (0=non-White, 1=White) and Hispanic ethnicity (0=non-Hispanic, 1=Hispanic), IRR (0=Urban, 1=Rural) Bolded parameters are significant $p < .05$; italicized parameters are $p < .10$.

Chapter Three:

Geographic Differences in Social Capital, Social Support and the Relation to Physical Health.

Social contexts may support or influence physical health and cognitive functioning. Higher social support and denser social networks have shown associations with better cognitive functioning (Barnes et al., 2004; Bassuk et al., 1999; Ertel et al., 2008; Holtzman et al., 2004; Kelly, Duff, Kelly, McHugh Power, et al., 2017; Krueger et al., 2009; Litwin & Stoeckel, 2015; Murayama et al., 2013, 2018; Yeh & Liu, 2003). Previous work has additionally examined the associations between social support and social networks with health behaviors. Studies suggest that individuals with larger social networks, more friends, and greater perceived support were associated with healthful behaviors such as increased physical activity engagement (Bot et al., 2016; Emmons et al., 2007; Shelton et al., 2011; Spanier & Allison, 2001), better eating habits (Emmons et al., 2007), smoking cessation (Christakis & Fowler, 2008; Giannetti et al., 1985), and reductions in alcohol use (Rosenquist et al., 2010). Additionally, previous research suggests that areas with low social capital report worse self-rated health compared to areas with high social capital (Kawachi, 1999; Kawachi et al., 1999; Mohnen et al., 2011; Murayama et al., 2013; Petrou & Kupek, 2008; Poortinga, 2006; Waverijn et al., 2014). Distal versus proximal contexts may be salient to health, including rurality versus urbanicity, in understanding features of social connections and support on physical health (Befort et al., 2012; Behringer et al., 2007; Eberhardt & Pamuk, 2004; J. K. Harris et al., 2016; Patterson et al., 2004; Singh & Siahpush, 2014; Trivedi et al., 2015; Wen et al., 2018; Wilcox et al., 2000). We consider the effects of the social environment on physical health distally through measures of social capital as well as proximally through self-report measures of social networks and social support.

Social Networks & Social Support

Distinguishing between the terms social network, social support and social capital is important (Berkman, 1984; Gottlieb, 1981b, 1981a; Israel, 1982; Lochner et al., 1999). Broadly speaking, social networks are concerned with the linkages among members of the network, whereas social support is concerned with the function of the relationships resulting from the linkages in the network (Israel, 1982). Both social networks and social support are measured at the individual level, whereas social capital (discussed in further detail below) is measured at the societal level. Varying definitions for the term social network have been proposed, but this study aligns most closely with the definition of social networks proposed by Walker, MacBride, & Vachon (1977) in that a social network is the group of personal contacts that offer the individual emotional and material support as well as services and resources. Social networks are often conceptualized along three dimensions: (1) the structural characteristics such as size and density or the number of people in the network (2) the interactions among members of the network through measurement of things frequency of interaction among members of the network; and (3) the functional characteristics of the network measured through perceived affective support (care and love provided by members of the network), instrumental support (or tangible assistance through material items such as money or services), and cognitive support through the validity of advice or mentorship (Israel, 1982; Mitchell & Trickett, 1980). Like social networks, many definitions have been proposed to define social support. This study most closely aligns with the conceptualization of social support provided by Leavy, 1983 in that social support is comprised of the structure and content of the relationship that interacts with "the way an individual develops, nurtures, and uses supportive ties" (p. 17). The current study will evaluate social networks and social support in three dimensions (appraisal, belonging, and tangible) by evaluating the number of friends reported, the frequency of contact with friends and family, and the perceived support from these networks. It has been argued that social support can directly or indirectly affect health behaviors. Direct ways that social support can promote health behaviors is by increasing positive affect, self-esteem and feelings of belonging (Ashida & Heaney, 2008; Cohen et al., 1985; Williams et al., 1981), which in turn increases the likelihood of engaging in health behaviors. Indirect ways in which social support can affect health behaviors is by acting as a buffer to stressors by reducing the adverse effect of stressors when individuals feel that they have a social network that can provide resources and assistance (Ashida & Heaney, 2008; Cohen et al., 1985; House, 1981). Franks et. al, (1992) finds evidence that social support directly affects health behaviors by offering tangible support and resources as well as indirectly by altering the mood or psychological state of the individual, which results in changes to health behaviors (Franks et al., 1992). What's more, even when direct associations between social support and physical health are not observed, greater social support has been shown to improve individuals' abilities to cope with their health condition(s) through practical and emotional support (Reeves et al., 2014).

Older research suggests there are little differences in the number of individuals in social networks for rural and urban individuals (Fischer, 1982), however more recent evidence suggest that there are significant differences in both the quantity as well as the quality of the social networks for rural and urban residing individuals (Beaudoin & Thorson, 2004; Sørensen, 2016). An important geographic difference in social networks discussed in the literature, is the theory that while rural residing individuals tend to have fewer social interactions, the social networks that exist are much denser and more meaningful (Sørensen, 2012). It has been suggested that these denser networks naturally create a more trusting environment which contributes to increased social capital (Sørensen, 2012). Social engagement has additionally been shown to differ across rural and urban areas, with rural individuals being less socially engaged than urban individuals (Vogelsang, 2016).

Social Capital

The origin of social capital has been long debated through the fields of sociology, economy and philosophy. While many sociologists give credit to researchers such as Emile Durkheim, Max Webber or Karl Marx (Song et al., 2013); one key researcher in the domain of social capital (Putnam, 2000) gives credit to work done by Lyda Judson Hanifan for originating the term “social capital”. A standardized definition of social capital has yet to manifest (Poortinga, 2006; Rupasingha et al., 2006). Following the theoretical framework put forth by Putnam; the current study conceptualizes social capital as “features of social organizations, such as trust, norms and networks that can improve the efficiency of society by facilitating coordinated actions” (Putnam et al., 1994). Putnam later states that social capital is composed of three notions: "social networks and the norms of reciprocity and trustworthiness that arise from them" (Putnam, 2000).

Interestingly, it has been debated that social capital is a construct that should be measured as an attribute of the community rather than an attribute of the individual (Poortinga, 2006). Following Putnam's definition of social capital, analysis of social capital would be evaluated as a group level construct (i.e., neighborhood, county, state, etc.) rather than something that is accomplished by the individual solely (Poortinga, 2006; Putnam, 2000; Putnam et al., 1994). Comparatively, social capital has been examined at the geographic or societal level which is described as the "collective good" (Waverijn et al., 2014), that benefits all members of a geographic region (i.e., neighborhood, community, county, etc.) (Coleman, 1988). Alternatively, studies have proposed that social capital is a construct that can be evaluated in small groups such as the family all the way to the largest of groups such as nations (Fukuyama, 1995). Prior work has examined social capital at the individual level and defined it similarly to the social networks and support described above (Kawachi, 2006).

Multiple studies have assessed how to best evaluate the differences in social capital between rural and urban communities (Beaudoin & Thorson, 2004; Hofferth & Iceland, 1998; Onyx & Bullen, 2000; Putnam, 2000; Sampson, 1988; Sørensen, 2012, 2016; Ziersch et al., 2009) as well as how social capital can influence physical health (Ashida & Heaney, 2008; Bot et al., 2016; Franks et al., 1992; Pinillos-Franco & Kawachi, 2018; Reeves et al., 2014; Waverijn et al., 2014). Because of the complexity of social capital measurements, most studies use proxy measures to assess certain aspects of social capital such as club involvement (Sørensen, 2016), civic engagement (Ziersch et al., 2009), feelings of trust or safety (Onyx & Bullen, 2000; Sørensen, 2012, 2016), social networks (Hofferth & Iceland, 1998; Sampson, 1988; Sørensen, 2012; Ziersch et al., 2009), or voluntary work (Sørensen, 2012, 2016). Researchers propose other variables that contribute to the development of social capital including ethnic divisions, income and income inequality, education, community attachment, age, suburbanization, employment type and homeownership and while these measures are convenient, these and the aforementioned proxy measures of social capital have a high risk of a tautology because each of these variables could be both a predictor of or outcome of social capital (Alesina & La Ferrara, 2000; Brehm & Rahn, 1997; Glaeser et al., 2002; Lee & Kim, 2013; Putnam et al., 1994).

In 2000, Putnam developed a state-level social capital index (Putnam, 2000), which was later developed for county-level analysis (Rupasingha et al., 2006). This allows researchers to measure the levels of social capital in each county quantitatively to evaluate social capital's effects on numerous outcomes. The current study will use the publicly available, county level, Social Capital Index (SCI) provided by Pennsylvania State College of Agricultural Sciences (Rupasingha et al., 2006), updated in 2014 (Northeast Regional Center for Rural Development, 2019). Following Putnam's work suggesting that membership in local organizations will increase social capital (Putnam, 2000), this measure of social capital combines the total number of available membership organizations at the county level (e.g. civic groups, sports clubs, religious organizations, political and business organizations, etc.). This measure also includes the total population, voter turnout, and census response rates, all of which have been suggested as important factors contributing to social capital (Putnam, 2000; Rupasingha et al., 2006).

Geographic differences in Social Capital and Health

While some studies find that rural areas demonstrate more social capital (Onyx & Bullen, 2000; Putnam, 2000; Sørensen, 2012), one study finds that urban residing individuals may have more social capital (Sampson, 1988) and most studies report mixed findings depending on the aspect of social capital being measured (Beaudoin & Thorson, 2004; Hofferth & Iceland, 1998; Sørensen, 2016; Ziersch et al., 2009). Health behaviors and outcomes have also been associated with rural and urban differences, as well as levels of social capital. Prior research has suggested that rural populations experience higher rates of chronic health conditions (Harris et al., 2016), which may be contributing to health disparities. These rural disparities include greater reports of hypertension (Behringer et al., 2007; Eberhardt & Pamuk, 2004; Harris et al., 2016; Singh & Siahpush, 2014), higher accounts of conditions such as diabetes (Eberhardt & Pamuk, 2004; Harris et al., 2016; Smith et al., 2008), and obesity (Befort et al., 2012; Eberhardt & Pamuk, 2004; Harris et al., 2016; Patterson et al., 2004; Trivedi et al., 2015; Wen et al., 2018; Wilcox et al., 2000).

What's more, research suggests that areas with low social capital have been associated with worse subjective health, greater numbers of poor mental health and physical health days as well as premature death (Kawachi, 2006; Lee & Kim, 2013; Putnam, 2000). This association is not supported in all studies, however. Lynch et al.

(2001) measured the social environment through an aggregate of perceived trust, control, and organizational membership and found no evidence that these measures of the social environment are key for understanding health differences (Lynch et al., 2001). Similarly, a 2018 study evaluated the relationship between social capital and self-rated health and found that men and women benefit from differing aspects of social capital with women benefiting most from involvement with close relationships such as the family, whereas men benefit from political parties or action groups (Pinillos-Franco & Kawachi, 2018). Most studies however, demonstrate that areas with low social capital are associated with poorer health outcomes and worse self-rated health (Kawachi et al., 1999; Petrou & Kupek, 2008) while areas with greater social capital show better self-rated health (Kawachi, 1999; Mohnen et al., 2011; Murayama et al., 2013; Poortinga, 2006; Waverijn et al., 2014).

Expanding on previous literature, this study aims to examine social capital and its facets, such as social networks and social support, across rural and urban residing individuals using the Index of Relative Rurality created in Study 1. Additionally, this study will evaluate geographic differences in self-reported health indices. Because prior research has only examined the associations between in social capital, and social networks or support, and self-reported health using categorical classifications of rural and urban, this will be the first study to examine the geographic differences in these domains on a continuous scale of rurality. Thus, the first research question for this study asks: How does social capital and its facets, such as social networks and social support, differ across rural and urban residing individuals? The county level Social Capital Index (SCI)

(Rupasingha et al., 2006), along with self-reported social networks, and social support were used to evaluate geographic differences in social capital and social support. The second research question for this study asks: How does social capital and its facets, such as social networks and social support, relate to physical health differences between rural and urban residing individuals? Self-reported health status, the Social Capital Index, measures of social support, and the Index of Relative Rurality were used to evaluate the geographic differences in physical health.

Method

Participants

The current study includes participant data from the on-going Colorado Adoption/Twin Study of Lifespan behavioral development and cognitive aging (CATSLife (Wadsworth et al., 2019a, 2019b)). A total of 1155 individuals have been tested as part of CATSLife that have previously participated in the Colorado Adoption Project (CAP, N = 500; (Plomin & DeFries, 1983; Rhea, Bricker, et al., 2013b)) or the Longitudinal Twin Study (LTS, N= 655; (Rhea et al., 2013)) as of May 31, 2019. The age for the full sample ranged from 28.06 to 49.33 years (*M*age = 33.02, *SD*=4.91) and 53.56% were female. Ethnicity included 5.97% self-reporting as Hispanic and race included 92.19% self-reporting as white.

The analysis sample in the current study includes those who reside in the United States and thus had available US geographic measurements (N=1139) and answered the online survey (N=1153) for an effective analysis sample of N = 1131. Participant demographics are shown in Table 2.1.

Measures

Educational Attainment

One item on educational attainment was adopted from prior adult assessments of the Colorado Adoption Project (Rhea, Bricker, et al., 2013b). Participants were asked "What is the highest year of school you have completed?" were they could select from a Likert scale which was recoded to reflect 11= less than high school diploma, 12= high school or GED, 13= one year, 14= two years (Associate of Arts), 15= three years, 16= four years, no degree, 17= five years or more, no degree, 18= bachelors, 20= masters, 22= advanced degree (e.g. doctorate, M.D., law degree).

Relationship, Friendship, & Social Network.

Items on relationship status were adapted from other studies including Add Health Wave IV (Chantala, Tabor & National Longitudinal Study of Adolescent Health. 1999; Brownstein et al., 2011) for use in CATSLife to index relationship and parenthood demographics.

Relationship Status. Marital/partner status was coded from three items: "When were you married to your current spouse?", "How many persons have you ever married?", and "When did your current romantic relationship begin?". This study utilized two of the five items assessing marriage to create a variable to indicate if the participant had a partner. The first item asks "*Are you now married, widowed, divorced, separated, never married, or living with a partner?*" where participants responded on a 6-point Likert scale ranging from 1=Married, 2=Widowed, 3=Divorced, 4=Separated, 5=Never married, to 6=Living with partner with options "Don't know" and "would rather not answer" also available. The second item asked, "Are you currently in a romantic relationship?" where participants could have responded with 1=Yes, 2=No, or would rather not answer. Participants who were missing on both items were marked as missing (N=13). Participants who were missing on marital status but who reported being in a romantic relationship were coded as partnered (N=2) while those who were missing on marital status and not in a romantic relationship were coded as single (N=5). Participants who answered "1=Married" for the martial status question were not shown the romantic relationship item and were coded as partnered (N=558). Participants who were widowed and not in a romantic relationship were coded as single (N=1). Participants who were divorced and missing on relationship status were coded as single (N=1) along with those who were divorced and/or separated and not in a romantic relationship (N=38), while those who were divorced and/or separated but were in a romantic relationship were coded as partnered (N=42). For participants who were never married if relationship status was missing they were coded as missing (N=5), these participants were not in a romantic relationship they were coded as single (N=219) while those who are never married but in a romantic relationship were coded as partnered (N=91). Lastly, those who didn't know if they were married but indicated they were in a romantic relationship were coded as partnered (N=1) while those who indicated they were not in a romantic relationship were coded as single (N=5) or if missing on relationship status then partnership was coded as missing (N=1). Descriptives for these variables are shown in Table 2.1.

Friendships. Two items evaluated the participants number of friends and frequency of contact with friends. The first of these two items was adapted from Add

Health Wave IV (Chantala, Tabor & National Longitudinal Study of Adolescent Health. 1999; Brownstein et al., 2011) and asks: "*How many close friends do you have? (Close friends include people whom you feel at ease with, can talk to about private matters, and can call on for help.)*" where participants provided the number of friends, they felt met this description. Responses ranged from 0 to more than 30 with positive skew and a long tail after 16. This item was bounded such that those with greater than 16 friends were recoded to 16 and then to adjust for remaining skew, the variable was natural log transformed while adding 1 to account for 0's in the data. See Table 2.2 for descriptives.

The second item on frequency of contact with friends was adapted from the MIDUS study (Brim et al., 2007) asks: "*How often are you in contact with any of your friends, including visits, phone calls, letters, or electronic mail messages?*" Participants responded on an 8-point Likert scale which was recoded such that 7=Several times a day, 6=About once a day, 5=Several times a week, 4=About once a week, 3=2 or 3 times a month, 2=About once a month, 1=Less than once a month, to 0=Never or hardly ever. Descriptives for the number of close friends (Close Friends (LN)) and the frequency of contact with friends (Friend Contact) are shown in Table 2.2.

Family Contact Frequency. One item assessed frequency of contact with family and was adapted from the MIDUS study (Brim et al., 2007). Participants were asked, "How often are you in contact with any members of your family, that is, any of your brothers, sisters, parents, or children who do not live with you, including visits, phone calls, letters, or electronic mail messages?" Participants could respond on a 8-point Likert scale which was recoded such that 7=Several times a day, 6=About once a day, 5=Several times a week, 4=About once a week, 3=2 or 3 times a month, 2=About once a month, 1=Less than once a month, to 0=Never or hardly ever. Descriptives for this variable can be found in Table 2.3.

Perceived Support and Relationship quality

Interpersonal Support Evaluation List (ISEL). The 12-item Interpersonal Support Evaluation List (ISEL) is a measure of perceptions of social support (Cohen et al., 1985). The questionnaire has three subscales (with 4 items each) designed to measure the dimensions of perceived social support (Appraisal Support, Belonging Support, and Tangible Support) (Cohen et al., 1985). Example items include: "*There is someone I can turn to for advice about handling problems with my family*." (Appraisal Support), "*If I wanted to have lunch with someone, I could easily find someone to join me*." (Belonging Support), "*If I was stranded 10 miles from home, there is someone I could call who could come and get me*" (Tangible Support). Participants responded to the 12 items on a 4-point Likert scale ranging from 0=Definitely false, 1=Probably false, 2=Probably true, to 3=Definitely true. Six of the items are reverse scored due to the negative phrasing and responses are then summed in each of the 3 dimensions of social support. Descriptives for individual items and the three dimensions of perceived social support are shown in Table 2.2.

Family Relationship Quality. The 10 item Close Relationship Quality scale (Walen & Lachman, 2000) measures the extent to which family relationships are characterized by support and strain. The first six items assess family support. Example items include "How much do they understand the way you feel about things?", and "How much can you rely on them for help if you have a serious problem?" where participants answered on a 4-point Likert which was recoded such that 0=Not at all, 1=A little, 2=Some, and 3=A lot. The last four items assess family strain. Example items include "How often do members of your family make too many demands on you?", and "How often do they get on your nerves?" where participants could have answered on a 4-point Likert which was recoded such that 0=Never, 1=Rarely, 2=Sometimes, and 3=Often. Descriptives for these variables can be found in Table 2.3.

Geospatial

Index of Relative Rurality (IRR). The IRR_{tract} and IRR_{county} which were developed in Study 1 will be utilized for this study, and the possible range is between 0 and 1reflecting least rural (i.e. urban) to most rural. These were created by linking data from five sources: (1) US Department of Agriculture's (USDA's) Economic Research Service (ERS) Rural/Urban Continuum Codes (RUCC); (2) USDA's ERS Rural/Urban Commuting Areas (RUCA) data; (3) US Census Bureau's 2010 Census Urban List Records Layout data; (4) US Census Bureau's 2000 to 2010 Census Tract Population Change data; and (5) US Census Bureau's Principal cities of metropolitan and micropolitan statistical areas (MMSA) data. Descriptives for these variables are shown in Table 2.4. The effective range of IRR values in this sample was .75 for IRRtract and .73 for IRRcounty.

Social Capital Index (SCI). The updated 2014 social capital index obtained from the Northeast Regional Center for Rural Development (Northeast Regional Center for Rural Development, 2019; Rupasingha et al., 2006) was used as the measure of Social

Capital. This measure combines data from 10 sources believed to contribute to social capital to form a social capital index score for each county in the United States. These sources include the number of establishments in each county: (a) religious organizations, (b) civic organizations, (c) business organizations, (d) political organizations, (e) professional organizations, (f) labor organizations, (g) bowling centers, (h) fitness centers, (i) golf clubs; and (j) sports organizations. Other measures include the percentage of voters who voted in the presidential elections (Alesina and La Ferrara), the county-level response rate to the Census Bureau's decennial census (Knack, 2002), and the number of tax-exempt non-profit organizations from the National Center for Charitable Statistics. Creators of the Social Capital Index extracted the first factor from the last three variables as well as a factor from the aggregate of all above variables diving by the population per 1,000. These four factors were standardized to have a mean of zero and a standard deviation of one, and the first principal component was considered as the index of social capital. Descriptives for Social Capital Index are shown in Table 2.4.

Health Measures

Self-Report Health. Participants self-reported health was assessed using 7 items. The first was adapted from earlier waves of CAP (Rhea, Bricker, et al., 2013b): (1) "*In general, would you say that your health is...*" where participants could respond on a 5-point Likert Scale ranging from 1=Excellent, 2=Good, 3=Fair, 4=Not well, to 5=Poor. The next 3 items were adopted from the Swedish Adoption/Twin Study of Aging (Svedberg et al., 2005). These items assess participants' perceived health comparison. Items included are: (2)"*How would you rate your general health status compared to 5* *years ago?*" and (3)"*How would you rate your health status compared to others in your age group?*", where participants could respond on a 3-point Likert scale ranging from 1=Worse, 2=About the same, to 3=Better; and (4)"*Do you think your health prevents you from doing things you would like to do?*" where participants could respond on a 3-point Likert scale ranging from 1=To a great extent, 2=Partly, to 3=Not at all.

The last 3 items included in the self-report health measures assess participants perception of recent health status with a similar format to the SF-36 of which the last item was adapted (Ware & Sherbourne, 1992). Items included are: (5) "*During the past four weeks, have physical health problems caused you difficulty in doing your work or other regular activities?*", (6) "*During the past four weeks, have emotional problems, such as feeling depressed or anxious, led you to accomplish less than you would have liked at work or other daily activities?*", and (7) "*During the past four weeks, have physical or emotional problems interfered with your normal social activities with family, friends, neighbors, or groups?*". Participants responded to these three items on a 5-point Likert scale ranging from 1=Not at all, 2=Not very much, 3=Somewhat, 4=Pretty much, to 5=Very much. All items in the self-rated health items were put into an exploratory factor analysis with priors equal to the squared multiple correlation (SAS 9.4 PROC Factor; SAS Inc., Cary NC) to obtain a common factor of self-rated health. Items with low communalities (i.e., < .40; items 2, 6 and 7) were removed and four items remained (1,3,4, and 5). The final factor analysis employed a maximum likelihood method extracting one common factor of self-rated health, accounting for 118% of the common variance with an eigenvalue of 3.94. To adjust for the skew of the self-rated health factor several transformations were performed after translating the factor score to be within positive bounds using a T-score transformation (M=50, SD=10). Although the rank transformation was the best for this factor (skew= 0.12, kurtosis= -0.34), we chose the natural log transformation (plus 1.0) which fell within the reasonable bounds (skew= 0.90, kurtosis= 0.57), for ease of presentation for other transformed health variables. Descriptive statistics for retained self-report health items and the log transformed self-rated health factor are shown in Table 2.5.

Illness Checklist. The illness checklist subscale was implemented in previous waves of CAP (Rhea, Bricker, et al., 2013b) to measure the number of illnesses a participant has experienced. The scale includes 26 items such as: *Broken bones or fractures*, *Diabetes*, and *High blood pressure*. Participants were asked to select from two options which were recoded to reflect 0= No if they had never experienced the item, or 1= Yes if they had ever experienced the item. Items were summed to create one variable representing the number of illnesses the individual had experienced. The skew in the sum of illnesses item (skew=0.51, kurtosis=0.12) was deemed acceptable with no transformation.

Somatic Complaints. The somatic complaints subscale was developed to measure the frequency in which participants experience illnesses. This scale was included in prior adult waves of CAP (Rhea, Bricker, et al., 2013b); and includes 19 items such as *Dizziness*, *Nausea or stomach pains*, or *Headaches*. Two additional illness checklist items were adopted from wave four of the Add Health study (Chantala, Tabor & National Longitudinal Study of Adolescent Health. 1999; Brownstein et al., 2011) for the

CATSLife assessment: (1) "*Active seasonal allergies (hay fever)*" and (2) "*Gum disease (gingivitis; periodontal disease) or tooth loss because of cavities*". Participants are asked to indicate how often they experienced each of the 21 items on a 6-point Likert scale ranging from 0=Never, 1=Less than once a year, 2=About once a year, 3=About once a month, 4=Once a week to 5=Daily. The mean of all items were taken to create one measure that is indicative of the frequency of somatic health problems. To adjust for the skew of this item (skew=1.06, kurtosis=1.28), the natural log transformation of the somatic measure (plus 1.0) was retained for use in models (skew=0.21, kurtosis= -0.34). Descriptives for all somatic complaint items are shown in Table 2.5.

Statistical Analysis

Multilevel models were fitted using PROC Mixed in SAS 9.4 (SAS Institute Inc., Cary, NC) to evaluate the associations of rurality at the tract and county levels with the SCI, Close Friends (LN) and Friend Contact based on partial correlations as described below, accounting for sex, age, project (CAP or LTS), adoption status, partnership status, Hispanic and white ethnicities. In addition, a sensitivity analyses considered siblings who live together (0=not living together, 1=living together). For analyses, both IRRcounty and IRRtract were centered at .24 at their approximate means value. The SCI had an effective centering of 0 given it was derived in a PCA. In models with frequency of somatic complaints (LN), the fitted models were as described with the additional covariate of years of educational attainment (centered at 16.82 years).

All multi-level models accounted for differential sibling relatedness both between (σ^2BW) and within (σ^2WI) sibships by estimating separate random effects for those siblings in adoptive, control, or twin families (dizygotic, DZ; monozygotic, MZ). Sibling similarity for all outcomes were measured by calculating intraclass correlations (ICCs) by taking σ^2BW over the sum of σ^2BW and the σ^2WI for each family type. The largest sibship size in multilevel models was 5 (range 1 to 5).

To evaluate spatial clustering in separate multilevel models, a variable named Alternative FIPS was created. Because 61.90% of the sample population lived within Colorado their full FIPS identifier was used to cluster by county whereas those living outside of Colorado were clustered by state identifiers. The models accounted for clustering between (σ^2BW) and within (σ^2WI) Alternative FIPS identifiers. In multilevel models, the maximum number of individuals in a given county-state was N=100 (range = 1 to 100).

Full-information maximum-likelihood was used. To assess model fit, we included standard fit indices including: the chi-square difference test ($\Delta\chi 2$) for nested models. Additionally, we used practical fit indices such as: the Akaike Information Criterion (AIC) and lowest possible values are preferred between nested models (Beal, 2007; Burnham & Anderson, 2003); and the Bayesian Information Criterion (BIC), again with lowest possible values being preferred (Beal, 2007; Raftery, 1995b).

Results

Descriptive Statistics

Mean IRRcounty was 0.25 (SD= 0.10) while mean IRRtract was 0.24 (SD= 0.10), indicating that most individuals in this study live in areas that are more urban than rural. Pearson correlation coefficients indicated moderate associations of IRRtract, using the participants geocoded address to measure their distance from the closest MMSA, with IRRcounty, using the centroid of the county to measure distance to the closest MMSA (r=0.66, N = 1139, p=<0.0001).

Social Capital Index.

Pearson correlation coefficients reported in Table 2.6 were partialed for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), partnered (0=single, 1=partnered), race (0=non-White, 1=White) and Hispanic ethnicity (0=non-Hispanic, 1=Hispanic), resulting in N=1095 with complete data on all geospatial and social capital variables. Small associations were observed for social capital index with IRR at the county level (r =0.19, p <0.0001) and at the tract level (r =0.17, p <0.0001) but because social capital index was calculated at the county level, subsequent analytical models evaluating social capital index included IRR at the county level only. Small negative associations were observed for number of close friends reported at the county level (r =-0.14, p <0.0001) and at the tract level (r =-0.09, p 0.002). A negative correlation were observed for friend contact frequency at the county level (r =-0.07, p <0.03) but not at the tract level (r =-0.007, p =0.81). These associations led to further analysis using multilevel models to address family and spatial dependencies. As negligible associations were observed for family contact frequency and all perceived support and strain variables with IRR at the county and tract level (r =-0.02 to 0.04, p > .22), we did not carry these forward in multi-level analyses.

***Health*.**

Pearson correlation coefficients reported in Table 2.7 were partialed for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), partnered (0=single, 1=partnered), race (0=non-White, 1=White) and Hispanic ethnicity (0=non-Hispanic, 1=Hispanic), resulting in N= 1124 with complete data on all health variables and covariates, and N=1088 with complete data on all geospatial, social capital variables, health variables and covariates. The three health variables correlated significantly and moderately to strongly with each other, (r =.36 to .61, $p < .001$). The three health variables were uncorrelated with the IRR measures or the SCI geospatial measures (all $p \geq .148$). Number of friends was correlated with fewer Somatic complaints and better SRH (r =-.08 and -.13, $p < .01$) while greater frequency of friend contact was correlated modestly with Illness Sum and better SRH (r =-.07 and -.06, $p < .04$). A greater frequency of family contact was likewise associated with better SRH (r =-0.08, p=0.01). The perceived support variables and strain variables were otherwise modestly to moderately correlated with all three health variables where support was correlated with fewer symptoms or better SRH (r =-.11 to -.23, $p < .0001$), while family strain was correlated with more symptoms or worse SRH (r =.21 to .25, $p < .0001$). Based on these patterns of correlations and the limited geospatial associations, we did not carry perceived support and strain forward in multi-level analyses.

IRR and Social Capital Index (SCI)

Similarities in the SCI were evaluated within and between families in multi-level models regardless of geographic location, adjusting for sociodemographic covariates as a baseline model (Model 0) prior to comparing geographic associations with social capital index. Table 2.8 shows fixed and random effects parameters of Model 0. ICCs calculated from the random effects were small to moderate across all sibling types, with lower ICCs in siblings from adoptive and control families (.13, .09, respectively) compared to twin siblings (DZ=.45, MZ=.38; see supplemental Table ST2.1). Next, including IRR at county level as a covariate (Model 1) was significant and showed improved fit over Model 0 [$\Delta\chi2$ (1) =59.5, p=1.22E-14] (see Table 2.8), where IRRcounty uniquely contributed to SCI (B= 1.45, SE=.18, $p<0.0001$). The ICCs were similar in range but with decreased similarity of siblings in adoptive families and increased similarity for those in control families after inclusion of the IRR covariate (range = .09 - .47) (see supplemental Table ST2.1).

Model 2 for SCI excluded 30 individuals who were members of sibling pairs living together at the time of testing; parameter estimates did not show notable change from Model 1 particularly for the IRR covariates (see Table 2.8), suggesting that these siblings did not appreciably influence IRR association. IRRcounty remained a unique contributor to Social Capital Index (B= 1.46, SE=0.19, $p<0.0001$). ICCs calculated from the random effects were similar to Model 1 across all sibling types, ranging from .09 to .46 (see supplemental Table ST2.1).

Models were then run to account for spatial but not sibling clustering, adjusting for socio-demographic covariates (Model 3). Table 2.9 shows parameter estimates and fit statistics of Model 3 for Social Capital Index. The consideration of spatial clustering in the random effects suggested that .904 or 90.4% of the total variance in SCI was attributable to spatial clustering. Model 4 for Social Capital Index included IRR at the county level as a covariate in the model while controlling for spatial clustering. Including IRR at the county level in model 4 was significant [$\Delta\chi 2$ (1) = 8.0, p=4.68E-03] and individually (B=0.44, SE=0.16, p=0.004) (see Table 2.9). The spatial clustering after including the IRR covariate was .899 or 89.9%. In considering Models 3 and 4, spatial clustering effects were very large; hence, spatial clustering was more appropriate to include in models of SCI.

Based on Model 4, the effect size difference comparing observed IRR values in our samples, suggest a small effect size in SCI when considering a very urban county (IRRcounty=.10) to a moderately rural county (IRR=.70), where the differences in the expected SCI representative IRR values denoting Rural vs Urban was -.25 - .02 = -.27 with Cohen's *d* equivalent of -.40, where a moderately rural county showed higher SCI than a very urban county.

IRR and Number of Close Friends

Similarities in Close Friends (LN) were evaluated within and between families in in multi-level models regardless of geographic location, adjusting for sociodemographic covariates as a baseline model (Model 0) prior to comparing geographic associations with number of friends. Table 2.10 shows fixed and random effects parameters of Model 0.

ICCs calculated from the random effects were small to moderate across all sibling types, ranging from .07 among siblings in adoptive families to .30 among MZ twins (see supplemental Table ST2.1). Next, including IRR at county and tract levels as covariates (Model 1) was significant and showed improved fit over Model 0 [$\Delta\chi 2$ (2) =16.0, p=3.35E-04] (see Table 2.10), where IRRcounty uniquely contributed to number of friends (B= -0.71, SE=.21, p=0.001) but IRRtract did not (B= 0.12, SE=.21, p=0.58) (see Table 2.10). The ICCs were generally consistent across sibling types after inclusion of the IRR covariates, apart from DZ twins which dropped by .06 (ICC range = .08 - .30; see supplemental Table ST2.1).

Model 2 for number of friends excluded 30 individuals who were members of sibling pairs living together at the time of testing; parameter estimates did not show notable change from Model 1 particularly for the IRR covariates (see Table 2.10), suggesting that these siblings did not appreciably influence IRR association. IRRcounty remained a unique contributor to number of friends (B= -0.67, SE=0.22, p=0.002) while IRRtract did not (B= 0.09, SE=0.22, p=0.68) (see Table 2.10). ICCs calculated from the random effects were similarly small across all sibling types, ranging from .08 to .25, but reduced for DZ and MZ twins (see supplemental Table ST2.1).

Models were then run to account for spatial but not sibling clustering, adjusting for socio-demographic covariates (Model 3). Table 2.11 shows parameter estimates and fit statistics of Model 3 for number of friends. The consideration of spatial clustering in the random effects suggested that only .023 or 2.3% of the total variance in number of friends was attributable to spatial clustering. Model 4 for number of friends included

IRR at the county and tract levels as a covariate in the model while controlling for spatial clustering. Including IRR at both the tract and county level a covariate in model 4 was significant [$\Delta\chi 2$ (2) = 18.1, p=1.17E-04] and individually at the county level (B= -0.74, SE= 0.22, p<0.001) but not at the tract level (B= 0.05, SE= 0.21, p=0.81). The spatial clustering after including the IRR covariate was .012 or 1.2%. In considering Models 3 and 4, spatial clustering effects were small; hence, spatial clustering was less appropriate to include in models of number of friends.

Based on Model 1, the effect size difference comparing observed IRR values in our samples, suggest a medium effect size in Close Friends (LN). Specifically, those is a very urban county (IRRcounty=.10) had expected Close Friends (LN) =1.73, or 4.62 friends back-transformed, compared to those in a moderately rural county (IRR=.70) with expected Close Friends (LN) =1.30 or 2.67 close friends. This is a difference of .43 in transformed units with Cohen's *d* equivalent of .79; back-transformed, the difference is equivalent to about 2 close friends.

IRR and Friend Contact Frequency

Similarities in contact frequency with friends were evaluated within and between families in multi-level models regardless of geographic location, adjusting for sociodemographic covariates as a baseline model (Model 0) prior to comparing geographic associations with contact frequency with friends. Table 2.12 shows fixed and random effects parameters of Model 0. ICCs calculated from the random effects were small across all sibling types, ranging from .03 among siblings in adoptive families and DZ twins to .25 among MZ twins (see supplemental Table ST2.1). Next, including IRR at county and tract levels as covariates (Model 1) was significant and showed improved fit over Model 0 [$\Delta\chi2$ (2) =6.8, *p*=3.34E-02] (see Table 2.12), where IRRcounty uniquely contributed to contact frequency with friends (B= -1.58, SE=.60, *p*=0.009) whereas IRRtract was at trend effect (B= 1.00, SE=.61, *p*<0.10). The ICCs were similar after inclusion of the IRR covariates (.01 - .25), suggesting little effect of IRR attributes on sibling similarity (see supplemental Table ST2.1).

Model 2 for number of friends excluded 30 individuals who were members of sibling pairs living together at the time of testing; parameter estimates did not show notable change from Model 1 particularly for the IRR covariates (see Table 2.12), suggesting that these siblings did not appreciably influence IRR association. IRRcounty remained a unique contributor to contact frequency with friends but was smaller in size (B= -1.36, SE=0.61, *p*=0.0253) while IRRtract did not (B= 0.93, SE=0.61, *p*=0.13) (see Table 2.12). ICCs calculated from the random effects were similarly small across all sibling types, ranging from .02 to .29 (see supplementary Table ST2.1).

Models were then run to account for spatial but not sibling clustering, adjusting for socio-demographic covariates (Model 3). Table 2.13 shows parameter estimates and fit statistics of Model 3 for contact frequency with friends. The consideration of spatial clustering in the random effects suggested that only .012 or 1.2% of the total variance in contact frequency with friends was attributable to spatial clustering. Model 4 for number of friends included IRR at the county and tract levels as a covariate in the model while controlling for spatial clustering. Including IRR at both the tract and county level a covariate in model 4 was significant [$\Delta\chi2$ (2) = 6.0, *p*=4.98E-02] and individually at the county level (B= -1.49, SE=0.60, p=0.013) but not at the tract level (B=0.88, SE= 0.59, p=.14). The spatial clustering after including the IRR covariate was 0.008 or less than 1%. In considering Models 3 and 4, spatial clustering effects were small; hence, spatial clustering was not appropriate to include in models of contact frequency with friends. Based on Model 1, the effect size difference comparing observed IRR values in our samples, suggest a medium effect size in friends contact frequency when considering IRR value representing a very urban county (IRRcounty=.10) with expected frequency =5.37 to a moderately rural county (IRR=.70) with expected frequency=4.42. This is a difference of .95 with Cohen's *d* equivalent of .62. Hence, those in very urban counties report friend contact consistent with several times a week whereas in the moderately rural repot contact with friends equivalent to about once a week on the friends contact frequency scale.

Somatic Complaints, Close Friends, and IRR

We next evaluated how the number of close friendships was associated with the average frequency of somatic complaints, adjusting for IRR measures. A series of multilevel models were fitted based on observing correlations between IRR and number of close friends and between number of friends and the frequency of endorsing somatic complaints to jointly consider whether friendship network relates to physical health differences accounting for rurality.

Similarities in somatic complaints were evaluated within and between families in in multi-level models regardless of geographic location, adjusting for sociodemographic covariates as well as years of education (centered at the mean of on 16.82 years) and whether siblings live together, as a baseline model (Model 0) prior to comparing geographic associations with somatic complaints. Table 2.14 shows fixed and random effects parameters of Model 0. ICCs calculated from the random effects were small across all sibling types apart from MZ twins, ranging from .00 among adopted participants to .43 among MZ siblings (see supplemental Table ST2.2). Next, including number of friends reported as a covariate (Model 1) was significant and showed improved fit over Model 0 [$\Delta\chi2$ (1) =7.6, p= 5.84E-03] (see Table 2.14), where number of friends uniquely contributed to somatic complaints (B= -0.05, SE=.02, p= 0.0057). The ICCs tended were similar (.00 - .43), suggesting little effect of number of friends on sibling similarity (see supplemental Table ST2.2). Including IRRcounty and IRRtract as covariates (Model 2) was not significant and did not show improved fit over Model 1 [$\Delta\chi2$ (2) =0.5, p=7.79E-01], and neither IRRcounty (B= 0.09, SE=.12, p=0.47) nor IRRtract (B= -0.06, SE=.12, p=0.64) contributed to somatic complaints (see Table 2.14). Models were then run to account for spatial but not sibling clustering, adjusting for socio-demographic covariates (Model 3). Table 2.15 shows parameter estimates and fit statistics of Model 3 for somatic complaints. The consideration of spatial clustering in the random effects suggested that 0% of the total variance in somatic complaints was attributable to spatial clustering. Model 4 for somatic complaints included number of friends reported as a covariate in the model while controlling for spatial clustering. Including number of friends (LN) showed improved model fit [$\Delta\chi2$ (1) = 6.9, p= 8.62E-03] and was significant (B= -0.05, SE=0.02, p<0.0087). Including IRR at both the tract and county level a covariate in model 5 was not significant [$\Delta\chi2$ (2) = 0.0, p=1.00E+00] and not significant individually at the county level (B= 0.02, SE=0.13, *p*=0.87) nor at the tract level (B=-0.01, SE= 0.13, *p*=.95). The spatial clustering after including the IRR covariate remained at 0%. In considering Models 3 through 5, spatial clustering effects were non-existent; hence, spatial clustering was not appropriate to include in models of somatic complaints.

Based on Model 2, the effect size difference comparing observed effect size for Close Friends (LN) on Somatic Complaints (LN) when considering those at one standard deviation below the mean (Close Friends (LN) = 1.07, equivalent to 1.9 friends) to one standard deviation above the mean (Close Friends (LN)= 2.15; equivalent to 7.6 friends). This is a difference of .53 in transformed units with Cohen's *d* equivalent of 1.64. When expected values are back transformed, the difference is related to a tendency to report on average a frequency of complaints of "never" versus "less than one time a year".

Discussion

The present study investigated the differences in social capital and its facets such as social support, across rural and urban residing individuals. Additionally, this study investigated how social capital and its facets, such as social support, related to physical health differences between rural and urban residing individuals. We expected to find that social capital would differ across rural and urban individuals with rural individuals having more social capital than urban residing individuals. Moreover, we expected that facets of social capital such as social support would differ across rural and urban individuals. Lastly, we expected to find that individuals in rural areas would display significantly more health problems than urban residing individuals.

To investigate social capital, this study utilized the publicly available Social Capital Index (Rupasingha et al., 2006), updated in 2014, which provides a county level measure of social capital. Results indicated that when controlling for sociodemographic variables, IRRcounty was a significant predictor of social capital suggesting that the more rural the county, the higher the level of social capital. This finding complements previous literature investigating geographic differences of social capital (Beaudoin & Thorson, 2004; Fischer, 1982; Onyx & Bullen, 2000; Sørensen, 2016; Ziersch et al., 2009). Notably however, many studies propose that geographic differences can be observed across rural and urban residing individuals when examining individual components of social capital. For example, Onyx & Bullen (2000) report that rural communities have higher overall social capital, but when examining the individual components of social capital, rural individuals showed higher levels of trust and safety and greater participation in community engagement, whereas urban individuals showed higher levels of social agency and higher levels of tolerance of diversity. Similarly, studies have shown that rural individuals report significantly more voluntary work for associations within the community (Sørensen, 2012, 2016), whereas urban residing individuals report greater membership in non-local civic organizations such as national and regional business associations (Sørensen, 2016) and no differences in levels of trust across rural and urban individuals.

Few individual-level social capital facets showed relationships with IRR. For self-reported number of close friends, IRRcounty was a significant predictor of the number of close friends' participants reported where the more rural the county, participants reported fewer friends. This is consistent with prior research that suggests that rural residing individuals typically have smaller networks but the relationships within those networks are further developed compared to urban residing individuals who report more friends but the relationships are more shallow and less developed (Beggs et al., 1996; Sørensen, 2012). For contact frequency with friends, models indicated that a higher IRRcounty score was a significant predictor of a lower frequency of contact with friends. This suggests that when controlling for sociodemographic variables, the more rural the county, the less contact participants report with friends. These findings are consistent with the literature which suggest that urban residing individuals often live further away from their family members and thus have more contact with friends than rural residing individuals (Amato, 1993a; Sørensen, 2012). This is further supported by older research suggesting that rural individuals are more likely to have social exchanges exclusively with the family than are urban dwellers (Hofferth & Iceland, 1998; Key, 1961). However, no geographic differences were observed for perceived social support (Appraisal, Tangible, Belonging). Additionally, no geographic differences were observed for family support related measures (frequency of family contact, Family support, and Family strain). These findings are inconsistent with the literature which suggest that rural individuals often have more family contact than urban residing individuals (Hofferth & Iceland, 1998; Key, 1961), and that tangible family support (measured as giving financial assistance) is greater in rural areas than in urban areas (Hofferth & Iceland, 1998).

Lastly, no geographic differences were observed for physical health measures, nor were there any associations between the geospatial measure of social capital and physical health. This finding is consistent with another finding by Lynch et al., (2001) who found no associations between social capital and physical health (Lynch et al., 2001). We did observe geographic differences in some individual level social capital facets such as the number of friends and friend contact frequency. Individuals in urban areas report more friends and contact that is more frequent with friends. Moreover, we did find associations between individual level variables, i.e., number of close friends variable and somatic health. Individuals who reported more close friends reported less frequent somatic health problems. Similarly, other studies have suggested that certain (but not all) dimensions of social capital such as close relationships or civic and political involvement may be associated with physical health (Pinillos-Franco & Kawachi, 2018). Notably however, much of the prior literature has suggested that higher levels of social capital are significantly associated with better physical health for urban residing individuals (Kawachi et al., 1999; Kawachi, 2006; Lee & Kim, 2013; Mohnen et al., 2011; Murayama et al., 2013; Petrou & Kupek, 2008; Pinillos-Franco & Kawachi, 2018; Poortinga, 2006; Putnam, 2000; Waverijn et al., 2014; Ziersch et al., 2009).

In the current study, individual facets of social capital showed fairly consistent associations with health. Although small, higher perceived support and family support measures associated with better self-rated health, fewer illness counts and lower illness frequency as one would expect, while higher family strain was associated with poorer self-rated health, higher illness counts and illness frequency. The number of close friends reported was a significant predictor of fewer somatic complaints. While the number of close friends was predicted by IRR, including IRR in models for number of close friends and somatic complaints did not diminish the association for number of close friends and somatic complaints. This is suggestive that while there are geographic differences in the number of friends, the relationship between number of close friends and somatic complaints remains significant despite geographic differences in the number of close friends. In the aging literature it has been suggested that friends may be associated with better mental and physical health through the similarities that friends often share (Bøen et al., 2012; Felmlee & Muraco, 2009). Friends are typically the same gender, age, and have often had similar life experiences which allows for the opportunity to offer greater social support to one another (Bøen et al., 2012; Felmlee & Muraco, 2009). Thus, the benefits of having close friends to one's physical health may be driven by the influence of social support irrespective of geography.

A limitation for this study is this is a relatively young, and healthy sample that is not showing significant health problems yet. This could explain the lack of findings when evaluating the geographic differences in general physical health. However, there is evidence to suggest that geographic differences in specific health domains such as cardiovascular health can be seen in populations of similar, yet even younger ages (24-34 years) than CATSLife (Lawrence et al., 2017). Using a nationally representative and longitudinal sample of more than 12,000 individuals from the Add Health study, Lawrence and colleagues (2017) observed that individuals living in areas with low population density (i.e. more rural) had worse cardiovascular health than those who were residing in more densely populated areas (i.e. more urban). Lawrence and colleagues (2017) attribute the finding of urban individuals displaying better cardiovascular health to better street connectivity and opportunities for physical activity engagement in urban areas. Additional studies (using the same sample of individuals at a mean age 37), have also noted geographic differences in the upregulation of inflammatory biomarker levels for individuals in the southern United States (which are typically considered more rural) and further illustrates the interplay between an individual's biology and their environment (Cole et al., 2020). Relatedly, there are calls for research to take a life-course approach when considering health disparities and intersections with other disparities such as SES, race and even geography (Jones et al., 2019).

Although the current study did not find geographic differences in physical health, there is a rich literature evaluating rural health disparities (Eberhardt & Pamuk, 2004; Fan et al., 2014; Harris et al., 2016; Smith et al., 2008; Spencer et al., 2018; Weden et al., 2018; Weeks et al., 2004). One way in which the environment may be influencing these geographic health disparities is through accessibility to health care. It has been suggested that rural individuals are more likely to see a primary care physician for all health related matters as compared to urban residing individuals who are more likely to see specialist for specific health concerns (Harris et al., 2016; Probst et al., 2002). In future work, efforts to evaluate differences in rural and urban access to healthcare facilities as well as any associations between social capital and healthcare facility availability will be undertaken.

Overall, this study explored the geographic differences in social capital and its facets such as social support and the relationship between social capital and its facets to physical health. Geographic differences were observed for the county level measure of social capital such that rural counties have higher social capital. Additionally, geographic differences were observed in number of close friends and contact frequency with friends (facets of social capital) with urban residing individuals reporting more friends and more friend contact. The geographic differences in social capital and its facets are in line with prior work that has evaluated these relationships previously (Amato, 1993a; Beggs et al., 1996; Hofferth & Iceland, 1998; Onyx & Bullen, 2000; Putnam, 2000; Sørensen, 2012). However, we observed limited findings pertaining to social capital and its facets and the associations with general indices physical health. Prior literature provides mixed results concerning the associations between social capital and health. While some studies find associations between low social capital and worse subjective health (Kawachi et al., 1999; Kawachi, 2006; Lee & Kim, 2013; Petrou & Kupek, 2008; Putnam, 2000; Subramanian et al., 2001; Wen et al., 2003), other studies find associations of individual level aspects of social capital (i.e. having a close friend, high levels of social participation) to have positive associations with subjective physical health (Bolin et al., 2003; Lindström, 2004). As prior studies point out, when examining social capital, it has not been established if better health is the product of higher social capital, the facilitator of social capital, or the result of other influences which have not been explored (Kawachi, 2006). Future work on the geography of social capital may benefit from closer examinations of specific domains of health, e.g., cardiovascular health, and behavioral health factors such as body mass index BMI, and comparable individual and geographical levels of social capital measures to evaluate proximal and distal factors.

References

Alesina, A., & La Ferrara, E. (2000). Participation in Heterogeneous Communities. *The Quarterly Journal of Economics*, *115*(3), 847–904. https://doi.org/10.1162/003355300554935

Amato, P. R. (1993). Urban-Rural Differences in Helping Friends and Family Members. *Social Psychology Quarterly*, *56*(4), 249–262. JSTOR. https://doi.org/10.2307/2786662

Ashida, S., & Heaney, C. A. (2008). Differential Associations of Social Support and Social Connectedness With Structural Features of Social Networks and the Health Status of Older Adults. *Journal of Aging and Health*, *20*(7), 872–893. https://doi.org/10.1177/0898264308324626

Barnes, L. L., De Leon, C. M., Wilson, R. S., Bienias, J. L., & Evans, D. A. (2004). Social resources and cognitive decline in a population of older African Americans and whites. *Neurology*, *63*(12), 2322–2326.

Bassuk, S. S., Glass, T. A., & Berkman, L. F. (1999). Social disengagement and incident cognitive decline in community-dwelling elderly persons. *Annals of Internal Medicine*, *131*(3), 165–173.

Beal, D. J. (2007). Information criteria methods in SAS for multiple linear regression models. *15th Annual SouthEast SAS Users Group (SESUG) Proceedings, South Carolina, Paper SA05*.

Beaudoin, C. E., & Thorson, E. (2004). Social Capital in Rural and Urban Communities: Testing Differences in Media Effects and Models. *Journalism & Mass Communication Quarterly*, *81*(2), 378–399. https://doi.org/10.1177/107769900408100210

Befort, C. A., Nazir, N., & Perri, M. G. (2012). Prevalence of obesity among adults from rural and urban areas of the United States: Findings from NHANES (2005-2008). *The Journal of Rural Health*, *28*(4), 392–397.

Beggs, J. J., Haines, V. A., & Hurlbert, J. S. (1996). Revisiting the Rural-Urban Contrast: Personal Networks in Nonmetropolitan and Metropolitan Settings1. *Rural Sociology*, *61*(2), 306–325. https://doi.org/10.1111/j.1549-0831.1996.tb00622.x

Behringer, B., Friedell, G. H., Dorgan, K. A., Hutson, S. P., Naney, C., Phillips, A., & Cantrell, E. (2007). Understanding the challenges of reducing cancer in Appalachia: Addressing a place-based health disparity population. *Californian Journal of Health Promotion*, *5*, 40–49.

Berkman, L. F. (1984). Assessing the Physical Health Effects of Social Networks and Social Support. *Annual Review of Public Health*, *5*(1), 413–432. https://doi.org/10.1146/annurev.pu.05.050184.002213

Bøen, H., Dalgard, O. S., & Bjertness, E. (2012). The importance of social support in the associations between psychological distress and somatic health problems and socio-economic factors among older adults living at home: A cross sectional study. *BMC Geriatrics*, *12*(1), 27. https://doi.org/10.1186/1471-2318-12-27

Bolin, K., Lindgren, B., Lindström, M., & Nystedt, P. (2003). Investments in social capital—Implications of social interactions for the production of health. *Social Science & Medicine*, *56*(12), 2379–2390. https://doi.org/10.1016/S0277-9536(02)00242-3

Bot, S. D., Mackenbach, J. D., Nijpels, G., & Lakerveld, J. (2016). Association between Social Network Characteristics and Lifestyle Behaviours in Adults at Risk of Diabetes and Cardiovascular Disease. *PLOS ONE*, *11*(10), e0165041. https://doi.org/10.1371/journal.pone.0165041

Brehm, J., & Rahn, W. (1997). Individual-level evidence for the causes and consequences of social capital. *American Journal of Political Science*, 999–1023.

Brim, O., Baltes, P., Bumpass, L., Cleary, P., Featherman, D., Hazzard, W., & Shweder, R. (2007). *Midlife in the United States (MIDUS 1), 1995-1996. Inter-university Consortium for Political and Social Research [distributor]*.

Brownstein, N., Kalsbeek, W. D., Tabor, J., Entzel, P., Daza, E., & Harris, K. M. (2011). Non-response in wave IV of the National Longitudinal Study of Adolescent Health. Carolina Population Center, University of North Carolina: Chapel Hill.

Burnham, K. P., & Anderson, D. R. (2003). *Model selection and multimodel inference: A practical information-theoretic approach*. Springer Science & Business Media.

Chantala, K., & Tabor, J. (1999). National Longitudinal Study of Adolescent Health: Strategies to perform a design-based analysis using the Add Health data.

Christakis, N. A., & Fowler, J. H. (2008). The Collective Dynamics of Smoking in a Large Social Network. *New England Journal of Medicine*, *358*(21), 2249–2258. https://doi.org/10.1056/NEJMsa0706154

Cohen, S., Mermelstein, R., Kamarck, T., & Hoberman, H. M. (1985). Measuring the functional components of social support. In *Social support: Theory, research and applications* (pp. 73–94). Springer.

Cole, S. W., Shanahan, M. J., Gaydosh, L., & Harris, K. M. (2020). Population-based RNA profiling in Add Health finds social disparities in inflammatory and antiviral gene regulation to emerge by young adulthood. *Proceedings of the National Academy of Sciences*, *117*(9), 4601–4608.

Coleman, J. S. (1988). Social Capital in the Creation of Human Capital. *American Journal of Sociology*, *94*, S95–S120. https://doi.org/10.1086/228943

Eberhardt, M. S., & Pamuk, E. R. (2004). The Importance of Place of Residence: Examining Health in Rural and Nonrural Areas. *American Journal of Public Health*, *94*(10), 1682–1686. https://doi.org/10.2105/AJPH.94.10.1682

Emmons, K. M., Barbeau, E. M., Gutheil, C., Stryker, J. E., & Stoddard, A. M. (2007). Social Influences, Social Context, and Health Behaviors Among Working-Class, Multi-Ethnic Adults. *Health Education & Behavior*, *34*(2), 315–334. https://doi.org/10.1177/1090198106288011

Ertel, K. A., Glymour, M. M., & Berkman, L. F. (2008). Effects of social integration on preserving memory function in a nationally representative US elderly population. *American Journal of Public Health*, *98*(7), 1215–1220.

Fan, J. X., Wen, M., & Kowaleski-Jones, L. (2014). Rural–Urban Differences in Objective and Subjective Measures of Physical Activity: Findings From the National Health and Nutrition Examination Survey (NHANES) 2003–2006. *Preventing Chronic Disease*, *11*. https://doi.org/10.5888/pcd11.140189

Felmlee, D., & Muraco, A. (2009). Gender and Friendship Norms Among Older Adults. *Research on Aging*, *31*(3), 318–344. https://doi.org/10.1177/0164027508330719

Fischer, C. S. (1982). *To Dwell Among Friends: Personal Networks in Town and City*. University of Chicago Press.

Franks, P., Campbell, T. L., & Shields, C. G. (1992). Social relationships and health: The relative roles of family functioning and social support. *Social Science & Medicine*, *34*(7), 779–788. https://doi.org/10.1016/0277-9536(92)90365-W

Fukuyama, F. (1995). *Trust: The social virtues and the creation of prosperity* (Vol. 99). Free press New York.

Giannetti, V. J., Reynolds, J., & Rihn, T. (1985). Factors which differentiate smokers from ex-smokers among cardiovascular patients: A discriminant analysis. *Social Science & Medicine*, *20*(3), 241–245. https://doi.org/10.1016/0277-9536(85)90237-0

Glaeser, E. L., Laibson, D., & Sacerdote, B. (2002). An economic approach to social capital. *The Economic Journal*, *112*(483), F437–F458.

Gottlieb, B. H. (1981a). *Social networks and social support* (Vol. 4). Sage Publications, Inc.

Gottlieb, B. H. (1981b). Social networks and social support in community mental health. *Social Networks and Social Support*, *4*, 11–42.

Harris, J. K., Beatty, K., Leider, J. P., Knudson, A., Anderson, B. L., & Meit, M. (2016). The Double Disparity Facing Rural Local Health Departments. *Annual Review of Public Health*, *37*(1), 167–184. https://doi.org/10.1146/annurev-publhealth-031914-122755

Harris, K. M. (2013). *The Add Health Study: Design and Accomplishments*.

Hofferth, S. L., & Iceland, J. (1998). Social Capital in Rural and Urban Communities1. *Rural Sociology*, *63*(4), 574–598. https://doi.org/10.1111/j.1549-0831.1998.tb00693.x

Holtzman, R. E., Rebok, G. W., Saczynski, J. S., Kouzis, A. C., Wilcox Doyle, K., & Eaton, W. W. (2004). Social network characteristics and cognition in middle-aged and older adults. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *59*(6), P278–P284.

House, J. S. (1981). Work stress and social support reading. *MA: Addison-Wesley*.

Israel, B. A. (1982). Social networks and health status: Linking theory, research, and practice. *Patient Counselling and Health Education*, *4*(2), 65–79. https://doi.org/10.1016/S0190-2040(82)80002-5

Jones, N. L., Gilman, S. E., Cheng, T. L., Drury, S. S., Hill, C. V., & Geronimus, A. T. (2019). Life course approaches to the causes of health disparities. *American Journal of Public Health*, *109*(S1), S48–S55.

Kawachi, I. (1999). Social capital and community effects on population and individual health. *Annals of the New York Academy of Sciences*, *896*(1), 120–130.

Kawachi, I. (2006). Commentary: Social capital and health: making the connections one step at a time. *International Journal of Epidemiology*, *35*(4), 989–993. https://doi.org/10.1093/ije/dyl117

Kawachi, I., Kennedy, B. P., & Glass, R. (1999). Social capital and self-rated health: A contextual analysis. *American Journal of Public Health*, *89*(8), 1187–1193. https://doi.org/10.2105/AJPH.89.8.1187

Kelly, M. E., Duff, H., Kelly, S., McHugh Power, J. E., Brennan, S., Lawlor, B. A., & Loughrey, D. G. (2017). The impact of social activities, social networks, social support and social relationships on the cognitive functioning of healthy older adults: A systematic review. *Systematic Reviews*, *6*(1), 259. https://doi.org/10.1186/s13643-017-0632-2

Key, W. H. (1961). Rural-Urban Differences and the Family. *The Sociological Quarterly*, *2*(1), 49–56. https://doi.org/10.1111/j.1533-8525.1961.tb01484.x

Knack, S., & Kropf, M. (2002). Who uses inferior voting technology?. PS: Political Science and Politics, 35(3), 541-548.

Krueger, K. R., Wilson, R. S., Kamenetsky, J. M., Barnes, L. L., Bienias, J. L., & Bennett, D. A. (2009). Social engagement and cognitive function in old age. *Experimental Aging Research*, *35*(1), 45–60.

Lawrence, E., Hummer, R. A., & Harris, K. M. (2017). The cardiovascular health of young adults: Disparities along the urban-rural continuum. *The Annals of the American Academy of Political and Social Science*, *672*(1), 257–281.

Leavy, R. L. (1983). Social support and psychological disorder: A review. *Journal of Community Psychology*, *11*(1), 3–21. https://doi.org/10.1002/1520-6629(198301)11:1<3::AID-JCOP2290110102>3.0.CO;2-E

Lee, C.-J., & Kim, D. (2013). A Comparative Analysis of the Validity of US State- and County-Level Social Capital Measures and Their Associations with Population Health. *Social Indicators Research*, *111*(1), 307–326. https://doi.org/10.1007/s11205-012-0007-y

Lindström, M. (2004). Social capital, the miniaturisation of community and self-reported global and psychological health. *Social Science & Medicine*, *59*(3), 595–607. https://doi.org/10.1016/j.socscimed.2003.11.006

Litwin, H., & Stoeckel, K. J. (2015). Social Network, Activity Participation, and Cognition: A Complex Relationship. *Research on Aging*, *38*(1), 76–97. https://doi.org/10.1177/0164027515581422

Lochner, K., Kawachi, I., & Kennedy, B. P. (1999). Social Capital: A guide to its measurement. *Health & Place*, *5*, 259–270. https://doi.org/10.1016/S1353-8292(99)00016-7

Lynch, J., Smith, G. D., Hillemeier, M., Shaw, M., Raghunathan, T., & Kaplan, G. (2001). Income inequality, the psychosocial environment, and health: Comparisons of wealthy nations. *The Lancet*, *358*(9277), 194–200. https://doi.org/10.1016/S0140-6736(01)05407-1

Mitchell, R. E., & Trickett, E. J. (1980). Task force report: Social networks as mediators of social support. *Community Mental Health Journal*, *16*(1), 27–44. https://doi.org/10.1007/BF00780665

Mohnen, S. M., Groenewegen, P. P., Völker, B., & Flap, H. (2011). Neighborhood social capital and individual health. *Social Science & Medicine*, *72*(5), 660–667.

Murayama, H., Nishi, M., Matsuo, E., Nofuji, Y., Shimizu, Y., Taniguchi, Y., Fujiwara, Y., & Shinkai, S. (2013). Do bonding and bridging social capital affect self-rated health, depressive mood and cognitive decline in older Japanese? A prospective cohort study. *Social Science & Medicine*, *98*, 247–252. https://doi.org/10.1016/j.socscimed.2013.09.026

Murayama, H., Sugiyama, M., Inagaki, H., Okamura, T., Miyamae, F., Ura, C., Edahiro, A., Motokawa, K., & Awata, S. (2018). Is community social capital associated with subjective symptoms of dementia among older people? A cross-sectional study in Japan: Social capital and dementia symptoms. *Geriatrics & Gerontology International*. https://doi.org/10.1111/ggi.13519

Northeast Regional Center for Rural Development, S. C. V. for 2014. (2019). *Social Capital Variables for 2014 (Northeast Regional Center for Rural Development)*. Northeast Regional Center for Rural Development (Penn State University). https://aese.psu.edu/nercrd/community/social-capital-resources/social-capital-variables-for-2014

Onyx, J., & Bullen, P. (2000). Measuring Social Capital in Five Communities. *The Journal of Applied Behavioral Science*, *36*(1), 23–42. https://doi.org/10.1177/0021886300361002

Patterson, P. D., Moore, C. G., Probst, J. C., & Shinogle, J. A. (2004). Obesity and Physical Inactivity in Rural America. *The Journal of Rural Health*, *20*(2), 151–159. https://doi.org/10.1111/j.1748-0361.2004.tb00022.x

Pedersen, N. L. (2015). *Swedish Adoption/Twin Study on Aging (SATSA), 1984, 1987, 1990, 1993, 2004, 2007, and 2010*. Inter-university Consortium for Political and Social Research [distributor]. https://doi.org/10.3886/ICPSR03843.v2

Petrou, S., & Kupek, E. (2008). Social capital and its relationship with measures of health status: Evidence from the Health Survey for England 2003. *Health Economics*, *17*(1), 127–143. https://doi.org/10.1002/hec.1242

Pinillos-Franco, S., & Kawachi, I. (2018). The relationship between social capital and self-rated health: A gendered analysis of 17 European countries. *Social Science & Medicine*, *219*, 30–35. https://doi.org/10.1016/j.socscimed.2018.10.010

Plomin, R., & DeFries, J. C. (1983). The Colorado adoption project. *Child Development*, 276–289.

Poortinga, W. (2006). Social capital: An individual or collective resource for health? *Social Science & Medicine*, *62*(2), 292–302. https://doi.org/10.1016/j.socscimed.2005.06.008

Probst, J. C., Moore, C. G., Baxley, E. G., & Lammie, J. J. (2002). Rural-Urban Differences in Visits to Primary Care Physicians. *Family Medicine*, *34*(8), 609–615.

Putnam, R. D. (2000). Bowling alone: The Collapse and Revival of American Community. In *Bowling alone: The Collapse and Revival of American Community*. Simon & Schuster.

Putnam, R. D., Leonardi, R., & Nanetti, R. Y. (1994). *Making democracy work: Civic traditions in modern Italy*. Princeton university press.

Raftery, A. E. (1995). Bayesian Model Selection in Social Research. *Sociological Methodology*, *25*, 111–163. JSTOR. https://doi.org/10.2307/271063

Reeves, D., Blickem, C., Vassilev, I., Brooks, H., Kennedy, A., Richardson, G., & Rogers, A. (2014). The Contribution of Social Networks to the Health and Self-Management of Patients with Long-Term Conditions: A Longitudinal Study. *PLOS ONE*, *9*(6), e98340. https://doi.org/10.1371/journal.pone.0098340

Rhea, S.-A., Bricker, J. B., Wadsworth, S. J., & Corley, R. P. (2013). The Colorado Adoption Project. *Twin Research and Human Genetics: The Official Journal of the International Society for Twin Studies*, *16*(1), 358–365. https://doi.org/10.1017/thg.2012.109

Rosenquist, J. N., Murabito, J., Fowler, J. H., & Christakis, N. A. (2010). The Spread of Alcohol Consumption Behavior in a Large Social Network. *Annals of Internal Medicine*, *152*(7), 426–433. https://doi.org/10.7326/0003-4819-152-7-201004060-00007

Rupasingha, A., Goetz, S. J., & Freshwater, D. (2006). The production of social capital in US counties. *The Journal of Socio-Economics*, *35*(1), 83–101. https://doi.org/doi:10.1016/j.socec.2005.11.001

Sampson, R. J. (1988). Local Friendship Ties and Community Attachment in Mass Society: A Multilevel Systemic Model. *American Sociological Review*, *53*(5), 766–779. https://doi.org/10.2307/2095822

Shelton, R. C., McNeill, L. H., Puleo, E., Wolin, K. Y., Emmons, K. M., & Bennett, G. G. (2011). The Association Between Social Factors and Physical Activity Among Low-Income Adults Living in Public Housing. *American Journal of Public Health*, *101*(11), 2102–2110. https://doi.org/10.2105/AJPH.2010.196030

Singh, G. K., & Siahpush, M. (2014). Widening Rural–Urban Disparities in Life Expectancy, U.S., 1969–2009. *American Journal of Preventive Medicine*, *46*(2), e19–e29. https://doi.org/10.1016/j.amepre.2013.10.017

Smith, K. B., Humphreys, J. S., & Wilson, M. G. (2008). Addressing the health disadvantage of rural populations: How does epidemiological evidence inform rural health policies and research? *Australian Journal of Rural Health*, *16*(2), 56–66. https://doi.org/doi: 10.1111/j.1440-1584.2008.00953.x

Song, L., Son, J., & Lin, N. (2013). *Social capital and health* (W. C. Cockerham, Ed.). Springer.

Sørensen, J. F. L. (2012). Testing the Hypothesis of Higher Social Capital in Rural Areas: The Case of Denmark. *Regional Studies*, *46*(7), 873–891. https://doi.org/10.1080/00343404.2012.669471

Sørensen, J. F. L. (2016). Rural–Urban Differences in Bonding and Bridging Social Capital. *Regional Studies*, *50*(3), 391–410. https://doi.org/10.1080/00343404.2014.918945

Spanier, P. A., & Allison, K. R. (2001). General Social Support and Physical Activity: An Analysis of the Ontario Health Survey. *Canadian Journal of Public Health*, *92*(3), 210–213. https://doi.org/10.1007/BF03404308

Spencer, J. C., Wheeler, S. B., Rotter, J. S., & Holmes, G. M. (2018). Decomposing Mortality Disparities in Urban and Rural U.S. Counties. *Health Services Research*. https://doi.org/10.1111/1475-6773.12982

Subramanian, S. V., Kawachi, I., & Kennedy, B. P. (2001). Does the state you live in make a difference? Multilevel analysis of self-rated health in the US. *Social Science & Medicine*, *53*(1), 9–19. https://doi.org/10.1016/S0277-9536(00)00309-9

Svedberg, P., Gatz, M., Lichtenstein, P., Sandin, S., & Pedersen, N. L. (2005). Self-Rated Health in a Longitudinal Perspective: A 9-Year Follow-Up Twin Study. *The Journals of Gerontology: Series B*, *60*(6), S331–S340. https://doi.org/10.1093/geronb/60.6.S331

Trivedi, T., Liu, J., Probst, J., Merchant, A., Jones, S., & Martin, A. (2015). Obesity and obesity-related behaviors among rural and urban adults in the USA. *Rural Remote Health*, *15*(4), 11.

Vogelsang, E. M. (2016). Older adult social participation and its relationship with health: Rural-urban differences. *Health & Place*, *42*, 111–119. https://doi.org/10.1016/j.healthplace.2016.09.010

Wadsworth, S. J., Corley, R. P., Munoz, E., Trubenstein, B. P., Knaap, E., DeFries, J. C., Plomin, R., Reynolds, C. A., & The CATSLife Team. (2019a). CATSLife: A Study of Lifespan Behavioral Development and Cognitive Functioning. *Twin Research and Human Genetics*, *22*(6), 695–706. https://doi.org/10.1017/thg.2019.49

Wadsworth, S. J., Corley, R. P., Munoz, E., Trubenstein, B. P., Knaap, E., DeFries, J. C., Plomin, R., Reynolds, C. A., & The CATSLife Team. (2019b). CATSLife: A Study of Lifespan Behavioral Development and Cognitive Functioning – Corrigendum. *Twin Research and Human Genetics*, *22*(6), 829–829. https://doi.org/10.1017/thg.2019.126

Walen, H. R., & Lachman, M. E. (2000). Social support and strain from partner, family, and friends: Costs and benefits for men and women in adulthood. Journal of social and personal relationships, 17(1), 5-30.

Walker, K. N., MacBride, A., & Vachon, M. L. S. (1977). Social support networks and the crisis of bereavement. *Social Science & Medicine (1967)*, *11*(1), 35–41. https://doi.org/10.1016/0037-7856(77)90143-3

Ware, J. E., & Sherbourne, C. D. (1992). The MOS 36-Item Short-Form Health Survey (SF-36): I. Conceptual Framework and Item Selection. *Medical Care*, *30*(6), 473–483. JSTOR.

Waverijn, G., Wolfe, M. K., Mohnen, S., Rijken, M., Spreeuwenberg, P., & Groenewegen, P. (2014). A prospective analysis of the effect of neighbourhood and individual social capital on changes in self-rated health of people with chronic illness. *BMC Public Health*, *14*(1), 675.

Weden, M. M., Shih, R. A., Kabeto, M. U., & Langa, K. M. (2018). Secular Trends in Dementia and Cognitive Impairment of U.S. Rural and Urban Older Adults. *American Journal of Preventive Medicine*, *54*(2), 164–172. https://doi.org/10.1016/j.amepre.2017.10.021

Weeks, W. B., Kazis, L. E., Shen, Y., Cong, Z., Ren, X. S., Miller, D., Lee, A., & Perlin, J. B. (2004). Differences in health-related quality of life in rural and urban veterans. *American Journal of Public Health*, *94*(10), 1762–1767. https://doi.org/10.2105/AJPH.94.10.1762

Wen, M., Browning, C. R., & Cagney, K. A. (2003). Poverty, affluence, and income inequality: Neighborhood economic structure and its implications for health. *Social Science & Medicine*, *57*(5), 843–860. https://doi.org/10.1016/S0277-9536(02)00457-4

Wen, M., Fan, J. X., Kowaleski-Jones, L., & Wan, N. (2018). Rural–urban disparities in obesity prevalence among working age adults in the United States: Exploring the mechanisms. *American Journal of Health Promotion*, *32*(2), 400–408. https://doi.org/DOI: 10.1177/0890117116689488

Wilcox, S., Castro, C., King, A., Housemann, R., & Brownson, R. (2000). Determinants of leisure time physical activity in rural compared with urban older and ethnically diverse women in the United States. *Journal of Epidemiology & Community Health*, *54*(9), 667–672. https://doi.org/10.1136/jech.54.9.667

Williams, A. W., Ware Jr, J. E., & Donald, C. A. (1981). A model of mental health, life events, and social supports applicable to general populations. *Journal of Health and Social Behavior*, 324–336.

Yeh, S.-C. J., & Liu, Y.-Y. (2003). Influence of social support on cognitive function in the elderly. *BMC Health Services Research*, *3*(1), 9. https://doi.org/10.1186/1472-6963-3-9

Ziersch, A. M., Baum, F., Darmawan, I. G. N., Kavanagh, A. M., & Bentley, R. J. (2009). Social capital and health in rural and urban communities in South Australia. *Australian and New Zealand Journal of Public Health*, *33*(1), 7–16. https://doi.org/10.1111/j.1753-6405.2009.00332.x

Table 2.1: Sociodemographic Descriptive Statistics

	N	*Range*	*Min*	*Max*	*Mean*	*SD*	*Variance*
Age	1139	21.28	28.06	49.33	33.03	4.91	24.15
CAP	493	18.32	31.01	49.33	38.00	3.22	10.35
LTS	646	5.85	28.06	33.91	29.23	1.15	1.31
Gender	1139	1	0	1	0.54	0.50	0.25
CAP	493	1	0	1	0.52	0.50	0.25
LTS	646	1	0	1	0.54	0.50	0.25
White	1139	1	0	1	0.92	0.27	0.07
CAP	493	1	0	1	0.93	0.26	0.07
LTS	646	1	0	1	0.92	0.28	0.08
Hispanic	1139	1	0	1	0.06	0.24	0.06
CAP	493	1	0	1	0.01	0.09	0.01
LTS	646	1	0	1	0.10	0.30	0.09
Partnered	1122	1	0	1	0.77	0.42	0.18
CAP	489	1	0	1	0.83	0.38	0.14
LTS	633	1	0	1	0.73	0.45	0.20
Education	1130	11	11	22	16.82	2.97	8.82
CAP	493	11	11	22	17.11	2.92	8.55
LTS	646	11	11	22	16.60	2.99	8.93

Note: Values are showing those participants who had IRR scores. CAP=Colorado Adoption Project; LTS=Longitudinal Twin Study. Gender (male=0, female=1), White (no=0, yes=1), Hispanic (no=0, yes=1), Partnered (no=0, yes=1). Educational attainment reported in year equivalents. Descriptives are showing those participants who had IRR scores.

Table 2.2 Friendship and Social Support Descriptive Statistics

Measure/Item	*N*	*Mean*	*SD*	*Min*	*Max*	*Var.*
Close Friends	1128	4.75	3.21	0	16	10.29
Close Friends (LN)	1128	1.61	0.54	0	2.83	0.29
Friend Contact Frequency	1119	4.95	1.53	0	7	2.35
Appraisal Support	1115	9.62	2.43	0	12	5.92
I feel that there is no one I can share my most private worries and fears with.	1121	2.46	0.83	0	3	0.69
There is someone I can turn to for advice about handling problems with my family.	1120	2.43	0.77	0	3	0.60
When I need suggestions on how to deal with a personal problem, I know someone I can turn to.	1120	2.51	0.70	0	3	0.48
If a family crisis arose, it would be difficult to find someone who could give me good advice about how to handle it.	1121	2.20	0.93	0	3	0.87
Belong Support	1120	8.43	2.52	0	12	6.35
If I wanted to go on a trip for a day (for example, to the country or mountains), I would have a hard time finding someone to go with me.	1122	2.08	0.83	0	3	0.69
If I decide one afternoon that I would like to go to a movie that evening, I could easily find someone to go with me.	1121	2.06	0.79	0	3	0.63
I don't often get invited to do things with others.	1122	2.08	0.87	0	3	0.75
If I wanted to have lunch with someone, I could easily find someone to join me.	1122	2.22	0.74	0	3	0.55
Tangible Support	1120	9.05	2.34	0	12	5.46
If I were sick, I could easily find someone to help me with my daily chores.	1123	2.19	0.88	0	3	0.77
If I had to go out of town for a few weeks, it would be difficult to find someone who would look after my house or apartment.	1122	2.16	0.86	0	3	0.74
If I was stranded 10 miles from home, there is someone I could call who could come and get me.	1120	2.60	0.63	0	3	0.40
If I needed some help in moving to a new house or apartment, I would have a hard time finding someone to help me.	1121	2.10	0.97	0	3	0.95

Note. N = participants with IRR scores. LN = natural log transformed after adding 1.

Table 2.3 Family Contact Frequency, Family Support and Strain Descriptive Statistics.

	N	*Mean*	*SD*	*Min*	*Max*	*Var.*
Family Contact Frequency	1121	5.13	1.45	0	7	2.11
Family Support	1123	12.91	2.33	0	15	5.44
Not including your spouse or partner, how much do members of your family really care about you?	1124	2.82	0.49	0	3	0.24
How much do they understand the way you feel about things?	1125	2.19	0.80	0	3	0.63
How much can you rely on them for help if you have a serious problem?	1124	2.65	0.70	0	3	0.49
How much can you open up to them if you need to talk about your worries?	1124	2.32	0.87	0	3	0.76
How much do you really care about the members of your family, not including your partner or spouse?	1123	2.88	0.40	0	3	0.16
How much do you understand the way they feel about things?	1124	2.37	0.68	0	3	0.46
Family Strain	1123	4.79	2.51	0	12	6.29
Not including your spouse or partner, how often do members of your family make too many demands on you?	1124	1.16	0.81	0	3	0.66
How often do they criticize you?	1124	1.20	0.81	0	3	0.65
How often do they let you down when you are counting on them?	1123	0.88	0.80	0	3	0.64
How often do they get on your nerves?	1123	1.55	0.77	0	3	0.60

Note. N = participants with IRR scores.

Table 2.4: Descriptives of Geospatial Measures

	N	*Mean*	*SD*	*Min*	*Max*	*Range*	*Var.*
IRRtract	1139	0.24	0.10	0.05	0.80	0.75	0.01
IRRcounty	1139	0.25	0.10	0.06	0.79	0.73	0.01
Social Capital Index (SCI)	1139	-0.47	0.67	-2.42	3.34	5.76	0.45

Table 2.5: Descriptives of Health Measures

	N	*Mean*	*SD*	*Min*	*Max*	*Var.*
In general, would you say your health is…	1130	2.02	0.71	1	5	0.50
How would you rate your health status compared to others in your age group?	1121	2.21	0.65	1	3	0.43
Do you think your health prevents you from doing things you would like to do?	1126	2.72	0.53	1	3	0.28
During the past four weeks, have physical health problems caused you difficulty in doing your work or other regular activities.	1128	-0.01	0.92	1	5	0.85
Self-Rated Health Factor (LN)	1118	3.91	0.18	3.67	4.53	0.03
Illness Checklist	1130	4.98	2.86	0	18.00	0.11
Somatic Complaints (LN)	1125	0.62	0.32	0	1.57	0.10

Note. N = participants with IRR scores. LN = natural log transformed after adding 1.

Table 2.6: Pearson Partial Correlation Coefficients of geospatial and social capital variables.

		1	2	3	4	5	6	7	8	9	10	11
1	**IRRtract**	1										
	p											
2	**IRRcounty**	**0.666**	1									
	p	<.0001										
3	**SCI**	**0.170**	**0.193**	1								
	p	<.0001	<.0001									
4	**Close Friends (LN)**	**-0.092**	**-0.141**	0.023	1							
	p	0.002	<.0001	0.450								
5	**Friend Contact**	-0.007	**-0.067**	0.001	**0.404**	1						
	p	0.814	0.027	0.975	<.0001							
6	**Family Contact**	-0.003	-0.009	-0.027	0.030	**0.142**	1					
	p	0.910	0.755	0.371	0.328	<.0001						
7	**Appraisal Support**	0.009	-0.005	0.021	**0.422**	**0.330**	**0.123**	1				
	p	0.763	0.864	0.497	<.0001	<.0001	<.0001					
8	**Belong Support**	-0.011	-0.024	0.010	**0.472**	**0.375**	**0.115**	**0.585**	1			
	p	0.724	0.422	0.734	<.0001	<.0001	0.000	<.0001				
9	**Tangible Support**	0.037	0.031	-0.024	**0.349**	**0.306**	**0.121**	**0.651**	**0.623**	1		
	p	0.227	0.315	0.424	<.0001	<.0001	<.0001	<.0001	<.0001			
10	**Family support**	0.032	0.000	0.018	**0.212**	**0.115**	**0.335**	**0.367**	**0.316**	**0.334**	1	
	p	0.286	0.997	0.555	<.0001	0.000	<.0001	<.0001	<.0001	<.0001		
11	**Family Strain**	-0.019	-0.012	-0.021	**-0.108**	-0.047	-0.004	**-0.268**	**-0.228**	**-0.283**	**-0.408**	1
	p	0.530	0.690	0.493	0.000	0.124	0.899	<.0001	<.0001	<.0001	<.0001	

Note. $N = 1095$. SCI=Social Capital Index; LN = natural log transformed after adding 1. Partialed for female (male=0, female=1), age, project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), partnered (0=Non-partnered, 1=Partnered), Hispanic (0=non-Hispanic, 1=Hispanic), White (0=non-White, 1=White). Bolded correlations are $p < .05$.

Table 2.7: Pearson Partial Correlation Coefficients of geospatial and social capital variables with health.

N=1124	**Illness Sum**	**Somatic (LN)**	**SRH (LN)**
Sum Illness	1		
p	--		
Somatic (LN)	**0.612**	1	
p	<.0001	--	
SRH (LN)	**0.359**	**0.478**	1
p	<.0001	<.0001	--
N=1088	**Illness Sum**	**Somatic (LN)**	**SRH (LN)**
IRRtract	-0.012	0.001	0.002
p	0.701	0.969	0.935
IRRcounty	0.026	0.016	0.025
p	0.389	0.609	0.410
SCI	-0.002	-0.035	-0.044
p	0.952	0.251	0.148
Close Friends (LN)	-0.048	**-0.083**	**-0.129**
p	0.115	0.007	<.0001
Friend Contact	**-0.066**	-0.029	**-0.063**
p	0.031	0.344	0.039
Family Contact	-0.038	-0.047	**-0.079**
p	0.218	0.119	0.010
Appraisal Support	**-0.108**	**-0.144**	**-0.183**
p	0.000	<.0001	<.0001
Belong Support	**-0.112**	**-0.163**	**-0.175**
p	0.000	<.0001	<.0001
Tangible Support	**-0.122**	**-0.161**	**-0.184**
p	<.0001	<.0001	<.0001
Family support	**-0.148**	**-0.213**	**-0.228**
p	<.0001	<.0001	<.0001
Family Strain	**0.209**	**0.253**	**0.249**
p	<.0001	<.0001	<.0001

Note. SCI=Social Capital Index; LN = natural log transformed after adding 1. Partialed for female (male=0, female=1), age, project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), partnered (0=Non-partnered, 1=Partnered), Hispanic (0=non-Hispanic, 1=Hispanic), White (0=non-White, 1=White). Bolded correlations are $p < .05$; Italicized correlations are $p < .10$.

Table 2.8: Social Capital Index Multilevel Models with Random Effects for Siblings.

	Model 0		Model 1		Model 2	
	B	se	B	se	B	se
Fixed Effects						
Intercept	**-0.41**	0.10	**-0.37**	0.10	**-0.37**	0.10
Female	0.04	0.04	0.04	0.04	0.04	0.04
Centered Age	0.00	0.01	0.00	0.01	0.00	0.01
Project	0.05	0.10	0.07	0.09	0.08	0.09
Adoption Status	-0.07	0.06	-0.06	0.06	-0.07	0.06
Partnership Status	**-0.08**	0.04	**-0.10**	0.04	**-0.11**	0.04
Hispanic	*-0.18*	0.10	*-0.17*	0.10	*-0.18*	0.10
White	-0.01	0.08	-0.03	0.08	-0.03	0.08
Living Together	-0.04	0.10	-0.07	0.10	--	--
IRRcounty	--	--	**1.45**	0.18	**1.46**	0.19
Random Effects						
σ^2_{BW} Adopted	*0.05*	0.03	0.03	0.03	0.03	0.03
σ^2_{BW} Control	0.06	0.10	*0.12*	0.08	*0.11*	0.09
σ^2_{BW} DZ	**0.19**	0.04	**0.20**	0.04	**0.20**	0.04
σ^2_{BW} MZ	**0.12**	0.03	**0.12**	0.03	**0.10**	0.03
σ^2_{WI} Adopted	**0.33**	0.04	**0.32**	0.04	**0.32**	0.04
σ^2_{WI} Control	**0.57**	0.10	**0.45**	0.08	**0.46**	0.08
σ^2_{WI} DZ	**0.23**	0.03	**0.22**	0.03	**0.23**	0.03
σ^2_{WI} MZ	**0.20**	0.03	**0.20**	0.02	**0.22**	0.03
Model Fit	**Model 0**		**Model 1**		**Model 2**	
-2 Log Likelihood	2151.3		2091.8		2063.8	
AIC	2185.3		2127.8		2097.8	
BIC	2261.8		2208.8		2174.2	
$\Delta\chi^2$	--		59.5		--	
df	--		1		--	
p	--		1.22E-14		--	
N individuals	1122		1122		1093	
N sibships	665		665		664	

Note. Adjusted for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), Partnered (0=single, 1=partnered), Hispanic (0=non-Hispanic, 1=Hispanic) and White (0=non-White, 1=White) . Bolded parameters are significant $p < .05$; italicized parameters are $p < .10$.

Table 2.9: Social Capital Inventory Multilevel Models with Random Effects for Spatial Clustering.

	Model 3		Model 4	
	B	**se**	**B**	**se**
Fixed Effects				
Intercept	-0.15	0.11	-0.19	0.11
Gender	0.03	0.02	*0.03*	0.02
Centered Age	0.00	0.00	0.00	0.00
Project	0.01	0.04	0.02	0.04
Adoption Status	0.02	0.03	0.02	0.03
Partnership Status	**-0.04**	0.02	**-0.05**	0.02
Hispanic	0.02	0.04	0.02	0.04
White	0.06	0.04	0.06	0.04
IRRcounty	--	--	**0.44**	0.16
Random Effects				
σ^2 Between Spatial Clusters	**0.79**	0.13	**0.74**	0.12
σ^2 Within Spatial Clusters	**0.08**	0.00	**0.08**	0.00
Model Fit	**Model 3**		**Model 4**	
-2 Log Likelihood	718.30		710.30	
AIC	738.30		732.30	
BIC	762.00		758.30	
$\Delta\chi^2$	--		8.00	
df	--		1	
p	--		4.68E-03	
N Individuals	1122		1122	
N Spatial Clusters	79		79	

Note. Adjusted for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), Partnered (0=single, 1=partnered), Hispanic (0=non-Hispanic, 1=Hispanic) and White (0=non-White, 1=White). Bolded parameters are significant $p < .05$; italicized parameters are $p < .10$.

Table 2.10: Number of Close Friends (LN): Multilevel Models with Random Effects for Siblings.

	Model 0		**Model 1**		**Model 2**	
	B	**se**	**B**	**se**	**B**	**se**
Fixed Effects						
Intercept	**1.64**	0.08	**1.63**	0.08	**1.65**	0.08
Female	**0.08**	0.03	**0.08**	0.03	**0.08**	0.03
Centered Age	0.00	0.01	0.00	0.01	0.00	0.01
Project	0.07	0.07	0.07	0.07	0.06	0.07
Adoption Status	-0.05	0.05	-0.06	0.05	-0.06	0.05
Partnership Status	**-0.08**	0.04	**-0.08**	0.04	**-0.09**	0.04
Hispanic	-0.12	0.09	-0.13	0.08	*-0.15*	0.09
White	-0.02	0.07	-0.01	0.07	-0.03	0.07
Living Together	0.00	0.08	0.01	0.08	**--**	**--**
IRRtract	**--**	**--**	0.12	0.21	0.08	0.22
IRRcounty	**--**	**--**	**-0.71**	0.21	**-0.67**	0.22
Random Effects						
σ^2_{BW} Adopted	0.02	0.02	0.02	0.02	0.02	0.02
σ^2_{BW} Control	*0.05*	0.04	0.04	0.04	0.04	0.04
σ^2_{BW} DZ	**0.07**	0.02	**0.05**	0.02	**0.04**	0.02
σ^2_{BW} MZ	**0.10**	0.03	**0.09**	0.03	**0.08**	0.03
σ^2_{WI} Adopted	**0.22**	0.03	**0.22**	0.03	**0.22**	0.03
σ^2_{WI} Control	**0.27**	0.04	**0.27**	0.04	**0.27**	0.04
σ^2_{WI} DZ	**0.20**	0.02	**0.20**	0.02	**0.21**	0.03
σ^2_{WI} MZ	**0.22**	0.03	**0.22**	0.02	**0.23**	0.03
Model Fit	**Model 0**		**Model 1**		**Model 2**	
-2 Log Likelihood	1747.4		1731.4		1685.5	
AIC	1781.4		1769.4		1721.5	
BIC	1857.9		1854.9		1802.4	
$\Delta\chi^2$	**--**		16.0		**--**	
df	**--**		2		**--**	
p	**--**		3.35E-04		**--**	
N individuals	1122		1122		1093	
N sibships	665		665		664	

Note. Adjusted for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), Partnered (0=single, 1=partnered), Hispanic (0=non-Hispanic, 1=Hispanic) and White (0=non-White, 1=White). LN = natural log transformed after adding 1. Bolded parameters are significant $p < .05$; italicized parameters are $p < .10$.

Table 2.11: Number of Close Friends (LN) Multilevel Models with Random Effects for Spatial Clustering.

	Model 3		**Model 4**	
	B	**se**	**B**	**se**
Fixed Effects				
Intercept	**1.62**	0.08	**1.63**	0.08
Gender	**0.07**	0.03	**0.07**	0.03
Centered Age	-0.01	0.01	-0.01	0.01
Project	0.08	0.07	0.07	0.07
Adoption Status	-0.04	0.05	-0.04	0.05
Partnership Status	**-0.08**	0.04	*-0.07*	0.04
Hispanic	*-0.14*	0.08	*-0.15*	0.08
White	-0.02	0.07	-0.01	0.07
IRRtract	--	--	0.05	0.21
IRRcounty	--	--	**-0.74**	0.22
Random Effects				
σ^2 Between Spatial Clusters	**0.01**	0.00	0.00	0.00
σ^2 Within Spatial Clusters	**0.28**	0.01	**0.28**	0.01
Model Fit	**Model 3**		**Model 4**	
-2 Log Likelihood	1775.30		1757.20	
AIC	1795.30		1781.20	
BIC	1818.00		1809.60	
$\Delta\chi^2$	--		18.1	
df	--		2	
p	--		1.17E-04	
N Individuals	1122		1122	
N Spatial Clusters	79		79	

Note. Adjusted for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), Partnered (0=single, 1=partnered), Hispanic (0=non-Hispanic, 1=Hispanic) and White (0=non-White, 1=White). LN = natural log transformed after adding 1. Bolded parameters are significant $p < .05$; italicized parameters are $p < .10$.

Table 2.12: Friend Contact Frequency Multilevel Models with Random Effects for Siblings.

	Model 0		Model 1		Model 2	
	B	**se**	**B**	**se**	**B**	**se**
Fixed Effects						
Intercept	**5.17**	0.24	**5.15**	0.24	5.19	0.24
Female	**0.47**	0.09	**0.47**	0.09	**0.48**	0.09
Centered Age	**-0.05**	0.02	**-0.05**	0.02	**-0.05**	0.02
Project	0.13	0.20	0.11	0.20	0.10	0.20
Adoption Status	**0.33**	0.14	**0.30**	0.14	**0.30**	0.14
Partnership Status	**-0.54**	0.11	**-0.53**	0.11	**-0.53**	0.11
Hispanic	-0.19	0.23	-0.23	0.23	-0.22	0.23
White	-0.16	0.20	-0.14	0.20	-0.17	0.20
Living Together	-0.10	0.22	-0.10	0.22	--	--
IRRtract	--	--	*1.00*	0.61	0.93	0.61
IRRcounty	--	--	**-1.58**	0.60	**-1.36**	0.61
Random Effects						
σ^2_{BW} Adopted	0.05	0.19	0.04	0.19	0.04	0.19
σ^2_{BW} Control	0.24	0.24	0.24	0.23	0.24	0.24
σ^2_{BW} DZ	0.06	0.17	0.02	0.17	0.06	0.17
σ^2_{BW} MZ	**0.60**	0.21	**0.59**	0.21	**0.66**	0.21
σ^2_{WI} Adopted	**2.08**	0.27	**2.11**	0.27	**2.11**	0.27
σ^2_{WI} Control	**2.19**	0.29	**2.19**	0.29	**2.20**	0.29
σ^2_{WI} DZ	**1.88**	0.22	**1.87**	0.22	**1.84**	0.23
σ^2_{WI} MZ	**1.77**	0.21	**1.77**	0.21	**1.63**	0.20
Model Fit	**Model 0**		**Model 1**		**Model 2**	
-2 Log Likelihood	4027.1		4020.3		3904.6	
AIC	4061.1		4058.3		3940.6	
BIC	4137.6		4143.8		4021.5	
$\Delta\chi^2$	--		6.8		--	
df	--		2		--	
p	--		3.34E-02		--	
N individuals	1113		1113		1085	
N sibships	665		665		664	

Note. Adjusted for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), Partnered (0=single, 1=partnered), Hispanic (0=non-Hispanic, 1=Hispanic) and White (0=non-White, 1=White). Bolded parameters are significant $p < .05$; italicized parameters are $p < .10$.

Table 2.13: Friend Contact Frequency Multilevel Models with Random Effects for Spatial Clustering.

	Model 3		Model 4	
	B	**se**	**B**	**se**
Fixed Effects				
Intercept	**5.11**	0.23	**5.13**	0.23
Gender	**0.45**	0.09	**0.44**	0.09
Centered Age	**-0.05**	0.02	**-0.05**	0.02
Project	0.12	0.20	0.10	0.20
Adoption Status	**0.35**	0.14	**0.32**	0.14
Partnership Status	**-0.51**	0.11	**-0.50**	0.11
Hispanic	-0.29	0.23	-0.31	0.23
White	-0.11	0.20	-0.10	0.20
IRRtract	--	--	0.88	0.59
IRRcounty	--	--	**-1.49**	0.60
Random Effects				
σ^2 Between Spatial Clusters	0.03	0.02	0.02	0.02
σ^2 Within Spatial Clusters	**2.18**	0.09	**2.18**	0.09
Model Fit	**Model 3**		**Model 4**	
-2 Log Likelihood	4038.4		4032.4	
AIC	4058.4		4056.4	
BIC	4082.1		4084.8	
$\Delta\chi^2$	--		6.0	
df	--		2	
p	--		4.98E-02	
N Individuals	1113		1113	
N Spatial Clusters	79		79	

Note. Adjusted for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), Partnered (0=single, 1=partnered), Hispanic (0=non-Hispanic, 1=Hispanic) and White (0=non-White, 1=White). Bolded parameters are significant $p < .05$; italicized parameters are $p < .10$.

Table 2.14: Somatic Complaints (LN) Summary Multilevel models with Random Effects for Siblings.

	Model 0		Model 1		Model 2	
	B	**se**	**B**	**se**	**B**	**se**
Fixed Effects						
Intercept	**0.56**	0.05	**0.64**	0.06	**0.64**	0.06
Female	**0.17**	0.02	**0.17**	0.02	**0.17**	0.02
Centered Age	0.00	0.00	0.00	0.00	0.00	0.00
Project	**0.12**	0.04	**0.12**	0.04	**0.12**	0.04
Adoption Status	-0.01	0.03	-0.01	0.03	0.00	0.03
Partnership Status	**-0.06**	0.02	**-0.06**	0.02	**-0.06**	0.02
Parental Status	**-0.07**	0.02	**-0.08**	0.02	**-0.08**	0.02
Hispanic	**-0.10**	0.05	**-0.10**	0.05	**-0.10**	0.05
White	0.00	0.04	-0.01	0.04	-0.01	0.04
Years of Education	**-0.02**	0.00	**-0.01**	0.00	**-0.01**	0.00
Living Together	-0.03	0.05	-0.03	0.05	-0.03	0.05
Close Friends (LN)	**--**	--	**-0.05**	0.02	**-0.05**	0.02
IRRtract	**--**	--	--	--	-0.06	0.12
IRRcounty	--	--	--	--	0.09	0.12
Random Effects						
σ^2_{BW} Adopted	0.00	.	0.00	.	0.00	.
σ^2_{BW} Control	*0.01*	0.01	*0.01*	0.01	*0.01*	0.01
σ^2_{BW} DZ	0.01	0.01	0.01	0.01	0.01	0.01
σ^2_{BW} MZ	**0.04**	0.01	**0.04**	0.01	**0.04**	0.01
σ^2_{WI} Adopted	**0.11**	0.01	**0.11**	0.01	**0.11**	0.01
σ^2_{WI} Control	**0.07**	0.01	**0.07**	0.01	**0.07**	0.01
σ^2_{WI} DZ	**0.09**	0.01	**0.08**	0.01	**0.09**	0.01
σ^2_{WI} MZ	**0.05**	0.01	**0.05**	0.01	**0.05**	0.01
Model Fit	**Model 1**		**Model 2**		**Model 3**	
-2 Log Likelihood	480.7		473.1		472.6	
AIC	516.7		511.1		514.6	
BIC	597.7		596.6		609.1	
$\Delta\chi^2$	--		7.6		0.5	
df	--		1		2	
p	--		5.84E-03		7.79E-01	
N individuals	1116		1116		1116	
N sibships	665		665		665	

Note. Adjusted for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), race (0=non-White, 1=White) and Hispanic ethnicity (0=non-Hispanic, 1=Hispanic), Years of Education (centered at 16.82), Close Friends (LN), centered at mean. LN = natural log transformed after adding 1. Bolded parameters are significant $p < .05$; italicized parameters are $p < .10$.

Table 2.15: Somatic Complaints (LN) Summary Multilevel models with Random Effects for Spatial Clustering.

	Model 3		Model 4		Model 5	
	B	se	B	se	B	se
Fixed Effects						
Intercept	**0.56**	0.05	**0.64**	0.06	**0.64**	0.06
Gender	**0.17**	0.02	**0.17**	0.02	**0.17**	0.02
Centered Age	0.00	0.00	0.00	0.00	0.00	0.00
Project	**0.11**	0.04	**0.12**	0.04	**0.12**	0.04
Adoption Status	0.00	0.03	0.00	0.03	0.00	0.03
Partnership Status	**-0.06**	0.02	**-0.06**	0.02	**-0.06**	0.02
Parental Status	**-0.07**	0.02	**-0.08**	0.02	**-0.08**	0.02
Hispanic Ethnicity	-0.09	0.05	**-0.09**	0.05	**-0.09**	0.05
Caucasian Ethnicity	0.00	0.04	0.00	0.04	0.00	0.04
Years of Education	**-0.02**	0.00	**-0.01**	0.00	**-0.01**	0.00
Living Together	-0.02	0.04	-0.02	0.04	-0.02	0.04
Close Friends (LN)	--	--	**-0.05**	0.02	**-0.05**	0.02
IRRtract	--	--	--	--	-0.01	0.13
IRRcounty	--	--	--	--	0.02	0.13
Random Effects						
σ^2 Between Spatial Clusters	0.00	.	0.00	.	0.00	.
σ^2 Within Spatial Clusters	**0.09**	0.00	**0.09**	0.00	**0.09**	0.00
Model Fit	**Model 3**		**Model 4**		**Model 5**	
-2 Log Likelihood	516.5		509.6		509.6	
AIC	540.5		535.6		539.6	
BIC	569.0		566.4		575.1	
$\Delta\chi^2$	--		6.9		0.0	
df	--		1		2	
p	--		8.62E-03		1.00E+00	
N Individuals	1116		1116		1116	
N Spatial Clusters	79		79		79	

Note. Adjusted for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), race (0=non-White, 1=White) and Hispanic ethnicity (0=non-Hispanic, 1=Hispanic), Years of Education (centered at 16.82), Close Friends (LN), centered at mean. LN = natural log transformed after adding 1. Bolded parameters are significant $p < .05$; italicized parameters are $p < .10$.

Chapter Four:

Associations between Activity Engagement, Social Capital and Cognitive Performance

Geographic disparities in cognitive performance have been documented comparing the performance of rural to urban dwelling individuals and suggests that rural individuals typically demonstrate lower cognitive performance and differential dementia risk than their urban residing counterparts (Cassarino & Setti, 2015; McCall-Hosenfeld et al., 2014; Putnam, 2000; Russ et al., 2012; Saenz et al., 2018; Weden et al., 2018), and similar disparities have been observed across the globe (Bae et al., 2015; Cahill et al., 2012; Contador et al., 2015; Gavrila et al., 2009; Letellier et al., 2020; Nunes et al., 2010; Stepankova Georgi et al., 2019; Xiang et al., 2018). These cognitive disparities are often accounted for when controlling for the generally lower educational attainment achieved by rural residing individuals (Beaudoin & Thorson, 2004; Henning-Smith & Lahr, 2018; McCall-Hosenfeld et al., 2014; Putnam, 2000; Saenz et al., 2018; Sørensen, 2016; Weden et al., 2018) although, at least one study suggests this gap in the differences between educational attainment between rural and urban individuals has started to narrow based on the data from the 2000 to the 2010 census (Weden et al., 2018). However, the extent to which geographic cognitive disparities are buffered or magnified with respect to activity engagement and access to community level social capital is not understood, particularly in adults on the verge of midlife.

As Cassarino & Setti (2015) detail in their review of the geographical and physical environmental features associated with cognition, there are a number of direct and indirect pathways that may influence cognition. Indirect pathways include activity engagement (Cassarino & Setti, 2015). For example, if the environment provides places for physical activities (e.g. sidewalks, parks with exercise equipment, gyms, etc.) the residents of that environment are more likely to engage in physical activity that benefit physical and cognitive health (Clarke et al., 2011, 2012; Deng & Paul, 2018; Karp et al., 2006; Kerr et al., 2012; Sallis et al., 2009; Salvo et al., 2018; Scarmeas et al., 2001; Van Cauwenberg et al., 2011; Wilcox et al., 2000). Similarly, the environment may promote or impede social activity engagement thus modifying the pathway between the activity engagement and cognition. For example, living in areas with easy access to public parks and greenspace has been shown to increase social integration (Cassarino & Setti, 2015; Kweon et al., 1998; Maas et al., 2009). Alternatively, living in areas with high neighborhood deprivation (e.g. high crime, abandoned buildings, etc.) is associated with higher rates of social isolation (Buffel et al., 2012; Cassarino & Setti, 2015). An underappreciated environmental aspect that has received less attention in the field is the relationship between social capital and activity engagement, while no prior research (to the best of our knowledge) has evaluated social capital's effect on cognition. Social capital (described in further detail below), can be simply described as the relationship between members of the community that fosters trust and reciprocal helpful behaviors among community members (Putnam, 2000). It is possible that social capital may act as a mediator between activity engagement and cognition although this mediation has not been explored previously. Moreover, educational and occupational attainment must be considered to evaluate unique associations between activity engagement, social capital, and cognitive performance (Fors et al., 2009; Gatz et al., 2006; Glymour & Manly, 2008;

Jefferson et al., 2011; Lee et al., 2003; Saenz et al., 2018; Singh-Manoux et al., 2005; Weden et al., 2018). Last, the possibility that rurality may moderate activity engagement and social capital associations with cognition ought to be considered. Prior work has suggested that individuals living at the extremes of rurality and urbanicity may be at greater disadvantage due to the overload or lack of cognitive stimulation which demonstrates non-linearity in the measures of rurality (Wu, Prina, & Brayne, 2015; Wu, Prina, Jones, Matthews, et al., 2017). Similarly, other studies although not evaluating cognitive performance, have shown that urbanicity can moderate the relationship between exposure to greenspace and depression with the strongest relationships observed at the highest levels of urbanicity (Liu et al., 2019). Others have found geographic moderation in studying obesity with individuals at the most rural and most urban extremes being the least likely to be obese (Cohen et al., 2017).

Social Capital across Rural and Urban Areas

Previous literature has examined differences in social capital across rural and urban areas. Although a formal definition of social capital has yet to materialize, social capital has been described as the social networks available to an individual as well as the resources (both tangible and emotional) and the trust and interchange opportunities that are developed through those social networks (Putnam, 2000). While many studies have suggested that rural areas have higher amounts of social capital (Beaudoin & Thorson, 2004; Fischer, 1982; Onyx & Bullen, 2000; Sørensen, 2016; Ziersch et al., 2009), some studies suggest that there are geographic differences depending on the aspect of social capital being measured. For example, rural areas have been found to have higher levels of social trust (Beaudoin & Thorson, 2004; Onyx & Bullen, 2000) although this is debated (Sørensen, 2012), stronger family ties (Hofferth & Iceland, 1998), participation in the local community (Onyx & Bullen, 2000; Sørensen, 2012), and neighborhood connections (Onyx & Bullen, 2000). Alternatively, urban areas have been found to have higher levels of social agency (Onyx & Bullen, 2000) and tolerance of diversity (Onyx & Bullen, 2000). It is important to note, however, the methodological short comings of some of the current literatures examining differences in social capital. First, much of the prior literature has evaluated these rural-urban differences in social capital using a categorical representation of rurality. That is, when comparing social capital in rural and urban areas, studies often dichotomize between areas that represent highly rural and highly urban environments through the use of census rural/urban categorization, Rural Urban Continuum Codes (RUCC), or Rural Urban Commuting Area Codes (RUCA) (Beaudoin & Thorson, 2004; Hofferth & Iceland, 1998; Wilcox et al., 2000; Yang et al., 2011; Ziersch et al., 2009). As Wu et al., (2015, 2017) detail, when comparing highly rural to highly urban areas, there may be a u-shaped relationship between outcomes of interest and geography, with the individuals at the furthest ends of rurality or urbanicity showing the greatest disadvantages.

Moreover, these studies often draw conclusions based on bivariate comparisons between rural-urban and the outcome of interest without considering other possible factors (such as education) which could alter the results observed (Sørensen, 2016). This will be the first study to evaluate social capital on a continuous scale of rurality by utilizing the Index of Relative Rurality (IRR) (Inagami et al., 2016; Waldorf, 2006;

Waldorf & Ayoung, 2015) which is a continuous measure of rurality ranging from 0 being the most urban to 1 being the most rural. Additionally, this study will account for mediating factors of educational and occupational attainment. Educational attainment has long shown a strong relationship with cognitive functioning (Fors, Lennartsson, & Lundberg, 2009; Jefferson et al., 2011; Lee, Kawachi, Berkman, & Grodstein, 2003; Singh-Manoux, Richards, & Marmot, 2005) and even more so recently (Saenz et al., 2018; Weden et al., 2018). Much of the literature evaluating geographic differences also notes the importance of controlling for educational attainment due to the generally lower attainment by rural individuals as well as the high correlation between educational attainment and social capital (Sørensen, 2016; Ziersch et al., 2009). Second, lacking a formal operational definition of social capital, previous literature has utilized different measures thought to be related to social capital (e.g. community trust, perceived support, social network size, friend/family contact frequency, social support, personality type, political participation, etc.), making it difficult to compare the effects of social capital across studies (Petrou & Kupek, 2008; Pinillos-Franco & Kawachi, 2018; Reeves et al., 2014; Sørensen, 2012, 2016; Tulin et al., 2018; Van der Linden et al., 2003; Wilson & Musick, 1997; Ziersch et al., 2009). The county level Social Capital Index (SCI; described in further detail below) may be beneficial for use in analyses because it is an aggregated indicator of social capital which combines a number of community level factors such as organizations available for membership, voter and census participation and non-profit organizations (Rupasingha et al., 2006).

Relationship between Social Capital and Cognition

Although the differences in both cognitive abilities and social capital have been evaluated across rural and urban residing individuals, there is a gap in the literature addressing the relationship between social capital and cognitive performance. Many studies in the field of economics have discussed the influence of social capital and cognition on business success and entrepreneurship (Aldrich et al., 1986; De Carolis et al., 2009; De Carolis & Saparito, 2006; Nahapiet & Ghoshal, 1998). It is important to clarify the conceptualization of social capital and cognition from the economic perspective, however, as it differs from the conceptualization of social capital and cognition discussed in this study. Simply put, researchers in the field of economics utilize the traditional conceptualization of social capital as the collective resources within the social network that can be mobilized when in need (De Carolis et al., 2009; De Carolis & Saparito, 2006; Nahapiet & Ghoshal, 1998). What differentiates the economic perspective however is the focus on how the network connections and collective resources can help individuals move up the economic ladder, so to speak (De Carolis et al., 2009; De Carolis & Saparito, 2006). Under the economic conceptualization of social capital, social networks and collective resources can be utilized for personal economic gain. What's more, in economic studies of social capital and cognition the conceptualization of cognition is discussed in terms of perceived control and risk propensity or intellectual capital (De Carolis et al., 2009; De Carolis & Saparito, 2006; Nahapiet & Ghoshal, 1998). That is, the conceptualization of cognition from the economic perspective is more about the gathering of knowledge and information through the social network to inform decisions made regarding financial promotion and less about cognitive performance (De Carolis et al., 2009; De Carolis & Saparito, 2006; Nahapiet & Ghoshal, 1998). The current study similarly conceptualizes social capital as the collective resources within the community but is not concerned with economic growth. What's more, we consider cognition from a psychological perspective and evaluate cognitive performance rather than information gathering. To the best of our knowledge, this will be the first study to explore the associations between social capital and cognitive performance.

Relationship between Activity Engagement and Cognition

Lastly, there is a growing literature evaluating the differences in activity engagement across rural and urban individuals. Most of the literature has focused on the physical activity engagement differences across categorical measures of rural and urban areas (Aronson & Oman, 2004; Eyler & Vest, 2002; Patterson et al., 2004; Sanderson et al., 2002; Trivedi et al., 2015; Vogelsang, 2016; Wilcox et al., 2000). Because of the differing affordances and barriers to activity engagement in rural and urban environments, drawing conclusions from bivariate associations between categorical measures of rural-urban and activity engagement may lead to misrepresentation of engagement and cognitive performance (Annear et al., 2014; Eyler & Vest, 2002; Michael & Yen, 2014; Parks et al., 2003; Sanderson et al., 2002). Prior research has demonstrated that rural individuals report significantly less leisure time physical activity than their urban counter parts (Bot et al., 2016; Deng & Paul, 2018; Eyler & Vest, 2002; Patterson et al., 2004; Trivedi et al., 2015; Wilcox et al., 2000) with rural white women engaging in the lowest physical activity (Eyler & Vest, 2002; Wilcox et al., 2000). Prior literature suggests that individuals in rural areas have significantly more barriers that prevent them from engagement in physical activities than do urban residing individuals (Aronson & Oman, 2004; Eyler & Vest, 2002; Parks et al., 2003; Salvo et al., 2018; Sanderson et al., 2002; Wilcox et al., 2000). Barriers to physical activity engagement that rural individuals have reported include environmental factors such as weather extremes, lack of sidewalks or street lights, stray dogs or high crime (Aronson & Oman, 2004; Wilcox et al., 2000). Women report additional sociological factors preventing them from physical activity engagement such as caregiving, feelings of guilt related to not being at home with the family, family responsibility and lack of social support (Eyler & Vest, 2002; Parks et al., 2003; Sanderson et al., 2002; Wilcox et al., 2000). In a 2018 systematic literature review, researchers combined findings from 36 peer-reviewed articles to further support the notion that the functional, aesthetic, and safety characteristics influence physical activity engagement (Salvo et al., 2018). This adds support to ecological theories, which emphasize the interplay between the environment and the individual's behaviors (Bronfenbrenner, 1979; Bronfenbrenner & Ceci, 1994). Physical activity engagement has also been associated with better cognitive performance (Paluska & Schwenk, 2000). Findings from a 2011 meta-analysis which evaluated 15 longitudinal studies comprised of more than 33,000 individuals suggests that participants who engage in regular physical activity showed lessened cognitive impairment in follow-ups ranging from 1 to 12 years later (Sofi et al., 2011).

While most of the literature evaluating geographic differences in activity engagement have evaluated physical activity, others have looked at differences in social activity engagement across rural and urban residing individuals finding that rural individuals engage in significantly fewer social activities than urban individuals (Alesina & La Ferrara, 2000; Vogelsang, 2016). Lowered social activity engagement has been shown to have detrimental effects to cognition regardless of geographic location (Barnes et al., 2004; Bassuk et al., 1999; Bennett et al., 2006; Bot et al., 2016; Ertel et al., 2008; Holtzman et al., 2004; Kelly, Duff, Kelly, McHugh Power, et al., 2017; Krueger et al., 2009; Litwin & Stoeckel, 2015; Wang et al., 2002a). In a longitudinal study with a sample of more than 6,000 older individuals (≥ age 65), larger social networks and greater social engagement were associated with a reduced rate of cognitive decline after a 5 year follow up, even after controlling for socioeconomic status, depression, and engagement in cognitive and physical activities (Barnes et al., 2004).

Engagement in cognitive activities (e.g. reading, playing strategic games, crossword puzzles, etc.) has also shown beneficial effects on cognitive performance (e.g. Scarmeas et al., 2001; Wilson et al., 2013). However, one cross-sectional study reported contradictory findings using a sample with a wide age range (20-91) finding no association between engagement in cognitively stimulating activities, and age-related differences in cognition (Salthouse et al., 2002). What's more, this study found no support that individuals with a propensity to seek out cognitive activities showed any benefit in either fluid abilities or episodic memory performance (Salthouse et al., 2002). Similar to social capital and cognition, to the best of our knowledge, little research has examined the geographic differences in cognitive activity engagement. One study evaluated newspaper reading across rural and urban individuals as a means to measure social capital and observed that rural individuals engaged in more newspaper reading, but this finding was not the intent of the paper (Beaudoin & Thorson, 2004). Relatedly, the directionality of cognitive activity engagement to cognition is debatable (Salthouse et al., 2002). It is possible that engagement in cognitively stimulating activities enhance cognition, it could also be that those with higher cognition engage in more cognitively stimulating activities, or that other factors such as physical health could affect both activity engagement and cognition (Salthouse et al., 2002). Prior research suggests that individuals living in rural communities perform worse on cognitive tasks than their urban residing counterparts (Saenz et al., 2018). A possible explanation for this rural cognitive disparity is that individuals in rural areas often show lower educational attainment (Beaudoin & Thorson, 2004; Henning-Smith & Lahr, 2018; McCall-Hosenfeld et al., 2014; Putnam, 2000; Saenz et al., 2018; Weden et al., 2018). It has been suggested that the rural-urban gap in primary educational attainment has declined, although individuals from rural populations continue to be less likely to complete a college or advanced degree (Weden et al., 2018). An alternative explanation for the geographic differences seen in cognitive performance could be that rural individuals with higher cognitive performance may be migrating to more urban areas for better employment opportunities (Saenz et al., 2018; Sanchez & Pacheco, 2012). Supporting this, older work suggests that urban environments provide more opportunities for leisure activities that promote intellection stimulation such as museums and libraries (Kearns & Parkinson, 2001). In addition, urban environments may provide more cognitive stimulation (Keay et al., 2009; Linnell et al., 2013; Russ et al., 2012), although the increased stimulation found in urban areas may be excessively challenging and function as a deficit to cognitive performance, particularly for aging populations (Cassarino & Setti, 2015; Lövdén et al., 2005, 2010; Moffat & Resnick, 2002).

This study will seek to elucidate the pathways that contribute to cognitive performance above and beyond factors that are already identified as contributors to cognitive performance such as educational attainment or occupational attainment. To expand on previous literature, this study aims to examine how activity engagement and social capital influence cognitive performance in mid-life and how it differs across rural and urban residing individuals using the Index of Relative Rurality, which was created in Study 1. Because prior research has only examined the associations between activity engagement and social capital, using categorical classifications of rural and urban, this will be the first study to examine the geographic differences in these domains on a continuous scale of rurality. Thus, the first research question for this study asks: Are there significant differences cognitive performance as index by IQ for by continuous measure of rurality (IRR) residing individuals when considering educational and occupational attainment? The second research question for this study asks: What is the association between self-reported activity engagement, as mediated by county-level social capital (Rupasingha et al., 2006), and IQ when controlling for relevant covariates? This study will be the first to evaluate the association between activity engagement and IQ as mediated by social capital. Lastly, the third research question for this study expands on the two prior questions by asking: Do the associations between activity engagement, as mediated by social capital, and IQ differ for rural and urban residing individuals?

Method

Participants

The current study includes data collected through May 31, 2019 the 45th month of active collection for the on-going Colorado Adoption/Twin Study of Lifespan behavioral development and cognitive aging (CATSLife (Wadsworth et al., 2019a, 2019b)). A total of 1155 individuals participated, including 655 twins from the Longitudinal Twin Study (Rhea et al., 2013) and 500 from the Colorado Adoption Project (Plomin & DeFries, 1983; Rhea, Bricker, et al., 2013b). Ages ranged from 28.06 to 49.33 years in the full sample (*M*age = 33.03, *SD*=4.91) and 53.56% were female.   In terms of race and ethnicity, 92.19% identified as white and 5.97% identified as Hispanic.

We included in the analysis sample those residing in the United States with available geographic measurements (N=1139) and answered the online survey (N=1153) for an effective analysis sample of N = 1131. We note that the qualitative ratings of hobbies described below were only available for N=978 tested through July 30, 2018 (36 month of testing). Participant demographics are shown in Table 3.1.

Measures

Education & Occupation

Educational Attainment. *Educational attainment was measured using an item adopted* from the Colorado Adoption Project (Rhea, Bricker, et al., 2013b): “What is the highest year of school you have completed?”. Year equivalents were assigned to the following category choices: 11= “Less than high school diploma or GED”, 12= “high school or GED”, 13= “one year college” 14 “two years (Associate of Arts)”, 15= “three years”, 16= “four years, no degree”, 17= “five years or more, no degree”, 18= “bachelors”, 20= “masters”, 22= “Advanced degree (e.g. doctorate, M.D., law degree)”. Educational attainment was centered on 18 years or the equivalent of a bachelor’s degree. Descriptives are shown in Table 3.1.

Occupational Attainment. Participants were asked to “Rate your position at current job or if not currently employed, your most recent job. Which category best describes(d) your job?” adopted from the Colorado Adoption Project (Rhea, Bricker, et al., 2013b). Participants could select from 8 different categories that best described their current or past job: 1= top executive; proprietor of a major business; professional requiring an advanced degree, 2= manager; proprietor of a medium business; profession requiring a college degree, 3= administrative personnel; small business owner; semiprofessional, 4= sales and clerical work; technician, 5= skilled manual worker, 6= machine operator and semiskilled worker, 7= unskilled worker, 8= homemaker.

To address those individuals who were missing on their self-report occupational attainment (N=50), student status and two open-ended questions of self-described job title were reviewed to further classify their line of work. The open-ended questions asked participants to list their current or most recent occupation title (i.e. “What is the most important recent job you have had?” or “What is the most important job you currently have?”). Participants missing on occupational attainment but who provided a job title were then compared with participants with similar or identical job titles and who had reported their occupational attainment to identify occupational attainment for the missing individuals. For example, a participant who was missing on the occupational attainment variable but provided a job title such as “barista” was categorized as 7=unskilled worker, as this was the occupational attainment of self-report by participants who similarly responded as “barista” to their current or recent job title. If there was a range in responses on occupational level for compared job titles for participants missing occupational attainment, then the lower category was selected. This coding method for occupational attainment was utilized for 29 participants who were otherwise missing on this item. Two participants did not provide current or past job titles and were only identified as current students and were categorized at the Homemaker level. Participants who were missing on occupational attainment, occupational title, and were not students were coded as missing (N=19).

The occupational attainment values were then reversed scored such that higher scores indicated higher occupational attainment: 8= top executive; proprietor of a major business; professional requiring an advanced degree, 7= manager; proprietor of a medium business; profession requiring a college degree, 6= administrative personnel; small business owner; semiprofessional, 5= sales and clerical work; technician, 4= skilled manual worker, 3= machine operator and semiskilled worker, 2= unskilled worker, 1= homemaker. For the purposes of the current study, we recoded the 64 homemakers/students to be the same level as semi-skilled workers. Coding of homemakers as the equivalent of semi-skilled workers is not without precedence, such as on the Academic-Q survey form (Kaufman et al., 2015). Correlations of occupational attainment with educational attainment and IQ variables (described below) were within 0.01 correlation units between the original scale, dropping homemakers, or the recoding of homemakers to semi-skilled, with slightly stronger correlations with the latter. Occupational attainment was centered on 6 or the equivalent of administrative personnel, small business owner, or semi-professional. Descriptives are shown in Table 3.1.

Wechsler Adult Intelligence Scale-third edition (WAIS-III)

The Wechsler Adult Intelligence Scale – III (WAIS-III) is a normed measure of intellectual ability using a representative sample and is comprised of 14 possible subtests (11 used in this sample) (Wechsler, 1997). For the current study, we used the Full-scale IQ (FSIQ), Verbal IQ (VIQ), and Performance IQ (PIQ) scaled scores. IQ scores are expected to have a mean of 100 and SD of 15 (Wechsler, 1997). Descriptive statistics for FIQ, VIA, and PIQ are shown in Table 3.2.

Activity Engagement

The activity engagement 20-item scale measured the weekly engagement in hours form a list of leisure time activities (adapted from (Jessor & Jessor, 1977)). Example activity items include items such as “Working out as part of a personal exercise program?”, “Going out with friends or dating?” and “Doing things with your family?” These items were rescaled in hour units to capture total number of hours of engagement in each week for each of the items such that 0 = None, 1 = 1 hour a week, 2.5 = 2-3 hours a week, 4.5 = 4-5 hours a week, 6.5 = 6-7 hours a week, to 8 = 8 or more hours a week.

Placement of items into activity domains was informed by prior principal component work (Haberstick et al., 2014) and other work , e.g., cognitive activities vis-à-vis Stern & Munn (2010). The hours reported were summed into one of 5 activity domains. Four items comprise the social activity domain. Five items comprise the physical activity domain. Three items comprise the family activity domain. Four items comprise the sedentary activity domain. Three items comprise the cognitive activity domain. A total hours of activity engagement domain was also calculated by summing the total number of hours of engagement for all 19 items. Descriptives for the activity engagement items are shown in Table 3.3. To adjust for skew in these activity domains and to prepare the data for analysis where interaction terms would be formed, the natural log (plus 1 to account for zeros in the data) performed on each of the activity domain scores.

Open Ended Activity Engagement Coding. Twelve open-ended items, which corresponded to the above activity engagement items, were included in the CATSLife assessment. For the current analysis, we coded “What hobby(ies) do you do?”, and applied coding systems to evaluate the qualitative differences in engagement in hobbies across rural and urban residing individuals. Each entry coded using a blind dual entry technique by having a team of research assistants follow the rating system described in Study 1. Each hobby that participants listed was coded in multiple ways. The overall coding scheme, rating scale scheme, and examples were informed by prior work evaluating the multifaceted properties of activity engagement (Ainsworth et al., 1993; Salthouse et al., 2002; Wang et al., 2002a). For participants tested through July 30, 2018 (36 month of testing), provided qualitative answers were coded.

For a full description of all coding techniques, see Study 1 and Appendix 1. Raters provided a value based on the following instructions: "Rate how cognitively, socially, and physically demanding you feel each hobby is on a 5-point scale where:1 = absolutely no cognitive, social, or physical demand; 2 = some cognitive, social, or physical demand; 3 = moderate cognitive, social, or physical demand; 4 = a lot of cognitive, social, or physical demand; 5 = high cognitive, social, or physical demand.

To handle rater disagreements in the cognitive, social, and physical ratings of each hobby, consensus meetings were held using a separate set of raters. Between the dual entry and consensus coding of hobbies, raters were 50.3% in absolute agreement and 94.2% within 1 point for cognitive scores, 53.3% in absolute agreement and 93.1% within 1 point for social scores, and 41.6% in absolute agreement and 92.6% within 1 point for physical scores using the previously described coding system. Descriptives for cognitive hobby engagement is shown in Table 3.3.

Geospatial

Index of Relative Rurality (IRR). The IRRtract and IRRcounty which were developed and described in Study 1 will be applied for this study. Measures of population, population density, percent urban and distance to the nearest major city are combined to form a continuous scale ranging from 1 which represents an area that is totally rural to 0 which represents an area that is totally urban to. Descriptives for IRRtract and IRRcounty are shown in Table 3.4.

Social Capital Index (SCI). The county level social capital index (SCI, updated in 2014) was used as the measure of Social Capital (Northeast Regional Center for Rural

Development, 2019; Rupasingha et al., 2006). The SCI combines data sources believed to contribute to social capital such as: 1) the number of business, political, civic and professional organizations as well as resources available in the county (e.g. bowling alleys & fitness centers) accounting for population size; 2) measures of community engagement (census and voter response rates), and 3) quantity of non-profit organizations (local, state, or national). A standardized first principal component (M=0, SD=1) was formed via the four facets -- population-adjusted organizations, voter turnout, census response, and non-profits -- with higher scores indicating more social capital (see Northeast Regional Center for Rural Development, 2019). Descriptives for Social Capital Index are shown in Table 3.4.

Statistical Analysis

Multilevel models were fitted using PROC Mixed in SAS 9.4 (SAS Institute Inc., Cary, NC) to evaluate the associations of rurality at the proximal (i.e. IRRtract) and distal (i.e. IRRcounty) levels with the natural log transformed quantitative and qualitative activity engagement measures. Models accounted for covariates including age (centered at age 33), project (LTS=0, CAP=1), sex (male=0, female=1), adopted status (non-adopted=0, adopted=1), Hispanic ethnicity (0=non-Hispanic, 1=Hispanic), race (0=non-White, 1=White), and siblings who live together (0=not living together, 1=living together). For analyses, IRRcounty was centered at .25 and IRRtract was centered at .24 which reflects their mean values. Additional covariates included years of educational attainment (centered at 18 years) and occupational attainment (centered at 6 or semi-professional). Because it was derived in a PCA, the SCI had an effective centering of 0.

Differential sibling relatedness was accounted for both between (σ^2BW) and within (σ^2WI) sibships by estimating separate random effects for those siblings in adoptive, control, or twin families (dizygotic, DZ; monozygotic, MZ). To measure sibling similarity for all outcomes intraclass correlations (ICCs) were calculated by taking σ^2BW over the sum of σ^2BW and the σ^2WI for each family type.

Because 61.90% of the sample population lived within Colorado, their full FIPS identifier was used to cluster by county whereas those living outside of Colorado were clustered by state identifiers. The models accounted for clustering between (σ^2BW) and within (σ^2WI) the full FIPS identifier for those in Colorado and the state FIPS identifier for those outside of Colorado. In multilevel models, the maximum number of individuals in a given county-state was N=100 (range = 1 to 100).

To assess model fit, we included standard fit indices, which included: the chi-square difference test ($\Delta\chi 2$) for nested models. Under the chi-square difference test, nested models are compared and significant differences on the chi-square suggest the more constrained model between the two models compared is a better fitting model. Furthermore, we used practical fit indices the Akaike Information Criterion (AIC) where the lowest possible values are preferred between nested models (Beal, 2007; Burnham & Anderson, 2003); and the Bayesian Information Criterion (BIC), again with lowest possible values being preferred (Beal, 2007; Raftery, 1995b). Full-information maximum-likelihood was used to account for missingness.

Results

Descriptive Statistics

Descriptives indicate that overall, the participants of this study are living in areas that are more urban than rural (IRRcounty M=0.25, SD=0.10; IRRtract M=.24, SD=0.10). Strong associations of IRRtract with IRRcounty were observed when examining Pearson correlation coefficients (r=0.66, p=<0.0001). The mean for FSIQ was 110.41 (SD=11.86), for VIQ was 107.43 (SD=11.52), and for PIQ was 112.64 (SD=13.45), indicating that overall this sample had higher scores on average and smaller standard deviations than expected (M=100, SD=15).

Qualitative activity engagement responses were available for a subset (N=978) of the participants who were tested through the 36th month of active data collection with 968 also having IRR data. Of these, 702 individuals reported that they engaged in hobbies at least one hour per week, but only 592 of these individuals provided a description. Using simple t-tests and chi-square comparisons, the individuals who did not provide a description of their hobbies (n=110) did not significantly differ on the covariates age, female, and project (all $p \geq .13$). Nor did these individuals differ on either IRR measure ($p \geq .73$) or on SCI ($p = .14$). But, as verified by a multi-level model which accounts for sibling structure, those 110 individuals who did not provide a description of their hobby tended to report fewer hours of hobby engagement (B= -0.64, SE=0.22, p=0.0034) that the 592 individuals who did describe their hobbies. Additionally, using multi-level models that accounted for the sibling structure, these 110 individuals had lower educational (B= -0.64, SE=0.29, p=0.03) and occupational attainment (B= -0.39, SE=0.16, p=0.02), and lower scores on all IQ measures (B range -2.02 to -3.80, SE range 1.0 – 1.24, $p \leq 0.04$).

IQ & Geospatial

Pearson correlation coefficients reported in Table 3.5 were partialed for sex, age, project, adopted status, race, Hispanic ethnicity, and siblings who live together resulting an N=1125 with complete data on all geospatial and IQ variables. Small but significant associations were observed for some measures of IQ with IRR at the county level (FSIQ r= -0.095, p =0.001; VIQ r= -0.11, p=.0004) and for VIQ with SCI (r =0.07, p =0.03) but no significant associations were observed for any measure of IQ and IRR at the tract level. Subsequent analytical models evaluating IQ and geospatial measures included IRR at the county level and social capital index only.

IQ & Activity Engagement

Pearson correlation coefficients reported in Table 3.5 were partialed for sex, age, project, adopted status, race, Hispanic ethnicity, and siblings who live together resulting in N=1130 with complete data on all quantitative measures of activity engagement (i.e. hours per week) and IQ variables. For the rated hobbies of those participating from the first 36 months of data collection, N=592 had complete data on qualitative ratings of activity engagement (i.e. cognitively rated hobbies), and IQ variables. Small positive associations were observed for some measures of IQ with hours per week social activity engagement (FSIQ r= .063, p =0.036; VIQ r= 0.072, p=.015), and for VIQ with hours per week on family activities (r =-0.067, p =0.026) but no significant associations were observed for any measure of IQ and hours per week on physical, or sedentary activities.

Hours per week on cognitive activities, cognitively rated hobbies and total number of cognitive hobbies were all small to moderately, positively correlated with all measures of IQ (*r* range = 0.11-0.27, *p* range = 0.007-<.0001). Subsequent analytical models evaluating IQ and activity engagement included hours per week on social, family, and cognitive activities as well as cognitively rated hobbies and total number of cognitive hobbies with IRR at the county level only.

IRR: evaluating non-linearity of associations

As some work has indicated possible U-shaped associations of cognitive functioning by extreme rurality and urbanicity (Wu, Prina, & Brayne, 2015; Wu, Prina, Jones, Matthews, et al., 2017), we explored whether the $IRRtract^2$ and $IRRcounty^2$ showed possible associations with IQ and other study variables. As shown in Table ST3.1, no IQ variables were associated with $IRRtract^2$ and $IRRcounty^2$, with and without adjustment for sociodemographics (i.e., age, sex, Hispanic, white, project, adopted). Moreover, few other study variables were significantly correlated and most fell in significance when adjusted for sociodemographics, apart from small associations with SCI which showed significant positive associations with $IRRtract^2$ ($r = 0.19$, $p<.0001$), as well as with $IRRcounty^2$ ($r = 0.24$, $p<.0001$), and hours per week on family activities with $IRRtract^2$ ($r = 0.07$, $p=.03$). We did not consider $IRRtract^2$ and $IRRcounty^2$ in further analyses.

1.1 Effects of IRRcounty on FSIQ

We further evaluated differences in FSIQ by examining IRRcounty as a predictor and evaluating the role of educational attainment and occupational attainment in that association. The baseline model (model 0) included only IRRcounty as the lone fixed effect predictor on Full Scale IQ (FSIQ). This model decomposed the within and between random effects by family type (e.g., zygosity type) to adjust for sibling dependencies. IRRcounty was not significant (B= -2.23, SE=2.90, p=.44) and ICCs calculated from the random effects were small to large with lower ICCs in siblings from adoptive families (.11) compared to control and twin siblings (control=.56, DZ=.51, MZ=.84; see supplemental Table ST3.2), suggesting that once accounting for family structure the associations between IRRcounty and FSIQ attenuated to non-significance. Next including demographic covariates for Model 1 (i.e. gender, age, project, adoption status, Hispanic and white ethnicity, and siblings living together) showed improved fit over Model 0 [$\Delta\chi2$ (7) =50, p=1.44E-08], but IRRcounty remained nonsignificant (B= -3.16, SE=2.87, p=.27). The ICCs were similar in range but with decreased similarity for control and twin siblings. Model 2 for FSIQ included years of education as an additional covariate which showed improved fit over Model 1 [$\Delta\chi2$ (1) =158.8, p=2.07E-36]. The parameter estimate for years of education was individually significant (B= 1.42, SE=0.11, p<.0001) whereas IRRcounty remained nonsignificant (B=.60, SE=2.74, p=.83) but showed notable reduction in the unstandardized effect size compared to Model 1 suggesting that years of education is associated with IRRcounty and mediates any association with FSIQ association. The ICCs were similar in range but with decreased similarity for all family types. Model 3 for FSIQ included occupational attainment as an additional covariate which was not individually significant (B= .36, SE=.20, p=.07) and did not show improved fit over Model 2 [$\Delta\chi2$ (1) =3.3, p=6.93E-02] (see Table 3.6). Parameter estimates for IRRcounty did not show notable change from Model 2 and remained nonsignificant (B= .82, SE=2.74, p=.77). The ICCs remained the same for all family types. Table 3.6 shows parameter estimates and fit statistics of the fully adjusted Model 3 for FSIQ.

1.2 Effects of IRRcounty on VIQ

Next, we evaluated differences in VIQ by examining IRRcounty as a predictor and evaluating the role of educational attainment and occupational attainment in that association. The baseline model (model 0) included only IRRcounty as the lone fixed effect predictor on Verbal IQ (VIQ). This model decomposed the within and between random effects by family type (e.g., zygosity type), to adjust for sibling dependencies. IRRcounty was not significant (B= -2.64, SE=2.81, p=.35) and ICCs calculated from the random effects were small to large with lower ICCs in siblings from adoptive families (.10) compared to control and twin siblings (control=.44, DZ=.58, MZ=.84; see supplemental Table ST3.2) suggesting that once accounting for family structure any association of IRR with VIQ is attenuated. Next including demographic covariates Model 1 showed improved fit over Model 0 [$\Delta\chi 2$ (7) =47.4, p=4.66E-08], but did not bring IRRcounty to significance (B= -3.67, SE=2.78, p=.19). The ICCs were similar in range but with slightly decreased similarity for control and twin siblings (see supplemental Table ST3.2). Model 2 for VIQ included years of education as an additional covariate which showed improved fit over Model 1 [$\Delta\chi 2$ (1) =192.3, p=1.00E-43]. Parameter estimates for years of education was individually significant (B= 1.50, SE=0.10, p<.0001) and IRRcounty showed notable change from Model 1 suggesting that years of education may mediate associations with IRRcounty (B= .32, SE=2.62, *p*=.90). The ICCs were similar in range but with decreased similarity for all family types (see supplemental Table ST3.2). Model 3 for VIQ included occupational attainment as an additional covariate which was not individually significant (B= .21, SE=.19, *p*=.27) and did not show improved fit over Model 2 [$\Delta\chi2$ (1) =1.2, *p*=2.73E-01] (see Table 3.6). Parameter estimates for IRRcounty did not show notable change from Model 2 (B= .38, SE=2.62, *p*=.89) and the ICCs were similar (see supplemental Table ST3.2). Table 3.6 shows parameter estimates and fit statistics of the fully adjusted Model 3 for VIQ.

2.1 Social and Family Activity Engagement and FSIQ/VIQ

Next, we evaluated activity engagement as a main effect on IQ, controlling for relevant covariates, in a multilevel model accounting for sibling structure. Although correlations in Table 3.5 suggested a small effect of hours per week on social activities and Full Scale IQ (*r*=.06*, p*=.04), when accounting for covariates in a baseline multilevel model, hours per week on social activities is not a significant predictor of FSIQ (B=.13, SE=.47, *p*=.78) suggesting no main effect of social activities on FSIQ. Similarly, although correlations suggested a small effect of hours per week on social activities and Verbal IQ (*r*=.07*, p*=.015), when accounting for covariates in the baseline model, hours per week on social activities is not a significant predictor of VIQ (B=.14, SE=.45, *p*=.76) suggesting no main effect of hours per week on social activities on VIQ. Additionally, correlations suggested small effects of hours per week on family activities and Verbal IQ (*r*=-0.07*, p*=0.026), when accounting for covariates however, hours per week on family activities is not a significant predictor of VIQ (B=-0.02, SE=.40, *p*=.96), suggesting no main effect of hours per week on family activities on VIQ. Since no significant main effects of hours per week on social and family activities on FSIQ & VIQ, no further models were tested to examine mediation or moderation pathways.

2.2 Cognitive Activity and FSIQ as mediated by Social Capital

To test for potential main effects of hours per week on cognitive activities on Full Scale IQ, a multilevel Model 0 adjusted for sociodemographic covariates prior to adding social capital. The results of Model 0 suggested a main effect of hours per week (ln transformed) on cognitive activities on FSIQ (B=3.18, SE=0.38, p<.0001). ICCs calculated from the random effects were small to moderate across all sibling types, ranging from 0.00 in adopted families, to 0.76 in MZ twins (see Supplemental Table ST3.2). Next, including social capital in the model as a potential mediator (Model 1) did not show improved fit over Model 0 [$\Delta\chi 2$ (1) =2.1, p=1.47E-01] (see Table 3.7), where hours per week on cognitive activities uniquely contributed to FSIQ (B=3.15, SE=0.38, p<.0001), but social capital did not (B=0.63, SE=0.43, p=0.14). Further, the main effect of hours per week on cognitive activities was slightly reduced in Model 1 when social capital was added suggesting little evidence of mediation.

2.3 Cognitive Activity and VIQ as mediated by Social Capital

To test for potential main effects of hours per week on cognitive activities on Verbal IQ, a multilevel Model 0 adjusted for sociodemographic covariates prior to the consideration of social capital. Model 0 suggested a main effect of hours per week on cognitive activities (ln transformed) on VIQ (B=2.98, SE=0.36, p<.0001). ICCs calculated from the random effects were small to moderate across all sibling types, ranging from 0.04 in adopted families, to 0.78 in MZ twins (see Supplemental Table ST3.2). Next, including social capital in the model as a potential mediator (Model 1) did not show improved fit over Model 0 [$\Delta\chi 2$ (1) =3.0, p=8.33E-02] (see Table 3.7). Hours per week on cognitive activities continued to uniquely contribute to VIQ (B=2.94, SE=0.36, p<.0001), but social capital did not reach significance (B=0.71, SE=0.41, p=0.08). Further, the main effect of hours per week on cognitive activities was slightly reduced in model 1 when social capital was added but the difference was very small suggesting little evidence of mediation. Interpreting the regression weight for cognitive engagement indicates that for each log unit of hours of engagement, nearly 3 points difference in VIQ was observed similar to FSIQ. The ICCs were generally consistent across sibling types after inclusion of social capital (see Supplemental Table ST3.2)

2.4 Cognitively-Rated Hobbies and FSIQ as mediated by Social Capital

To test for potential main effects of cognitively rated hobbies on Full Scale IQ, a multilevel Model 0 adjusted for sociodemographic covariates and total number of cognitive hobbies reported in the subsample of those tested up through 36 months, prior to adding social capital to the models. Model 0 suggested a main effect cognitively rated hobbies (ln transformed) on FSIQ (B=7.01, SE=1.69, p<.0001). ICCs calculated from the random effects were small to moderate across all sibling types, ranging from 0.08 in adopted families, to 0.69 in MZ twins (see Supplemental Table ST3.2). Next, including social capital in the model as a covariate (Model 1) did not show improved fit over Model 0 [$\Delta\chi 2$ (1) =1.8, p=1.80E-01] (see Table 3.8), where cognitively rated hobbies uniquely contributed to FSIQ (B=6.89, SE=1.69, p<.0001), but social capital did not (B=0.90, SE=0.68, *p*=0.19). Further, the main effect cognitively rated hobbies was slightly reduced in model 1 when social capital was added but the difference was very small which is not suggestive of evidence towards mediation. Interpreting the regression weight for cognitively-rated hobbies suggests that for each log unit increase cognitive demands a nearly 6 point difference in FSIQ is observed. The cognitively-rated hobbies variable was centered at .69 which is a raw equivalent of a 2, or "some cognitive demands"; hence, if the demands increased to a raw equivalent of a 3 or "moderate cognitive demands", the IQ difference would be 2.82 IQ points. The ICCs were generally consistent across sibling types after inclusion of social capital (see Supplemental Table ST3.2)

2.5 Cognitively-Rated Hobbies and VIQ as mediated by Social Capital

To test for potential main effects of cognitively rated hobbies on Verbal IQ, multilevel Model 0 adjusted for sociodemographic covariates and total number of cognitive hobbies reported in the subsample of those tested up through 36 months, prior to adding social capital to the models. Model 0 suggested a main effect of cognitively rated hobbies on VIQ (B=5.34, SE=1.69, *p*=0.001). ICCs calculated from the random effects were small to moderate across all sibling types, ranging from 0.03 in adopted families, to 0.73 in MZ twins (see Supplemental Table ST3.2). Next, including social capital in the model as a covariate (Model 1) did not show improved fit over Model 0 [$\Delta\chi 2$ (1) =2.6, *p*=1.07E-01] (see Table 3.8), where cognitively rated hobbies uniquely contributed to VIQ (B=5.18, SE=1.59, *p*=0.0015), but social capital did not (B=1.04, SE=0.64, *p*=0.11). Further, the main effect of cognitively rated hobbies was slightly reduced in model 1 when social capital was added but the difference was very small which is not suggestive of mediation. Interpreting the regression weight for cognitively-rated hobbies in Model 1 suggests that for each log unit increase cognitive demands about a 5 point difference in VIQ is observed. The cognitively-rated hobbies variable (ln transformed) was centered at .69 which is a raw equivalent of a 2, or “some cognitive demands”; hence, if the demands increased to a raw equivalent of a 3 or “moderate cognitive demands”, the IQ difference would be 2.11 IQ points. The ICCs were generally consistent across sibling types after inclusion of social capital (see Supplemental Table ST3.2).

3.1 Cognitive Activity, Social Capital and FSIQ by Index of Relative Rurality

To test for moderating effects of IRRcounty on the associations between activity engagement, social capital and Full Scale IQ, multilevel Model 1 adjusted for sociodemographic covariates and main effects prior to adding any interaction effects to the models. Table 3.9 shows fixed and random effects parameters of Model 1, where hours per week on cognitive activities was a significant contributor to FSIQ (B=3.16, SE=.38, $p<0.0001$) but social capital was not significant (B=.66, SE=.44, $p=0.13$), nor was IRRcounty (B=-1.13, SE=2.76, $p=0.68$). ICCs were small to moderate across all sibling types with lower ICCs in siblings from adoptive and DZ twins (0.00 and 0.35 respectively) compared to control and MZ twin siblings (0.44 and .76 respectively) (see Supplemental Table ST3.2). Next including the interaction term for hours per week on cognitive activities by IRRcounty (Model 2) was not significant individually (B=0.46, SE=3.99, $p=0.91$) and did not improve model fit [$\Delta\chi2$ (1) =0.0, $p=1.00$] (see Table 3.9), but hours per week on cognitive activities remained a significant contributor to FSIQ

(B=3.16, SE=.38, $p<0.0001$), while social capital (B=.66, SE=.44, $p=.13$) and IRRcounty (B= -1.86, SE=6.94, $p=.79$) remained nonsignificant. ICCs remained the same for all family types (see Supplemental Table ST3.2). Next, including the interaction term for social capital by IRRcounty (Model 3) significantly improved model fit [$\Delta\chi2$ (1) =13.4, $p=0.00$] (see Table 3.9), and was uniquely significant (B= -9.61, SE=2.62, $p=.0003$). Additionally, hours per week on cognitive activities remained significant (B= 3.23, SE=0.37, $p<0.0001$), and the main effect of social capital became significant (B= 1.02, SE=0.45, $p=0.0226$), but the main effect of IRRcounty remained non-significant (B= -3.25, SE=6.90, $p=.64$). ICCs remained essentially the same (see Supplemental Table ST3.2).

Figure 3.1 depicts the interaction between SCI and IRR for hours per week on cognitive activities on FSIQ. The main effect of hours per week on cognitive engagement is shown as well, comparing those who did not engage in weekly cognitive activities versus those engaging in five hours per week. To plot this interaction, SCI was varied while for IRR, urban areas were identified by -0.1 points below the centered IRRcounty value which is the equivalent of an IRR of 0.15 while rural areas were identified by +0.1 points above centered IRRcounty value which is the equivalent of an IRR of .35. For individuals living in more urban county (IRR=.15), if the area was relatively low in social capital (SCI = -1.81, 2SD below sample mean), about 2.8 fewer FSIQ points are observed for these individuals compared to those who are living in a more rural county (IRR=.35), with the same levels of social capital (SCI = -1.81) and the same amount of time spent on cognitive activities. For individuals who are living in a more urban area (IRR=.15) and the area is relatively high in social capital (SCI =.87, 2SD above sample mean), they evidence 2.3 more FSIQ points their more rural counterparts (IRR=.35) with the same level of social capital and engaging in the same amount of time on cognitive activities. Last, for those who in live in more urban county (IRR=.15) and but which varies in social capital (SCI = -1.81 vs SCI = .87) the difference is a detriment of 5.3 fewer points for those lower in social capital compared to their counterparts who live in more rural area (IRR=.15) where the difference due to lower social capital results in virtually no difference in FSIQ points. Altogether, the interaction suggests that social capital may play a greater role in the associations between cognitive activity engagement and FSIQ for individuals living in more urban areas than individuals living in more rural areas.

Models evaluating hours per week on cognitive activities and VIQ as mediated by social capital and moderated by IRR were similar to models for FSIQ but no moderation terms with IRR reached significance (results not shown).

3.2 Cognitively-rated Hobbies, Social Capital and FSIQ by Index of Relative Rurality

To test for moderating effects of IRRcounty on the associations between the cognitive demands of hobbies, social capital and Full Scale IQ, multilevel Model 1 adjusted for sociodemographic covariates and main effects prior to adding any interaction effects to the models. Table 3.10 shows fixed and random effects parameters of Model 1, where cognitively rated hobbies was a significant contributor to FSIQ (B=6.78, SE=1.70, p=0.0001) but social capital was not significant (B=.98, SE=.69, p=0.16), nor was IRRcounty (B=-2.11, SE=3.75, p=0.58). ICCs were small to large across all sibling types with lower ICCs in siblings from adoptive siblings (0.09) comparable for control siblings and DZ twins (0.34 and 0.33 respectively) and largest among MZ twins (.69; see Supplemental Table ST3.2). Next, including the interaction term for cognitively rated hobbies by IRRcounty (Model 2) was not significant individually (B=11.89, SE=15.15, *p*=0.43) and did not improve model fit [$\Delta\chi2$ (1) =0.6, *p*=4.39E-01] (see Table 3.10), but cognitively rated hobbies remained a significant contributor to FSIQ (B=6.76, SE=1.70, *p*=0.0001), but social capital (B=1.05, SE=.70, *p*=.13) and the IRRcounty main effect (B= -4.32, SE=4.73, *p*=.36) remained nonsignificant. ICCs remained the virtually the same (see Supplemental Table ST3.2). Next, including the interaction term for social capital by IRRcounty (Model 3) significantly improved model fit [$\Delta\chi2$ (1) =5.7, *p*=1.70E-02] (see Table 3.10), and was uniquely significant (B= -9.33, SE=3.85, *p*=.0167). Additionally, cognitively rated hobbies remained significant (B= 6.42, SE=1.70, *p*=0.0002), and the main effects for social capital became significant (B= 1.47, SE=0.71, *p*=0.0412), but the main effect for IRRcounty remained nonsignificant (B= -5.58, SE=4.73, *p*=.24). ICCs were similar in this model (see Supplemental Table ST3.2).

Figure 3.2 shows the interaction between social capital and IRR for cognitively rated hobbies on FSIQ. The main effect of the cognitive demands of hobbies is shown as well, comparing those who average rating was equivalent to “some demands” versus those whose average rating was “moderate demands’. For individuals living in more urban county (IRR=.15), if the area is relatively low in social capital (SCI = -1.81, 2SD below sample mean), about 2.3 fewer FSIQ points are observed for these individuals compared to those who are living in a more rural county (IRR=.35), with the same levels of social capital (SCI = -1.81) and the same amount of cognitive demands in their hobbies. For individuals who are living in a more urban area (IRR=.15) and the area is relatively high in social capital (SCI =.87, 2SD above sample mean), they evidence 2.7 more FSIQ points their more rural counterparts (IRR=.35) with the same level of social capital and amount of cognitive demands of their hobbies. Last, for those who in live in more urban county (IRR=.15) and but which varies in social capital (SCI = -1.81 vs SCI = .87) the difference is a detriment of 6.4 fewer points for those lower in social capital compared to counterparts who live in more rural area (IRR=.15) where the difference due to lower social capital results in a detriment of less than 1.4 FSIQ points. This interaction suggest that social capital may play a greater role in the associations between engagement in cognitively demanding hobbies and FSIQ for individuals living in more urban areas than individuals living in more rural areas.

Models evaluating cognitively rated hobbies and VIQ as mediated by social capital and moderated by IRR were similar to models for FSIQ but no moderation terms reached significance.

Discussion

The present study investigated how activity engagement and social capital influence cognitive performance in a sample approaching mid-life and how it differs across rural and urban residing individuals using the Index of Relative Rurality. Because prior research has only examined the associations between activity engagement and social capital, using categorical classifications of rural and urban, this is the first study to examine the geographic differences in these domains on a continuous scale of rurality.

Additionally, we evaluated differences in cognitive performance in the form of IQ, for rural and urban residing individuals while controlling for relevant covariates, such as educational attainment and occupational attainment. We expected to find that rural residing individuals would show lower cognitive performance scores than those in urban areas. Further, this study was the first to evaluate social capital as a possible mediator of activity engagement and cognitive performance, controlling for educational and occupational attainment. Lastly, this study expanded on the two prior questions by examining if the associations between activity engagement, as mediated by social capital, on cognitive performance differed for rural and urban residing individuals, i.e. testing that rurality was a moderator. We expected to find that the associations between activity engagement and cognitive performance as mediated by social capital would differ for rural and urban individuals.

Leveraging the continuous Index of Relative Rurality (IRR) partial correlations suggested possible albeit small geographic associations of IRR with cognitive ability as indexed by WAIS-III FSIQ and VIQ. Once accounting for sibling structure however, the association between IRR and both measures of IQ was no longer significant, which suggests that environmental selection may be a factor. Although prior work looking at older individuals (*M*age=65.44) has found evidence suggesting that there are geographic differences in cognitive performance with rural individuals having worse cognitive performance than urban residing individuals, only unrelated individuals were included and no adjustment for selection was made (Saenz et al., 2018). Future research should interpret geographic differences found in cognitive performance with caution, as some aspects of the association may be due to environmental selection and should be investigated further. In support, other work using a nationally representative, longitudinal dataset of more than 12,000 individuals in Add Health (age 24-32) has found that individuals with genotypes associated with higher educational attainment sort into neighborhoods where the other residents also have higher educational attainment as well as higher population densities (Laidley et al., 2019).

To evaluate the association between activity engagement on cognitive performance as mediated by social capital, this study utilized the Social Capital Index (SCI) (Northeast Regional Center for Rural Development, 2019; Rupasingha et al., 2006), which provided a county level measure of Social Capital. Results indicated that when controlling for sociodemographic variables, social capital did not mediate the relationship between any form of activity engagement and cognitive performance. Moreover, although correlations indicated possible associations between VIQ with hours per week spent on Social and Family activities, no main effects were observed for these associations once accounting for sociodemographic variables. However, main effects were observed for hours per week on cognitive activities as well as cognitively rated hobbies on both FSIQ and VIQ. Once testing for mediation while controlling for sociodemographic variables, hours per week on cognitive activities and cognitively rated hobbies were significant predictors of both FSIQ and VIQ but social capital was not a significant predictor of cognitive performance in any of the models suggesting that social capital does not mediate the relationship between activity engagement and cognitive performance. This finding addresses a hole in the literature whereby no prior research (to the best of our knowledge) has evaluated social capital as a mediator between activity engagement and cognitive performance. Better understanding the relationship between activity engagement and social capital may have implications for future studies which plan to evaluate the associations between social capital and activity engagement. Because areas with higher social capital have been found to have higher levels of social trust, stronger family ties, and greater community and neighborhood participation (Beaudoin & Thorson, 2004; Hofferth & Iceland, 1998; Onyx & Bullen, 2000; Sørensen, 2012), it seems reasonable to speculate that these qualities may provide an environment that fosters activity engagement in multiple domains. Further research is warranted to elucidate the association between social capital and activity engagement.

When examining if activity engagement, as mediated by social capital, would differ for rural and urban individuals, geographic differences were observed for hours per week spent on cognitive activities and cognitively rated hobbies on FSIQ when including IRR as a moderator, specifically the interaction between social capital and IRR in models. For individuals living in areas that are more rural, social capital alone does not mediate the relationship between hours per week spent on cognitive activities and Full Scale IQ. Results suggest that for individuals in rural counties, there is less than a one-point change in FSIQ when going from a county that is low in social capital to a county high in social capital. For individuals living in more urban areas, levels of social capital matter to whether detriments or advantages in IQ performance are observed: at high levels of social capital we can see slightly more than 5 higher FSIQ points advantage over those in a county with low social capital. Moreover, considering cognitive activity engagement, values in Figure 3.1 suggest that if an individual is living in an area that is more urban and higher on social capital, and engaging in no hours per week of cognitive activity, their FSIQ is similar to that of an individual in a rural area with higher social capital and who is engaging in 5 hours per week of cognitive activities. This indicates that county-level indexed social capital plays a more important role in mediating the relationship between hours per week on cognitive activities and FSIQ for urban residing individuals than it does for rural individuals. Similarly, social capital plays a more important role in mediating the relationship between cognitively demanding hobbies and FSIQ for urban residing individuals than it does for rural individuals.

With no prior literature to help with the interpretation of the interactions found between social capital and FSIQ in relation to cognitive activity engagement and having cognitively rated hobbies, we propose a possible interpretation. It could be that the cognitive performance for individuals in urban areas is affected by increased social capital more than it is for rural individuals due to the greater opportunity for engagement in cognitive activities or having cognitively rated hobbies that are related to social capital. For example, urban areas are likely to have greater availability of civic, social, and business associations, as well political and professional organizations all of which are associated with higher social capital (Rupasingha et al., 2006) and are cognitively stimulating activities (Stern & Munn, 2010; Verghese et al., 2003; Wang et al., 2002a; Wilson et al., 2002, 2007). What's more, there are findings that suggest that individuals with higher levels of educational attainment are more likely to reside in urban areas due to the better opportunities for employment (Saenz et al., 2018; Sanchez & Pacheco, 2012). In Putnam's 1995 publication, he notes that education is the strongest correlate with social trust and membership in a broader range of groups (Putnam, 1995). This finding has been confirmed by other studies that similarly suggest that education has large positive effects on the creation of trust among members of the community and engagement in civic activities (Alesina & La Ferrara, 2000; Glaeser et al., 2002), such as voting, volunteering or even community gardening. Moreover, higher educational attainment has been shown to be a delaying factor for dementia onset beyond genetic factors (Gatz et al., 2006). Additionally, there are findings that individuals who engage in cognitively stimulating activities are likely to have higher educational attainment and to engage in cognitively stimulating activities across the lifespan (Gatz et al., 2006; Wilson et al., 2013b). Factors such as educational and occupational attainment or socioeconomic inequality can accumulate (for better or worse) to affect cognition in later life (Gatz et al., 2006). It is possible that the combination of higher education, greater participation in cognitively stimulating activities and living in an urban environment increases the social capital in the area, which points to a possible environmental selection. As mentioned above, there is supportive findings from other work suggesting that individuals select into environments that are complementary to their genotypes (Laidley et al., 2019). It is important to consider however, that areas with higher social capital may lead to individuals with more opportunities to achieve higher education (Rupasingha et al., 2006), and possibly individuals who engage in more cognitively stimulating activities. With the wealth of literature, both domestic and internationally, showing that rural individuals typically show worse cognitive performance and greater incidence of dementia, it is surprising that we did not observe geographic differences in cognitive performance (Bae et al., 2015; Cahill et al., 2012; Cassarino & Setti, 2015; Contador et al., 2015; Letellier et al., 2020; McCall-Hosenfeld et al., 2014; Nunes et al., 2010; Russ et al., 2012; Georgi et al., 2019; Xiang et al., 2018). Our lack of findings with respect to geographic differences in cognitive performance could be because we evaluated a sample who are now approaching mid-life with still yet preserved cognitive functioning whereas prior studies (with the exception of Contador et al., 2015) evaluated geographic differences in cognitive performance and dementia risk in older individuals. Importantly, it has been shown that early life factors may accumulate to affect cognitive performance in later life (Cassarino & Setti, 2015; Contador et al., 2015; Gatz et al., 2006). Longitudinal analysis of geographic influences would inform whether and how early and mid-life environments affect later life cognitive performance.

The findings of this study may have implications for future research. Ecological theories of development pose that the individual's development is a product of the dynamic interplay between the individual and their environment (Bronfenbrenner, 1979; Bronfenbrenner & Ceci, 1994). As Cassarino & Setti (2015) detail, the environment may be a means for promoting cognitive health through environmental factors such as activity engagement, education, and even social capital. Alternatively, the environment may be a detriment to cognitive performance through neighborhood deprivation, cognitive stimulation overload, or social isolation (Cassarino & Setti, 2015). Moreover, the individuals who live in the most rural areas may be at a disadvantage because of the lack of cognitive stimulation often present in rural areas, whereas urban dwellers may have the opposite effects with extremely urban areas being overwhelming to cognitive stimulation (Wu, Prina, Jones, Barnes, et al., 2017; Wu, Prina, Jones, et al., 2015). This suggests a U-shaped relationship between cognition and rurality/urbanicity (Wu, Prina, Jones, Barnes, et al., 2017; Wu, Prina, Jones, et al., 2015). This study did evaluate the potential for non-linearity but found no non-linear associations with IRR and few other study variables. This study sheds light upon behavioral and environmental factors such as activity engagement and social capital, respectively, and cognition, and the importance of moderated associations with rurality. Moreover, selection effects, as index by adjusting for familial similarity, were evident which may attenuate the findings between place of residence and cognitive performance.

This study has limitations that should be addressed. A possible limitation of this study is that the sample has higher than average scores on measures of IQ although this sample does show a reasonable IQ distribution collectively. Additionally, this study was unable to estimate random effects for both family and geospatial clustering because of the large geographic spread outside of Colorado. In future work, this limitation will be addressed by analyzing a subset of the participants who reside with Colorado and thus have a smaller geographic spread. Additionally, this study did not show geographic differences with respect to the other activity domains. Further evaluation of individual activities rather than domains of activity may be more illuminating to geographic differences.

In conclusion, this study explored the relationship between geographic location and cognitive performance (measured as IQ). Our primary findings are three-fold that raise implications and unanswered questions that may benefit future inquiries. First, small associations of rurality and cognitive performance in this sample approaching midlife were observed but attenuated when accounting for sibling structure, suggesting that environmental selection may be a factor to consider in future work (Laidley et al., 2019). Secondly, social capital does not independently mediate the relationship between activity engagement and cognitive performance but rather rurality and social capital must be considered together whereby social capital may be more associated with cognitive performance for individuals in urban areas than for individuals living in rural areas. This implies that urban residing individuals may be at a detriment if they are residing in areas with lower social capital. Last, time spent in cognitive leisure activities or the level of cognitive demands in leisure-time hobbies emerged as a unique influence that did not depend on geography as indexed in the current study. Hence, our work illustrates that individual factors and socio-geographic environments matter and suggests that a fuller appreciation of person-environment dynamics is needed to understand geographic differences in cognitive performance.

References

Ainsworth, B. E., Haskell, W. L., Leon, A. S., Jacobs, D. R. J., Montoye, H. J., Sallis, J. F., & Paffenbarger, R. S. J. (1993). Compendium of Physical Activities: Classification of energy costs of human physical activities. *Medicine & Science in Sports & Exercise*, *25*(1), 71–80.

Aldrich, H., Zimmer, C., Sexton, D., & Smilor, R. (1986). The art and science of entrepreneurship. *Ballinger, Cambridge, MA*, 3–23.

Alesina, A., & La Ferrara, E. (2000). Participation in Heterogeneous Communities. *The Quarterly Journal of Economics*, *115*(3), 847–904. https://doi.org/10.1162/003355300554935

Annear, M., Keeling, S., Wilkinson, T., Cushman, G., Gidlow, B., & Hopkins, H. (2014). Environmental influences on healthy and active ageing: A systematic review. *Ageing & Society*, *34*(4), 590–622.

Aronson, R. E., & Oman, R. F. (2004). Views on Exercise and Physical Activity Among Rural-Dwelling Senior Citizens. *The Journal of Rural Health*, *20*(1), 76–79. https://doi.org/10.1111/j.1748-0361.2004.tb00010.x

Bae, J. B., Kim, Y. J., Han, J. W., Kim, T. H., Park, J. H., Lee, S. B., Lee, J. J., Jeong, H. G., Kim, J. L., Jhoo, J. H., Yoon, J. C., & Kim, K. W. (2015). Incidence of and Risk Factors for Alzheimer's Disease and Mild Cognitive Impairment in Korean Elderly. *Dementia and Geriatric Cognitive Disorders*, *39*(1–2), 105–115. https://doi.org/10.1159/000366555

Barnes, L. L., De Leon, C. M., Wilson, R. S., Bienias, J. L., & Evans, D. A. (2004). Social resources and cognitive decline in a population of older African Americans and whites. *Neurology*, *63*(12), 2322–2326.

Bassuk, S. S., Glass, T. A., & Berkman, L. F. (1999). Social disengagement and incident cognitive decline in community-dwelling elderly persons. *Annals of Internal Medicine*, *131*(3), 165–173.

Beal, D. J. (2007). Information criteria methods in SAS for multiple linear regression models. *15th Annual SouthEast SAS Users Group (SESUG) Proceedings, South Carolina, Paper SA05*.

Beaudoin, C. E., & Thorson, E. (2004). Social Capital in Rural and Urban Communities: Testing Differences in Media Effects and Models. *Journalism & Mass Communication Quarterly*, *81*(2), 378–399. https://doi.org/10.1177/107769900408100210

Bennett, D. A., Schneider, J. A., Tang, Y., Arnold, S. E., & Wilson, R. S. (2006). The effect of social networks on the relation between Alzheimer's disease pathology and level of cognitive function in old people: A longitudinal cohort study. *The Lancet Neurology*, *5*(5), 406–412.

Bot, S. D., Mackenbach, J. D., Nijpels, G., & Lakerveld, J. (2016). Association between Social Network Characteristics and Lifestyle Behaviours in Adults at Risk of Diabetes and Cardiovascular Disease. *PLOS ONE*, *11*(10), e0165041. https://doi.org/10.1371/journal.pone.0165041

Bronfenbrenner, U. (1979). *The Ecology of Human Development*. Harvard University Press.

Bronfenbrenner, U., & Ceci, S. J. (1994). Nature-nuture reconceptualized in developmental perspective: A bioecological model. *Psychological Review*, *101*(4), 568–586. https://doi.org/10.1037/0033-295X.101.4.568

Buffel, T., Phillipson, C., Scharf, T., Warburton, J., Ng, S. H., & Shardlow, S. M. (2012). Experiences of neighbourhood exclusion and inclusion among older people living in deprived inner-city areas in Belgium and England. *Ageing and Society*, *33*(1), 89.

Burnham, K. P., & Anderson, D. R. (2003). *Model selection and multimodel inference: A practical information-theoretic approach*. Springer Science & Business Media.

Cahill, S., O'Shea, E., & Pierce, M. (2012). *Creating excellence in dementia care: A research review for Ireland's national dementia strategy*.

Cassarino, M., & Setti, A. (2015). Environment as 'Brain Training': A review of geographical and physical environmental influences on cognitive ageing. *Ageing Research Reviews*, *23*, 167–182. https://doi.org/10.1016/j.arr.2015.06.003

Clarke, P. J., Ailshire, J. A., House, J. S., Morenoff, J. D., King, K., Melendez, R., & Langa, K. M. (2011). Cognitive function in the community setting: The neighbourhood as a source of 'cognitive reserve'? *Journal of Epidemiology & Community Health*, jech–2010.

Clarke, P. J., Ailshire, J. A., House, J. S., Morenoff, J. D., King, K., Melendez, R., & Langa, K. M. (2012). Cognitive function in the community setting: The neighbourhood as a source of 'cognitive reserve'? *J Epidemiol Community Health*, *66*(8), 730–736.

Cohen, S. A., Cook, S. K., Kelley, L., Foutz, J. D., & Sando, T. A. (2017). A Closer Look at Rural-Urban Health Disparities: Associations Between Obesity and Rurality Vary by Geospatial and Sociodemographic Factors. *The Journal of Rural Health*, *33*(2), 167–179.

Contador, I., Bermejo-Pareja, F., & Benito-Leon, V. P.-M. and J. (2015, May 1). *Childhood and Adulthood Rural Residence Increases the Risk of Dementia: NEDICES Study*. Current Alzheimer Research. https://www.eurekaselect.com/129746/article

De Carolis, D. M., Litzky, B. E., & Eddleston, K. A. (2009). Why Networks Enhance the Progress of New Venture Creation: The Influence of Social Capital and Cognition. *Entrepreneurship Theory and Practice*, *33*(2), 527–545. https://doi.org/10.1111/j.1540-6520.2009.00302.x

De Carolis, D. M., & Saparito, P. (2006). Social Capital, Cognition, and Entrepreneurial Opportunities: A Theoretical Framework. *Entrepreneurship Theory and Practice*, *30*(1), 41–56. https://doi.org/10.1111/j.1540-6520.2006.00109.x

Deng, Y., & Paul, D. R. (2018). The Relationships Between Depressive Symptoms, Functional Health Status, Physical Activity, and the Availability of Recreational Facilities: A Rural-Urban Comparison in Middle-Aged and Older Chinese Adults. *International Journal of Behavioral Medicine*, *25*(3), 322–330. https://doi.org/10.1007/s12529-018-9714-3

Ertel, K. A., Glymour, M. M., & Berkman, L. F. (2008). Effects of social integration on preserving memory function in a nationally representative US elderly population. *American Journal of Public Health*, *98*(7), 1215–1220.

Eyler, A. A., & Vest, J. R. (2002). Environmental and Policy Factors Related to Physical Activity in Rural White Women. *Women & Health*, *36*(2), 109–119. https://doi.org/10.1300/J013v36n02_08

Fischer, C. S. (1982). *To Dwell Among Friends: Personal Networks in Town and City*. University of Chicago Press.

Fors, S., Lennartsson, C., & Lundberg, O. (2009). Childhood living conditions, socioeconomic position in adulthood, and cognition in later life: Exploring the associations. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *64*(6), 750–757.

Gatz, M., Prescott, C. A., & Pedersen, N. L. (2006). Lifestyle risk and delaying factors. *Alzheimer Disease & Associated Disorders*, *20*, S84–S88.

Gavrila, D., Antunez, C., Tormo, M., Carles, R., Garcia Santos, J., Parrilla, G., Fortuna, L., Jiménez, J., Salmerón, D., & Navarro, C. (2009). Prevalence of dementia and cognitive impairment in Southeastern Spain: The Ariadna study. *Acta Neurologica Scandinavica*, *120*(5), 300–307.

Glaeser, E. L., Laibson, D., & Sacerdote, B. (2002). An economic approach to social capital. *The Economic Journal*, *112*(483), F437–F458.

Glymour, M. M., & Manly, J. J. (2008). Lifecourse social conditions and racial and ethnic patterns of cognitive aging. *Neuropsychology Review*, *18*(3), 223–254.

Haberstick, B. C., Zeiger, J. S., & Corley, R. P. (2014). Genetic and environmental influences on the allocation of adolescent leisure time activities. *BioMed Research International*, *2014*.

Henning-Smith, C., & Lahr, M. (2018). Rural-Urban Difference in Workplace Supports and Impacts for Employed Caregivers: Rural-Urban Differences in Employed Caregivers. *The Journal of Rural Health*, *0*, 1–9. https://doi.org/10.1111/jrh.12309

Hofferth, S. L., & Iceland, J. (1998). Social Capital in Rural and Urban Communities1. *Rural Sociology*, *63*(4), 574–598. https://doi.org/10.1111/j.1549-0831.1998.tb00693.x

Holtzman, R. E., Rebok, G. W., Saczynski, J. S., Kouzis, A. C., Wilcox Doyle, K., & Eaton, W. W. (2004). Social network characteristics and cognition in middle-aged and older adults. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *59*(6), P278–P284.

Inagami, S., Gao, S., Karimi, H., Shendge, M. M., Probst, J. C., & Stone, R. A. (2016). Adapting the Index of Relative Rurality (IRR) to Estimate Rurality at the ZIP Code Level: A Rural Classification System in Health Services Research: Adapting the Index of Relative Rurality. *The Journal of Rural Health*, *32*(2), 219–227. https://doi.org/10.1111/jrh.12148

Jefferson, A. L., Gibbons, L. E., Rentz, D. M., Carvalho, J. O., Manly, J., Bennett, D. A., & Jones, R. N. (2011). A life course model of cognitive activities, socioeconomic status, education, reading ability, and cognition. *Journal of the American Geriatrics Society*, *59*(8), 1403–1411.

Jessor, R., & Jessor, S. L. (1977). *Problem behavior and psychosocial development: A longitudinal study of youth.*

Karp, A., Paillard-Borg, S., Wang, H.-X., Silverstein, M., Winblad, B., & Fratiglioni, L. (2006). Mental, physical and social components in leisure activities equally contribute to decrease dementia risk. *Dementia and Geriatric Cognitive Disorders*, *21*(2), 65–73.

Kaufman, A. S., Raiford, S. E., & Coalson, D. L. (2015). *Intelligent Testing with the WISC-V*. John Wiley & Sons.

Kearns, A., & Parkinson, M. (2001). The Significance of Neighbourhood. *Urban Studies*, *38*(12), 2103–2110. https://doi.org/10.1080/00420980120087063

Keay, L., Jasti, S., Munoz, B., Turano, K. A., Munro, C. A., Duncan, D. D., Baldwin, K., Bandeen-Roche, K. J., Gower, E. W., & West, S. K. (2009). Urban and rural differences in older drivers' failure to stop at stop signs. *Accident Analysis & Prevention*, *41*(5), 995–1000.

Kelly, M. E., Duff, H., Kelly, S., McHugh Power, J. E., Brennan, S., Lawlor, B. A., & Loughrey, D. G. (2017). The impact of social activities, social networks, social support and social relationships on the cognitive functioning of healthy older adults: A systematic review. *Systematic Reviews*, *6*(1), 259. https://doi.org/10.1186/s13643-017-0632-2

Kerr, J., Rosenberg, D., & Frank, L. (2012). The role of the built environment in healthy aging: Community design, physical activity, and health among older adults. *Journal of Planning Literature*, *27*(1), 43–60.

Krueger, K. R., Wilson, R. S., Kamenetsky, J. M., Barnes, L. L., Bienias, J. L., & Bennett, D. A. (2009). Social engagement and cognitive function in old age. *Experimental Aging Research*, *35*(1), 45–60.

Kweon, B.-S., Sullivan, W. C., & Wiley, A. R. (1998). Green common spaces and the social integration of inner-city older adults. *Environment and Behavior*, *30*(6), 832–858.

Laidley, T., Vinneau, J., & Boardman, J. D. (2019). Individual and Social Genomic Contributions to Educational and Neighborhood Attainments: Geography, Selection, and Stratification in the United States. *Sociological Science*, *6*, 580–608. https://doi.org/10.15195/v6.a22

Lee, S., Kawachi, I., Berkman, L. F., & Grodstein, F. (2003). Education, other socioeconomic indicators, and cognitive function. *American Journal of Epidemiology*, *157*(8), 712–720.

Letellier, N., Carrière, I., Cadot, E., Berkman, L., Goldberg, M., Zins, M., & Berr, C. (2020). Individual and neighbourhood socioeconomic inequalities in cognitive impairment: Cross-sectional findings from the French CONSTANCES cohort. *BMJ Open*, *10*(3), e033751. https://doi.org/10.1136/bmjopen-2019-033751

Linnell, K. J., Caparos, S., de Fockert, J. W., & Davidoff, J. (2013). Urbanization decreases attentional engagement. *Journal of Experimental Psychology: Human Perception and Performance*, *39*(5), 1232.

Litwin, H., & Stoeckel, K. J. (2015). Social Network, Activity Participation, and Cognition: A Complex Relationship. *Research on Aging*, *38*(1), 76–97. https://doi.org/10.1177/0164027515581422

Liu, Y., Wang, R., Xiao, Y., Huang, B., Chen, H., & Li, Z. (2019). Exploring the linkage between greenness exposure and depression among Chinese people: Mediating roles of physical activity, stress and social cohesion and moderating role of urbanicity. *Health & Place*, *58*, 102168.

Lövdén, M., Bäckman, L., Lindenberger, U., Schaefer, S., & Schmiedek, F. (2010). A theoretical framework for the study of adult cognitive plasticity. *Psychological Bulletin*, *136*(4), 659.

Lövdén, M., Schellenbach, M., Grossman-Hutter, B., Krüger, A., & Lindenberger, U. (2005). Environmental topography and postural control demands shape aging-associated decrements in spatial navigation performance. *Psychology and Aging*, *20*(4), 683–694. https://doi.org/10.1037/0882-7974.20.4.683

Maas, J., Van Dillen, S. M., Verheij, R. A., & Groenewegen, P. P. (2009). Social contacts as a possible mechanism behind the relation between green space and health. *Health & Place*, *15*(2), 586–595.

McCall-Hosenfeld, J. S., Mukherjee, S., & Lehman, E. B. (2014). The Prevalence and Correlates of Lifetime Psychiatric Disorders and Trauma Exposures in Urban and Rural Settings: Results from the National Comorbidity Survey Replication (NCS-R). *PLoS ONE*, *9*(11), e112416. https://doi.org/10.1371/journal.pone.0112416

Michael, Y. L., & Yen, I. H. (2014). *Aging and place—Neighborhoods and health in a world growing older*. *26*(8), 1251–1260.

Moffat, S. D., & Resnick, S. M. (2002). Effects of age on virtual environment place navigation and allocentric cognitive mapping. *Behavioral Neuroscience*, *116*(5), 851.

Nahapiet, J., & Ghoshal, S. (1998). Social Capital, Intellectual Capital, and the Organizational Advantage. *The Academy of Management Review*, *23*(2), 242–266. JSTOR. https://doi.org/10.2307/259373

Northeast Regional Center for Rural Development, S. C. V. for 2014. (2019). *Social Capital Variables for 2014 (Northeast Regional Center for Rural Development)*. Northeast Regional Center for Rural Development (Penn State University). https://aese.psu.edu/nercrd/community/social-capital-resources/social-capital-variables-for-2014

Nunes, B., Silva, R. D., Cruz, V. T., Roriz, J. M., Pais, J., & Silva, M. C. (2010). Prevalence and pattern of cognitive impairment in rural and urban populations from Northern Portugal. *BMC Neurology*, *10*(1), 42. https://doi.org/10.1186/1471-2377-10-42

Onyx, J., & Bullen, P. (2000). Measuring Social Capital in Five Communities. *The Journal of Applied Behavioral Science*, *36*(1), 23–42. https://doi.org/10.1177/0021886300361002

Paluska, S. A., & Schwenk, T. L. (2000). Physical activity and mental health. *Sports Medicine*, *29*(3), 167–180.

Parks, S. E., Housemann, R. A., & Brownson, R. C. (2003). Differential correlates of physical activity in urban and rural adults of various socioeconomic backgrounds in the United States. *Journal of Epidemiology & Community Health*, *57*(1), 29–35. https://doi.org/10.1136/jech.57.1.29

Patterson, P. D., Moore, C. G., Probst, J. C., & Shinogle, J. A. (2004). Obesity and Physical Inactivity in Rural America. *The Journal of Rural Health*, *20*(2), 151–159. https://doi.org/10.1111/j.1748-0361.2004.tb00022.x

Petrou, S., & Kupek, E. (2008). Social capital and its relationship with measures of health status: Evidence from the Health Survey for England 2003. *Health Economics*, *17*(1), 127–143. https://doi.org/10.1002/hec.1242

Pinillos-Franco, S., & Kawachi, I. (2018). The relationship between social capital and self-rated health: A gendered analysis of 17 European countries. *Social Science & Medicine*, *219*, 30–35. https://doi.org/10.1016/j.socscimed.2018.10.010

Plomin, R., & DeFries, J. C. (1983). The Colorado adoption project. *Child Development*, 276–289.

Putnam, R. D. (1995). Tuning in, tuning out: The strange disappearance of social capital in America. *PS: Political Science & Politics*, *28*(4), 664–683.

Putnam, R. D. (2000). Bowling alone: The Collapse and Revival of American Community. In *Bowling alone: The Collapse and Revival of American Community*. Simon & Schuster.

Raftery, A. E. (1995). Bayesian Model Selection in Social Research. *Sociological Methodology*, *25*, 111–163. JSTOR. https://doi.org/10.2307/271063

Reeves, D., Blickem, C., Vassilev, I., Brooks, H., Kennedy, A., Richardson, G., & Rogers, A. (2014). The Contribution of Social Networks to the Health and Self-Management of Patients with Long-Term Conditions: A Longitudinal Study. *PLOS ONE*, *9*(6), e98340. https://doi.org/10.1371/journal.pone.0098340

Rhea, S.-A., Bricker, J. B., Wadsworth, S. J., & Corley, R. P. (2013). The Colorado Adoption Project. *Twin Research and Human Genetics: The Official Journal of the International Society for Twin Studies*, *16*(1), 358–365. https://doi.org/10.1017/thg.2012.109

Rupasingha, A., Goetz, S. J., & Freshwater, D. (2006). The production of social capital in US counties. *The Journal of Socio-Economics*, *35*(1), 83–101. https://doi.org/doi:10.1016/j.socec.2005.11.001

Russ, T. C., Batty, G. D., Hearnshaw, G. F., Fenton, C., & Starr, J. M. (2012). Geographical variation in dementia: Systematic review with meta-analysis. *International Journal of Epidemiology*, *41*(4), 1012–1032. https://doi.org/10.1093/ije/dys103

Saenz, J. L., Downer, B., Garcia, M. A., & Wong, R. (2018). Cognition and Context: Rural–Urban Differences in Cognitive Aging Among Older Mexican Adults. *Journal of Aging and Health*, *30*(6), 965–986. https://doi.org/10.1177/0898264317703560

Sallis, J. F., Bowles, H. R., Bauman, A., Ainsworth, B. E., Bull, F. C., Craig, C. L., Sjöström, M., De Bourdeaudhuij, I., Lefevre, J., Matsudo, V., Matsudo, S., Macfarlane, D. J., Gomez, L. F., Inoue, S., Murase, N., Volbekiene, V., McLean, G., Carr, H., Heggebo, L. K., … Bergman, P. (2009). Neighborhood Environments and Physical Activity Among Adults in 11 Countries. *American Journal of Preventive Medicine*, *36*(6), 484–490. https://doi.org/10.1016/j.amepre.2009.01.031

Salthouse, T. A., Berish, D. E., & Miles, J. D. (2002). The role of cognitive stimulation on the relations between age and cognitive functioning. *Psychology and Aging*, *17*(4), 548–557. https://doi.org/10.1037/0882-7974.17.4.548

Salvo, G., Lashewicz, B. M., Doyle-Baker, P. K., & McCormack, G. R. (2018). Neighbourhood Built Environment Influences on Physical Activity among Adults: A Systematized Review of Qualitative Evidence. *International Journal of Environmental Research and Public Health*, *15*(5), 897. https://doi.org/10.3390/ijerph15050897

Sampaio, P. Y. S., Ito, E., & Carvalho Sampaio, R. A. (2013). The association of activity and participation with quality of life between Japanese older adults living in rural and urban areas. *Journal of Clinical Gerontology and Geriatrics*, *4*(2), 51–56. https://doi.org/10.1016/j.jcgg.2012.11.004

Sanchez, L., & Pacheco, E. (2012). Rural Population Trends in Mexico: Demographic and Labor Changes. In L. J. Kulcsár & K. J. Curtis (Eds.), *International Handbook of Rural Demography* (pp. 155–168). Springer Netherlands. https://doi.org/10.1007/978-94-007-1842-5_12

Sanderson, B., Littleton, M., & Pulley, L. V. (2002). Environmental, Policy, and Cultural Factors Related to Physical Activity Among Rural, African American Women. *Women & Health*, *36*(2), 73–88. https://doi.org/10.1300/J013v36n02_06

Scarmeas, N., Levy, G., Tang, M.-X., Manly, J., & Stern, Y. (2001). Influence of leisure activity on the incidence of Alzheimer's disease. *Neurology*, *57*(12), 2236–2242.

Singh-Manoux, A., Richards, M., & Marmot, M. (2005). Socioeconomic position across the lifecourse: How does it relate to cognitive function in mid-life? *Annals of Epidemiology*, *15*(8), 572–578. https://doi.org/10.1016/j.annepidem.2004.10.007

Sofi, F., Valecchi, D., Bacci, D., Abbate, R., Gensini, G. F., Casini, A., & Macchi, C. (2011). Physical activity and risk of cognitive decline: A meta-analysis of prospective studies. *Journal of Internal Medicine*, *269*(1), 107–117.

Sørensen, J. F. L. (2012). Testing the Hypothesis of Higher Social Capital in Rural Areas: The Case of Denmark. *Regional Studies*, *46*(7), 873–891. https://doi.org/10.1080/00343404.2012.669471

Sørensen, J. F. L. (2016). Rural–Urban Differences in Bonding and Bridging Social Capital. *Regional Studies*, *50*(3), 391–410. https://doi.org/10.1080/00343404.2014.918945

Stepankova Georgi, H., Frydrychova, Z., Horakova Vlckova, K., Vidovicova, L., Sulc, Z., & Lukavsky, J. (2019). Young-Old City-Dwellers Outperform Village Counterparts in Attention and Verbal Control Tasks. *Frontiers in Psychology*, *10*, 1224. https://doi.org/10.3389/fpsyg.2019.01224

Stern, C., & Munn, Z. (2010). Cognitive leisure activities and their role in preventing dementia: A systematic review. *International Journal of Evidence-Based Healthcare*, *8*(1), 2–17. https://doi.org/10.1111/j.1744-1609.2010.00150.x

Trivedi, T., Liu, J., Probst, J., Merchant, A., Jones, S., & Martin, A. (2015). Obesity and obesity-related behaviors among rural and urban adults in the USA. *Rural Remote Health*, *15*(4), 11.

Tulin, M., Lancee, B., & Volker, B. (2018). Personality and Social Capital. *Social Psychology Quarterly*, *81*(4), 295–318. https://doi.org/10.1177/0190272518804533

Van Cauwenberg, J., De Bourdeaudhuij, I., De Meester, F., Van Dyck, D., Salmon, J., Clarys, P., & Deforche, B. (2011). Relationship between the physical environment and physical activity in older adults: A systematic review. *Health & Place*, *17*(2), 458–469.

Van der Linden, J., Drukker, M., Gunther, N., Feron, F., & Van Os, J. (2003). Children's mental health service use, neighbourhood socioeconomic deprivation, and social capital. *Social Psychiatry and Psychiatric Epidemiology*, *38*(9), 507–514. https://doi.org/10.1007/s00127-003-0665-9

Verghese, J., Lipton, R. B., Katz, M. J., Hall, C. B., Derby, C. A., Kuslansky, G., Ambrose, A. F., Sliwinski, M., & Buschke, H. (2003). Leisure activities and the risk of dementia in the elderly. *New England Journal of Medicine*, *348*(25), 2508–2516.

Vogelsang, E. M. (2016). Older adult social participation and its relationship with health: Rural-urban differences. *Health & Place*, *42*, 111–119. https://doi.org/10.1016/j.healthplace.2016.09.010

Wadsworth, S. J., Corley, R. P., Munoz, E., Trubenstein, B. P., Knaap, E., DeFries, J. C., Plomin, R., Reynolds, C. A., & The CATSLife Team. (2019a). CATSLife: A Study of Lifespan Behavioral Development and Cognitive Functioning. *Twin Research and Human Genetics*, *22*(6), 695–706. https://doi.org/10.1017/thg.2019.49

Wadsworth, S. J., Corley, R. P., Munoz, E., Trubenstein, B. P., Knaap, E., DeFries, J. C., Plomin, R., Reynolds, C. A., & The CATSLife Team. (2019b). CATSLife: A Study of Lifespan Behavioral Development and Cognitive Functioning – Corrigendum. *Twin Research and Human Genetics*, *22*(6), 829–829. https://doi.org/10.1017/thg.2019.126

Waldorf, B. (2006). *A Continuous Multi-Dimensional Measure of Rurality: Moving Beyond Threshold Measures*. Selected Paper, Annual Meetings of the Association of Agricultural Economics, Long Beach, CA, July 2006.

Waldorf, B., & Ayoung, K. (2015). *Defining And Measuring Rurality in the US: From Typologies to Continuous Indices*. 26. https://doi.org/doi:10.4231/R7959FS8

Wang, H.-X., Karp, A., Winblad, B., & Fratiglioni, L. (2002). Late-life engagement in social and leisure activities is associated with a decreased risk of dementia: A longitudinal study from the Kungsholmen project. *American Journal of Epidemiology*, *155*(12), 1081–1087.

Wechsler, D. (1997). WAIS-III administration and scoring manual. San Antonio, TX: The Psychological Corporation.

Weden, M. M., Shih, R. A., Kabeto, M. U., & Langa, K. M. (2018). Secular Trends in Dementia and Cognitive Impairment of U.S. Rural and Urban Older Adults. *American Journal of Preventive Medicine*, *54*(2), 164–172. https://doi.org/10.1016/j.amepre.2017.10.021

Wilcox, S., Castro, C., King, A., Housemann, R., & Brownson, R. (2000). Determinants of leisure time physical activity in rural compared with urban older and ethnically diverse women in the United States. *Journal of Epidemiology & Community Health*, *54*(9), 667–672. https://doi.org/10.1136/jech.54.9.667

Wilson, J., & Musick, M. (1997). Who cares? Toward an integrated theory of volunteer work. *American Sociological Review*, *62*, 694–713. https://doi.org/10.2307/2657355

Wilson, R., Bennett, D., Bienias, J., Aggarwal, N., De Leon, C. M., Morris, M., Schneider, J., & Evans, D. (2002). Cognitive activity and incident AD in a population-based sample of older persons. *Neurology*, *59*(12), 1910–1914.

Wilson, R. S., Boyle, P. A., Yu, L., Barnes, L. L., Schneider, J. A., & Bennett, D. A. (2013). Life-span cognitive activity, neuropathologic burden, and cognitive aging. *Neurology*, *81*(4), 314–321. https://doi.org/10.1212/WNL.0b013e31829c5e8a

Wilson, R., Scherr, P., Schneider, J., Tang, Y., & Bennett, D. (2007). Relation of cognitive activity to risk of developing Alzheimer disease. *Neurology*, *69*(20), 1911–1920.

Wu, Y.-T., Prina, A. M., & Brayne, C. (2015). The association between community environment and cognitive function: A systematic review. *Social Psychiatry and Psychiatric Epidemiology*, *50*(3), 351–362. https://doi.org/10.1007/s00127-014-0945-6

Wu, Y.-T., Prina, A. M., Jones, A., Barnes, L. E., Matthews, F. E., & Brayne, C. (2017). Micro-scale environment and mental health in later life: Results from the Cognitive Function and Ageing Study II (CFAS II). *Journal of Affective Disorders*, *218*, 359–364. https://doi.org/10.1016/j.jad.2017.05.001

Wu, Y.-T., Prina, A. M., Jones, A., Matthews, F. E., & Brayne, C. (2017). The Built Environment and Cognitive Disorders: Results From the Cognitive Function and Ageing Study II. *American Journal of Preventive Medicine*, *53*(1), 25–32. https://doi.org/10.1016/j.amepre.2016.11.020

Wu, Y.-T., Prina, A. M., Jones, A. P., Barnes, L. E., Matthews, F. E., & Brayne, C. (2015). Community environment, cognitive impairment and dementia in later life: Results from the Cognitive Function and Ageing Study. *Age and Ageing*, *44*(6), 1005–1011.

Xiang, Y., Zare, H., Guan, C., & Gaskin, D. (2018). The impact of rural-urban community settings on cognitive decline: Results from a nationally-representative sample of seniors in China. *BMC Geriatrics*, *18*(1), 323. https://doi.org/10.1186/s12877-018-1003-0

Yang, T.-C., Jensen, L., & Haran, M. (2011). Social capital and human mortality: Explaining the rural paradox with county-level mortality data. *Rural Sociology*, *76*(3), 347–374. https://doi.org/10.1111/j.1549-0831.2011.00055.x

Ziersch, A. M., Baum, F., Darmawan, I. G. N., Kavanagh, A. M., & Bentley, R. J. (2009). Social capital and health in rural and urban communities in South Australia. *Australian and New Zealand Journal of Public Health*, *33*(1), 7–16. https://doi.org/10.1111/j.1753-6405.2009.00332.x

Table 3.1: Sociodemographic Descriptive Statistics

	N	*Range*	*Min*	*Max*	*Mean*	*SD*	*Var.*
Age	1139	21.28	28.06	49.33	33.03	4.91	24.15
CAP	493	18.32	31.01	49.33	38.00	3.22	10.35
LTS	646	5.85	28.06	33.91	29.23	1.15	1.31
Gender	1139	1	0	1	0.54	0.50	0.25
CAP	493	1	0	1	0.52	0.50	0.25
LTS	646	1	0	1	0.54	0.50	0.25
White	1139	1	0	1	0.92	0.27	0.07
CAP	493	1	0	1	0.93	0.26	0.07
LTS	646	1	0	1	0.92	0.28	0.08
Hispanic	1139	1	0	1	0.06	0.24	0.06
CAP	493	1	0	1	0.01	0.09	0.01
LTS	646	1	0	1	0.10	0.30	0.09
Educational Attainment	1130	11	11	22	16.82	2.97	8.82
CAP	492	11	11	22	17.11	2.92	8.55
LTS	638	11	11	22	16.60	2.99	8.93
Occupational Attainment	1120	6	2	8	5.94	1.54	2.37
CAP	489	6	2	8	6.19	1.4	2.09
LTS	631	6	2	8	5.76	1.59	2.52

Note: Values are showing those participants who had IRR scores. CAP=Colorado Adoption Project; LTS=Longitudinal Twin Study. Gender (male=0, female=1), White (no=0, yes=1), Hispanic (no=0, yes=1). N's reflect those with IRR scores.

Table 3.2: Descriptive Statistics of IQ

	N	*Range*	*Min*	*Max*	*Mean*	*SD*	*Var.*
FSIQ	1125	79	69	148	110.41	11.86	140.57
VIQ	1125	72	70	142	107.43	11.52	132.69
PIQ	1125	87	68	155	112.64	13.45	181.01

Note: N's reflect those with IRR scores. FSIQ = Full Scale IQ; VIQ = Verbal IQ; PIQ = Performance IQ.

Table 3.3: Descriptive Statistics of Activity Engagement

	N	*Range*	*Min*	*Max*	*Mean*	*SD*	*Var.*
HPW Social	1127	25	0	25	6.77	4.00	15.97
HPW Social (LN)	1127	3.26	0	3.26	1.91	0.57	0.33
HPW Family	1127	24	0	24	10.78	7.07	49.94
HPW Family (LN)	1127	3.22	0	3.22	2.26	0.68	0.47
HPW Physical	1127	32	0	32	6.54	4.74	22.50
HPW Physical (LN)	1127	3.50	0	3.50	1.78	0.76	0.57
HPW Sedentary	1127	32	0	32	11.88	5.86	34.29
HPW Sedentary (LN)	1127	3.50	0	3.50	2.44	0.52	0.27
HPW Cognitive	1127	24	0	24	4.65	3.78	14.32
HPW Cognitive (LN)	1127	3.22	0	3.22	1.50	0.72	0.52
Cognitively-Rated Hobbies	592	3.41	1.59	5	2.57	0.64	0.42
Cognitively-Rated Hobbies (LN)	592	1.15	0.46	1.61	0.91	0.23	0.05
N Cognitive Hobbies	592	11	1	12	2.20	1.48	2.18
N Cognitive Hobbies (LN)	592	1.87	0.69	2.57	1.08	0.40	0.17

Note: N's reflect those with IRR scores. HPW = hours per week. LN = natural log transformed after adding 1.

Table 3.4: Descriptive Statistics of Geographic Measures

	N	*Mean*	*SD*	*Min*	*Max*	*Range*	*Var.*
IRRtract	1139	0.24	0.10	0.05	0.80	0.75	0.01
IRRcounty	1139	0.25	0.10	0.06	0.79	0.73	0.01
Social Capital Index (SCI)	1139	-0.47	0.67	-2.42	3.34	5.76	0.45

Note: N's reflect those with IRR scores. IRR = Index of Relative Rurality

Table 3.5: Pearson Partial Correlation Coefficients of IQ with geospatial and activity engagement.

		FSIQ	VIQ	PIQ
FSIQ		1		
N=1125	*p*	--		
VIQ		**0.903**	1	
N=1125	*p*	<.0001	--	
PIQ		**0.858**	**0.564**	1
N=1125	*p*	<.0001	<.0001	--
		FSIQ	**VIQ**	**PIQ**
IRRtract		-0.026	-0.033	-0.008
N=1125	*p*	0.386	0.268	0.797
IRRcounty		**-0.095**	**-0.106**	*-0.057*
N=1125	*p*	0.001	0.000	0.056
SCI		*0.056*	**0.066**	0.023
N=1125	*p*	0.061	0.026	0.448
HPW Social (LN)		**0.063**	**0.072**	0.036
N=1130	*p*	0.036	0.015	0.230
HPW Physical (LN)		-0.020	-0.029	-0.003
N=1130	*p*	0.500	0.324	0.909
HPW Family (LN)		-0.034	**-0.067**	0.016
N=1130	*p*	0.255	0.026	0.586
HPW Sedentary (LN)		0.003	0.008	0.001
N=1130	*p*	0.915	0.777	0.963
HPW Cognitive (LN)		**0.269**	**0.265**	**0.198**
N=1130	*p*	<.0001	<.0001	<.0001
Cognitively Rated Hobbies (LN)		**0.131**	**0.111**	**0.110**
N=592	*p*	0.002	0.007	0.007
N Cognitive Hobbies (LN)		**0.203**	**0.214**	**0.142**
N=966	*p*	<.0001	<.0001	<.0001

Note. FSIQ = Full Scale IQ; VIQ = Verbal IQ; PIQ = Performance IQ; IRR = Index of Relative Rurality; SCI=Social Capital Index; LN = natural log transformed after adding 1. HPW=Hours per week. Partialed for female (male=0, female=1), age, project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), Hispanic (0=non-Hispanic, 1=Hispanic), White (0=non-White, 1=White). Bolded correlations are $p < .05$; italicized correlations are $p < .10$.

Table 3.6: IRRcounty & IQ Multilevel models with random effects for siblings.

	Model 3 - FSIQ		Model 3 - VIQ	
	B	**se**	**B**	**se**
Fixed Effects				
Intercept	**112.57**	1.57	**110.94**	1.52
IRRcounty	0.82	2.74	0.38	2.62
Female	**-2.64**	0.69	**-3.64**	0.66
Centered Age	-0.02	0.14	0.06	0.13
Project	**3.71**	1.48	0.85	1.38
Adoption Status	**-3.20**	1.08	**-3.30**	0.99
Hispanic	-2.65	1.75	-2.46	1.74
White	0.12	1.37	0.63	1.32
Living Together	-2.46	1.70	-1.10	1.70
Educational Attainment	**1.33**	0.12	**1.45**	0.11
Occupational Attainment	*0.36*	0.20	0.21	0.19
Random Effects				
σ^2_{BW} Adopted	1.98	12.63	5.41	11.34
σ^2_{BW} Control	**46.08**	14.37	**33.57**	10.07
σ^2_{BW} DZ	**36.60**	9.23	**46.08**	9.30
σ^2_{BW} MZ	**75.91**	9.82	**76.27**	9.76
σ^2_{WI} Adopted	**119.88**	16.68	**99.32**	14.21
σ^2_{WI} Control	**63.26**	11.00	**53.49**	8.37
σ^2_{WI} DZ	**65.26**	7.95	**54.65**	6.68
σ^2_{WI} MZ	**21.37**	2.57	**21.24**	2.54
Model Fit	**Model 3 - FSIQ**		**Model 3 - VIQ**	
-2 Log Likelihood	8113.6		8008.0	
AIC	8151.6		8046.0	
BIC	8237.0		8131.4	
$\Delta\chi^2$ (Model 2 vs Model 3)	3.3		1.2	
df	1		1	
p	6.93E-02		2.73E-01	
N individuals	1105		1105	
N sibships	663		663	

Note. Adjusted for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), Hispanic (0=non-Hispanic, 1=Hispanic) and White (0=non-White, 1=White), Living Together (0=no, 1=yes). Educational attainment was centered on the equivalent of a bachelor's degree. Occupational attainment was centered on 6 (semi-professional). FSIQ = Full Scale IQ; VIQ = Verbal IQ. Bolded parameters are significant $p < .05$; italicized parameters are $p < .10$.

Table 3.7: Cognitive Activity Engagement & IQ Multilevel models with random effects for siblings.

	Model 1 - FSIQ		**Model 1 - VIQ**	
	B	**se**	**B**	**se**
Fixed Effects				
Intercept	**108.70**	1.62	**107.34**	1.56
Female	**-2.37**	0.66	**-3.34**	0.64
Centered Age	0.02	0.14	0.09	0.13
Project	**3.12**	1.44	0.31	1.33
Adoption Status	**-2.76**	1.04	**-2.92**	0.95
Hispanic	-2.65	1.69	-2.42	1.69
White	-0.47	1.32	0.10	1.28
Living Together	*-2.97*	1.64	-1.66	1.65
Educational Attainment	**1.31**	0.11	**1.41**	0.11
Occupational Complexity	*0.34*	0.19	0.24	0.18
HPW Cognitive	**3.15**	0.38	**2.94**	0.36
Social Capital	0.63	0.43	*0.71*	0.41
Random Effects				
σ^2_{BW} Adopted	0.00	.	4.05	9.96
σ^2_{BW} Control	**46.01**	13.45	**30.09**	9.37
σ^2_{BW} DZ	**32.33**	8.47	**40.98**	8.52
σ^2_{BW} MZ	**71.47**	9.38	**75.03**	9.62
σ^2_{WI} Adopted	**109.08**	10.23	**89.86**	12.73
σ^2_{WI} Control	**59.43**	10.14	**51.24**	7.97
σ^2_{WI} DZ	**60.34**	7.37	**50.99**	6.24
σ^2_{WI} MZ	**21.87**	2.65	**21.05**	2.55
Model Fit	**Model 1 - FSIQ**		**Model 1 - VIQ**	
-2 Log Likelihood	8018.4		7910.8	
AIC	8056.4		7950.8	
BIC	8141.8		8040.7	
$\Delta\chi^2$	2.1		3.0	
df	1		1	
p	1.47E-01		8.33E-02	
N individuals	1101		1101	
N sibships	662		662	

Note. Adjusted for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), Partnered (0=single, 1=partnered), Hispanic (0=non-Hispanic, 1=Hispanic) and White (0=non-White, 1=White). Educational attainment was centered on the equivalent of a bachelor's degree. Occupational attainment was centered on the equivalent of semi-professional. FSIQ = Full Scale IQ; VIQ = Verbal IQ. Bolded parameters are significant $p < .05$; italicized parameters are $p < .10$.

Table 3.8: Cognitively-rated Hobbies & IQ Multilevel models with random effects for siblings.

	Model 1 - FSIQ		Model 1 – VIQ	
	B	se	B	se
Fixed Effects				
Intercept	**111.51**	2.31	**110.30**	2.26
Female	**-3.18**	0.88	**-4.42**	0.85
Centered Age	-0.04	0.20	0.08	0.19
Project	**4.69**	1.93	1.40	1.79
Adoption Status	**-2.87**	1.43	**-2.77**	1.33
Hispanic	-0.15	2.11	0.18	2.12
White	0.77	1.98	1.28	1.95
Living Together	**-4.63**	2.14	-2.81	2.14
Educational Attainment	**1.31**	0.16	**1.44**	0.15
Occupational Complexity	0.34	0.29	0.30	0.27
Cognitive Rated Hobbies	**6.89**	1.69	**5.18**	1.60
Number Cognitive Hobbies	**3.00**	0.93	**4.37**	0.87
Social Capital	0.90	0.68	1.04	0.64
Random Effects				
σ^2_{BW} Adopted	9.73	21.92	3.67	19.90
σ^2_{BW} Control	*36.29*	25.42	**24.35**	14.36
σ^2_{BW} DZ	**31.19**	12.36	**45.28**	12.77
σ^2_{BW} MZ	**55.14**	10.57	**58.23**	10.36
σ^2_{WI} Adopted	**93.36**	24.36	**90.20**	23.04
σ^2_{WI} Control	**71.28**	22.16	**58.05**	13.76
σ^2_{WI} DZ	**63.26**	11.42	**51.63**	9.71
σ^2_{WI} MZ	**24.87**	4.90	**20.80**	4.11
Model Fit	**Model 1 - FSIQ**		**Model 1 - VIQ**	
-2 Log Likelihood	4249.8		4191.9	
AIC	4291.8		4233.9	
BIC	4376.7		4318.7	
$\Delta\chi^2$	1.8		2.6	
df	1		1	
p	1.80E-01		1.07E-01	
N individuals	581		581	
N sibships	420		420	

Note. Adjusted for female (male=0, female=1), age (centered at age 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), Partnered (0=single, 1=partnered), Hispanic (0=non-Hispanic, 1=Hispanic) and White (0=non-White, 1=White). Educational attainment was centered 18 years (bachelor's degree). Occupational attainment centered on (semi-professional). FSIQ = Full Scale IQ; VIQ = Verbal IQ. Bolded parameters are significant $p < .05$; italicized parameters are $p < .10$.

Table 3.9: HPW Cognitive Activity & FSIQ Multilevel models with random effects for siblings.

	Model 1		Model 2		Model 3	
	B	**se**	**B**	**se**	**B**	**se**
Fixed Effects						
Intercept	**108.70**	1.62	**108.70**	1.62	**108.58**	1.61
Female	**-2.36**	0.66	**-2.36**	0.66	**-2.35**	0.66
Centered Age	0.02	0.14	0.02	0.14	0.00	0.14
Project	**3.11**	1.44	**3.11**	1.44	**3.53**	1.43
Adoption Status	**-2.78**	1.04	**-2.78**	1.04	**-2.94**	1.03
Hispanic	-2.66	1.69	-2.67	1.69	-2.48	1.68
White	-0.47	1.32	-0.46	1.32	-0.33	1.32
Living Together	*-2.95*	1.63	*-2.95*	1.63	*-3.07*	1.63
Educational Attainment	**1.31**	0.11	**1.31**	0.11	**1.28**	0.11
Occupational Complexity	*0.33*	0.19	*0.33*	0.19	*0.37*	0.19
HPW Cognitive	**3.16**	0.38	**3.16**	0.38	**3.23**	0.37
Social Capital	0.66	0.44	0.66	0.44	**1.02**	0.45
IRRcounty	-1.13	2.76	-1.86	6.94	-3.25	6.90
HPW Cognitive * IRRcounty	--	--	0.46	3.99	0.61	3.96
Social Capital* IRRcounty	--	--	--	--	**-9.61**	2.62
Random Effects						
σ^2_{BW} Adopted	0.00	.	0.00	.	0.00	.
σ^2_{BW} Control	**45.90**	13.42	**45.91**	13.43	**46.18**	13.13
σ^2_{BW} DZ	**32.34**	8.46	**32.37**	8.46	**31.36**	8.32
σ^2_{BW} MZ	**71.27**	9.39	**71.28**	9.39	**71.48**	9.37
σ^2_{WI} Adopted	**109.24**	10.26	**109.27**	10.26	**107.80**	10.13
σ^2_{WI} Control	**59.31**	10.12	**59.36**	10.14	**58.40**	9.88
σ^2_{WI} DZ	**60.14**	7.36	**60.10**	7.36	**59.51**	7.30
σ^2_{WI} MZ	**22.02**	2.69	**22.00**	2.70	**21.51**	2.63
Model Fit	**Model 1**		**Model 2**		**Model 3**	
-2 Log Likelihood	8018.2		8018.2		8004.8	
AIC	8058.2		8060.2		8048.8	
BIC	8148.1		8154.6		8147.7	
$\Delta\chi^2$	--		0		13.4	
df	--		1		1	
p	--		1.00E+00		2.52E-04	
N individuals	1101		1101		1101	
N sibships	662		662		662	

Note. Adjusted for female (male=0, female=1), age (centered at 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), Partnered (0=single, 1=partnered), Hispanic (0=non-Hispanic, 1=Hispanic) and White (0=non-White, 1=White). Education centered on bachelor's degree. Occupation centered on semi-professional. Bolded parameters significant $p < .05$; italicized parameters $p < .10$.

Table 3.10: Cognitively-rated Hobbies & FSIQ Multilevel models with random effects for siblings.

	Model 1		Model 2		Model 3	
	B	se	B	se	B	se
Fixed Effects						
Intercept	**111.57**	2.31	**111.62**	2.32	**111.49**	2.30
Female	**-3.17**	0.87	**-3.20**	0.88	**-3.19**	0.87
Centered Age	-0.04	0.20	-0.04	0.20	-0.06	0.20
Project	**4.68**	1.93	**4.67**	1.94	**5.07**	1.94
Adoption Status	**-2.91**	1.44	**-2.87**	1.44	**-3.05**	1.45
Hispanic	-0.20	2.11	-0.26	2.11	-0.05	2.09
White	0.78	1.98	0.81	1.99	1.15	1.98
Living Together	**-4.60**	2.13	**-4.60**	2.14	**-4.63**	2.13
Educational Attainment	**1.30**	0.16	**1.29**	0.16	**1.26**	0.16
Occupational Complexity	0.34	0.29	0.32	0.29	0.37	0.29
Cog. Rated Hobbies	**6.78**	1.70	**6.76**	1.70	**6.42**	1.69
Number Cognitive Hobbies	**3.01**	0.93	**3.02**	0.93	**3.19**	0.93
Social Capital	0.98	0.69	1.05	0.70	**1.47**	0.71
IRRcounty	-2.11	3.75	-4.32	4.73	-5.58	4.73
Cog. Rated Hobbies * IRRcounty	--	--	11.89	15.15	4.86	15.41
Social Capital* IRRcounty	--	--	--	--	**-9.33**	3.85
Random Effects						
σ^2_{BW} Adopted	9.40	21.84	10.00	21.91	11.47	21.54
σ^2_{BW} Control	*36.06*	25.24	*37.94*	25.21	**44.72**	23.49
σ^2_{BW} DZ	**31.03**	12.33	**31.08**	12.22	**28.05**	12.05
σ^2_{BW} MZ	**54.78**	10.57	**55.95**	10.80	**55.45**	10.68
σ^2_{WI} Adopted	**94.07**	24.42	**94.08**	24.41	**91.61**	23.82
σ^2_{WI} Control	**70.95**	22.03	**69.83**	21.66	**63.65**	19.11
σ^2_{WI} DZ	**63.19**	11.41	**62.19**	11.30	**63.41**	11.51
σ^2_{WI} MZ	**25.16**	4.98	**24.65**	4.94	**24.55**	4.91
Model Fit	**Model 1**		**Model 2**		**Model 3**	
-2 Log Likelihood	4249.5		4248.9		4243.2	
AIC	4293.5		4294.9		4291.2	
BIC	4382.4		4387.9		4388.2	
$\Delta\chi^2$	--		0.6		5.7	
df	--		1		1	
p	--		4.39E-01		1.70E-02	
N individuals	581		581		581	
N sibships	420		420		420	

Note. Adjusted for female (male=0, female=1), age (centered at 33), project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), Partnered (0=single, 1=partnered), Hispanic (0=non-Hispanic, 1=Hispanic) and White (0=non-White, 1=White). Education centered on bachelor's degree. Occupation centered on semi-professional. Bolded parameters significant $p < .05$; italicized parameters $p < .10$.

Figure 3.1: Hours per Week on Cognitive Activities and FSIQ by Social Capital and IRRcounty

Note. HPW = hours per week of cognitive activity engagement; + Urban = IRR at .15, + Rural = IRR at .35

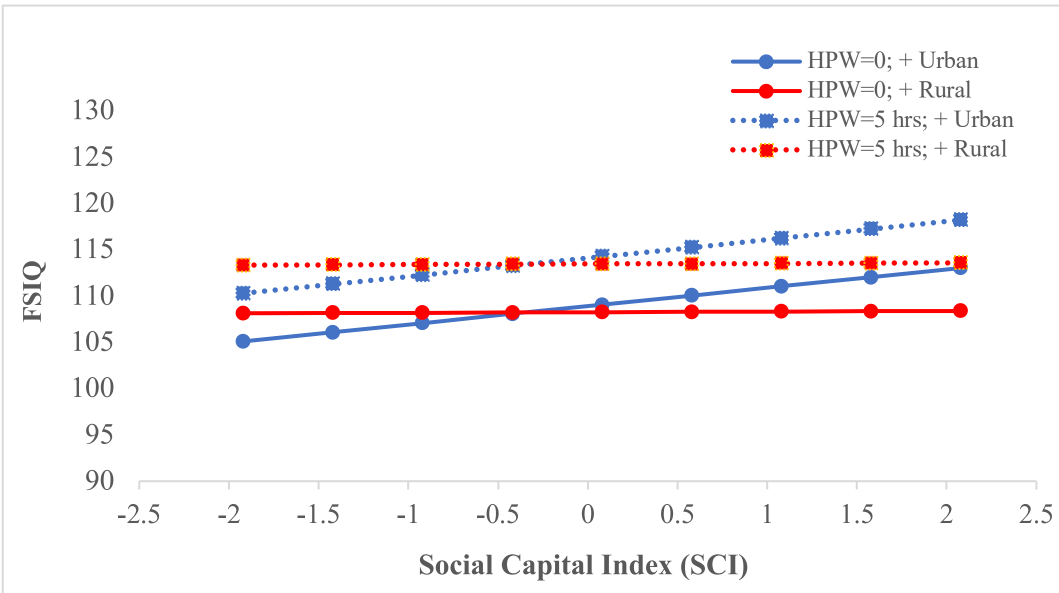
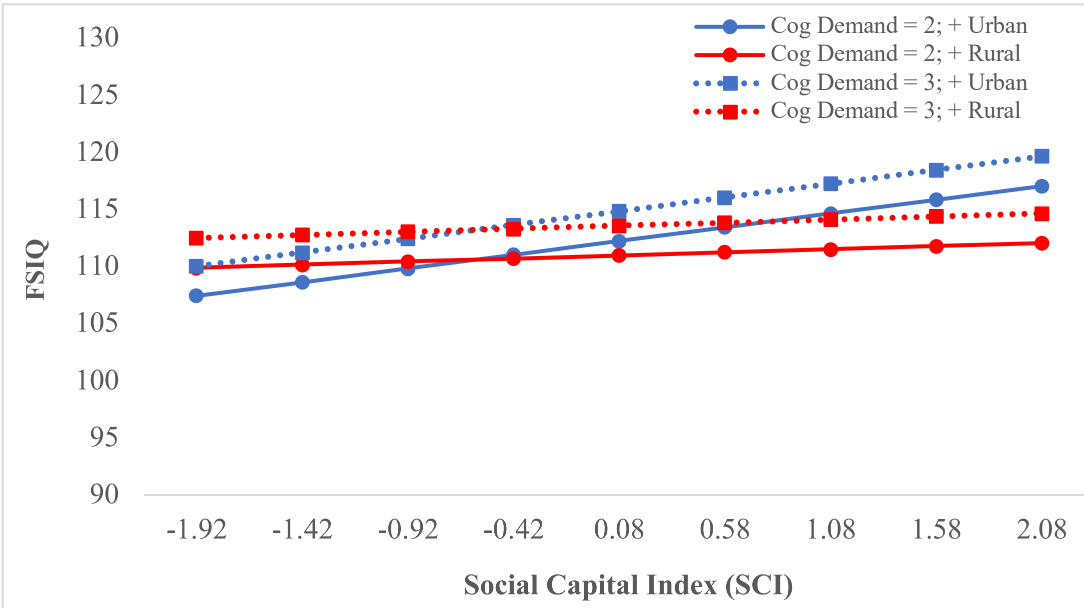


Figure 3.2: Cognitively-rated Hobbies and FSIQ by Social Capital and IRRcounty

Note. Cog Demand = cognitive demands of rated hobbies; + Urban = IRR at .15, + Rural = IRR at .35



Chapter Five:

General Discussion

Ecological theories suggest than an individuals' cognitive development is a product of the dynamic interplay between an individual and the systems in which they are embedded during their lifetime (Bronfenbrenner, 1979; Bronfenbrenner & Ceci, 1994; Clark, 1999b). Individual contexts, which can be understood as the environment in which an individual is situated, exist within many systems ranging from the individuals' home to the larger community. Expanding upon this, ecological theories serve to elucidate how these individual contexts may influence behavioral outcomes, such as cognitive status and cognitive aging across the lifespan, through both direct and indirect pathways. (Cassarino & Setti, 2015; Wahl et al., 2012). Taking a lifespan developmental approach, prior work has demonstrated how environmental influences (e.g., activity engagement, community resources, educational and occupational attainment) accumulate across time to affect later life cognitive abilities or dementia risk, for the better or for the worse (Gatz et al., 2006; Glymour & Manly, 2008; Katzman, 2004; Martin & Zimprich, 2005; Richards & Wadsworth, 2004; Salthouse, 2009).

Environmental factors associated with on cognitive abilities come in numerous forms, such as sociodemographic variables and affordances and barriers present in the geographic location where the individual lives that may influence engagement in leisure activities (Cassarino & Setti, 2015). For example, individuals who had greater educational or occupational attainment, engaged in cognitively stimulating activities, maintained physical activity routines, or live in more affluent neighborhoods, have a lowered risk of dementia in later life (Gatz et al., 2006; Katzman, 2004; Salthouse, 2009; Sharp & Gatz, 2011; Y. Stern, 2012; Valenzuela & Sachdev, 2009). Additionally, the environment may also hinder or encourage engagement in activities. Using physical activity engagement, for example, individuals in in urban areas typically report more physical activity engagement than rural residing individuals (Deng & Paul, 2018; Eberhardt & Pamuk, 2004; Harris et al., 2016; Patterson et al., 2004; Sampaio et al., 2013; Singh & Siahpush, 2014; Trivedi et al., 2015; Wilcox et al., 2000). The research on these geographic differences demonstrate how the resources in the environment may promote physical activity engagement through designated areas for physical activity engagement such as walking/biking trails or exercise facilities; or create barriers for physical activity engagement through lack of sidewalks/street lights or lack of safe places for physical activity engagement (Aronson & Oman, 2004; Eyler & Vest, 2002; Salvo et al., 2018; Sanderson et al., 2002; Wilcox et al., 2000; Yankeelov et al., 2015). Understanding how ones environment promotes or hinders engagement in leisure time activities is crucial to better conceptualize the interplay between the environment and an individual's physical and cognitive development.

Engagement in leisure time activities and the effects of activity engagement on cognitive performance have been well studied (Bennett et al., 2006; Chan et al., 2018b; Gow et al., 2017; Hoang et al., 2016; Karp et al., 2006; Scarmeas et al., 2001; Sofi et al., 2011; Taaffe et al., 2008; Wang et al., 2002, 2017; Wilson et al., 2013b). Prior work suggests that individuals who engage in cognitive activities in their leisure time such as reading, playing music, or strategic card games have also been shown to have better cognitive performance than those who do not engage in cognitive activities (Scarmeas et al., 2001; Wilson et al., 2013). Similarly, individuals who are physically active show less cognitive decline in later life compared to individuals who are not physically active (Sofi et al., 2011; Taaffe et al., 2008). Furthermore, engagement in social activities and having good social networks/support have been shown to delay dementia onset in older adults and has been shown to be beneficial to cognitive functioning (Barnes et al., 2004; Bassuk et al., 1999; Bennett et al., 2006; Bot et al., 2016; Ertel et al., 2008; Holtzman et al., 2004; Karp et al., 2006). For example, a longitudinal study from the Health and Retirement study found the rate of decline for memory performance was dampened 6 years later if individuals had greater social integration at baseline, suggesting social integration (e.g., contact with friends, family, and neighbors) may be a protective factor for preserving memory maintenance into later life (Ertel et al., 2008). The finding of social activity engagement was replicated in another multi-national longitudinal study covering similar age ranges and follow-up time span, where higher social participation at intake was predictive of slower rates of declines in memory performance and executive functioning (Bourassa et al., 2017). In addition, the effect of social participation was uniquely predictive of change in memory and executive functioning as well as comparable in the effect size to the included predictors of physical activity, health status, and depression. Others have found that the benefits of social engagement to cognitive performance can be observed in individuals after a 12-year follow-up, with those who had higher social integration showing stability or less decline than those who were less socially integrated at baseline (Holtzman et al., 2004). These associations between social activity engagement and cognitive performance further support the notion that earlier life experiences may have meaningful effects on cognitive development (Ertel et al., 2008; Holtzman et al., 2004). Interestingly, social engagement has been shown to have effects on other behaviors associated with cognitive performance as well; individuals who have denser and more cohesive relationships within their social network, are more likely to have healthier lifestyle behaviors such as increased amounts of physical activity, less sedentary activity, and better eating habits (e.g., more vegetable intake) (Bot et al., 2016).

Relatedly, a vast literature demonstrates the positive effect of physical activity engagement on both physical and mental health (Cotman & Engesser-Cesar, 2002; Paluska & Schwenk, 2000; Sofi et al., 2011). Physical activity is another form through which the environment can affect cognition, possibly by influencing the preservation of neuronal plasticity (Cotman & Engesser-Cesar, 2002) and lessened age-associated brain volume deterioration (Taaffe et al., 2008). Furthermore, these benefits have been shown to endure over time. A 2011 meta-analysis involving more than 33,000 participants from 15 longitudinal studies, showed that individuals engaging in physical activities at earlier points in their lifespan (up to 12 years prior) had lessened cognitive decline or lessened cognitive impairment when compared to those who did not engage in physical activities in earlier life (Sofi et al., 2011).

It is important to note that some studies have suggested possible reverse causation between activity and cognition (Gow et al., 2012; Sajeev et al., 2016; Salthouse et al., 2002). It is possible that activity engagement may reflect stable patterns set in early life and the causal direction may not be that activity engagement affects cognition, but that cognition affects activity engagement (Gow et al., 2012; Salthouse et al., 2002). Some studies find evidence suggestive that that early life cognition predicts later cognitive activity engagement and thus may reflect reverse cognition whereas physical activity may have direct benefits (Gow et al., 2012), while a later review supports a benefit of cognitive activity engagement that is only partially explained by reverse causation (Gow et al., 2012; Sajeev et al., 2016; Salthouse et al., 2002).

An additional environmental factor that may influence cognitive performance is social capital (i.e., the measure of trust and reciprocity between members of the community; Putnam, 2000). Although not formally tested before this dissertation, social capital could have indirect effects on cognitive performance through activity engagement. Areas high in social capital consist of residents who have high community engagement, high levels of trust for the other members of the community, and more engagement in social activities such as civic groups and sports clubs, thereby increasing opportunities for social, physical, and cognitive activity engagement.

Interest in examining how an individual's geographic location can offer cognitive and physical health benefits, or deficits, has grown, especially when evaluating disparities often found between rural and urban residing individuals (Cassarino & Setti, 2015). Prior work contains methodological issues in that prior studies compare groups dichotomously focusing on the most rural and most urban (Beggs et al., 1996; Cassarino & Setti, 2015; Debertin, 1996; Deng & Paul, 2018; Fan et al., 2014; Matz et al., 2015; Parks et al., 2003; Probst et al., 2002; Saenz et al., 2018; Vogelsang, 2016; Weden et al., 2018; Weeks et al., 2004; Wen et al., 2018; Wilcox et al., 2000). Wu and colleagues used land use patterns, or the mixture of commercial, recreational and residential areas, to identify highly urban and highly rural areas and have suggested a U-shaped relationship between rural-urban and cognitive performance (Wu, Prina, & Brayne, 2015; Wu, Prina, Jones, Matthews, et al., 2017). Their findings suggest that there may be a non-linear relationship when considering geographic differences in outcomes of interest, particularly cognitive performance (Wu, Prina, & Brayne, 2015; Wu, Prina, Jones, Matthews, et al., 2017). Based on patterns of correlations, non-linearity between IRR and IQ or was not suggested in this sample, and indeed few associations were evident among activity engagement or other mediators apart from social capital. Considering that most individuals will reside somewhere in-between the most urban and the most rural, a continuous measure of rurality allows for a more precise examination of the environmental affordances or hindrances present in the individual's proximal environment (Bronfenbrenner, 1979; Bronfenbrenner & Ceci, 1994).

Recognizing the gaps in the literature and opportunities to further examine environmental effects on outcomes such as activity engagement and cognitive performance (see Figure 1.1 in Chapter 1), the current dissertation investigated the following research questions:

Research Question 1.1. What knowledge is gained from examining rurality variables on a finer geographic scale (IRRtract) compared to a larger geographic scale (IRRcounty)?

Research Question 1.2. How does leisure time activity engagement differ quantitatively (i.e., hours per week) and qualitatively (i.e., types of activity) across rural and urban residing individuals for each domain of activity engagement (i.e., cognitive, physical, social)?

Research Question 2.1. How does social capital and its facets, such as social networks and social support, differ across rural and urban residing individuals?

Research Question 2.2. How does social capital and its facets, such as social networks and social support, relate to physical health differences between rural and urban residing individuals?

Research Question 3.1. Are there significant differences in cognitive performance for rural and urban residing individuals when controlling for relevant covariates, such as educational attainment and occupational complexity?

Research Question 3.2. What is the association between activity engagement, as mediated by social capital, on cognitive performance when controlling for relevant covariates?

Research Question 3.3. Do the associations between activity engagement, as mediated by social capital, on cognitive performance differ for rural and urban residing individuals?

In the series of cross-sectional analyses to address these research questions, we addressed possible selection effects as way to account for possible reverse causation, by leveraging the twin-sibling structure in CATSLife to evaluate possible selectivity of spatial, behavioral, and cognitive performance associations. As described in Studies 1-3, relatively few siblings (5.19%) sill live together, and as the sample is approaching midlife and many individuals have selected residences that, while physically distant may be similar. Hence, accounting for the continuous measure of rurality at the tract and county levels allowed us to adjust for similarities between relatives' residence at different ranges from the more proximal (i.e. microsystem or census tract) levels to the larger more distal (i.e. exosystem or county) levels (Bronfenbrenner, 1979; Bronfenbrenner & Ceci, 1994). Where possible we also evaluated spatial similarity beyond the direct spatial measures to consider salient features of the community and environmental space such as social capital.

Summary of General Findings and the Implications

Study 1 evaluated geographic differences in activity engagement from a more distal measurement of rurality (IRRcounty) and a more proximal measure of rurality (IRRtract). Both distal and proximal measures were included in models to compare whether one measure was more informative than the other, or if they could both uniquely contribute to activity engagement. For social activity engagement, the distal measurement of rurality, but not the proximal measure, was a significant negative predictor of the total number of hours per week spent on social activities, meaning the more rural the residential environment where an individual lived, the less hours per weeks they spend on social activities. It is possible that examining social engagement at the distal level was more important due to the potential for more opportunities for social engagement at a larger community level rather than the finer grain level of a census tract. In other words, evaluating social engagement at the county level would likely better capture the environmental facilitators of social engagement (such as going to restaurants or attending concerts) rather than the tract level because there may be more spread of these resources in a county's area than in a smaller geographic region such as the census tract. There is a well developed literature which suggests that the community (i.e. distal measurement) is vital for social engagement because the community offers more opportunity for social events such as attending sporting events or theaters (Arai & Pedlar, 2003; Dyck et al., 2020; Fan & Khattak, 2009; Mannarini & Fedi, 2009). Comparatively, when evaluating sedentary activity engagement, models suggested that the more rural the tract an individual lives in, the fewer hours per week individuals reported engaging in sedentary activities. It could be that the immediate environment has more implications for sedentary activities than does the distal environment. Unlike social activity which is facilitated by the distal parts of an individual's environment, engagement in sedentary activities do not typically encourage engagement with the distal environment (Kaushal & Rhodes, 2014). Research and common knowledge would suggest that we receive higher exposure to the environmental stimuli in the home more than the environmental stimuli in our neighborhood or community (Kaushal & Rhodes, 2014). The accessibility to and utilization of sedentary stimuli in the home (i.e. televisions, phones, tablets, computers) has impacts on our sedentary behaviors (Kaushal & Rhodes, 2014). Prior work has found geographic differences in the associations between time spent sitting and urban environments, such that urban dwellers report more hours spent sitting than do rural dwellers (Uijtdewilligen et al., 2014; Van Uffelen et al., 2012). Similarly, prior work has noted that urban dwellers report an average of 2 more hours per day watching television than do rural dwellers (Clark et al., 2010).

Interestingly, when evaluating family activity engagement, correlations showed associations for both proximal and distal measures of the environment, although the distal measure of IRRcounty was stronger in magnitude than the proximal measure of IRRtract but both were small (i.e., r<.15). In further testing, associations through multilevel models, the best fitting model indicated that the distal measure was a significant unique positive predictor of the total number of hours per week spent on family activities and was more informative than the proximal measure. As engagement with one's family is inherently the most proximal immediate environment, it makes sense that the tract measure would be positively associated with the proximal measure of rurality. The distal measure may be more informative for considering engagement in family activities such as going to a zoo or museum. Interestingly, one study details how family activities can typically be classified as either stay at home activities or going out activities (Churchill et al., 2007). Stay at home activities are things like playing outside, playing board/video games, or just spending time with one another and are inherently proximal as these activities are functioning at the microsystem-level as they are happening in the individual's immediate environment. The observed associations between family activities and proximal measure of rurality may be attributable to these stay at home activities. Going out activities are activities such as going shopping, going to theme parks or public pools and these types of activities are functioning at the exosystem-level as they are resources away from the individual's home. Similar to engagement in family activities, the county level rurality measurement, negatively correlated with social engagement, suggesting that more urban counties provide more opportunities for individuals to access amenities such as parks, sports complexes, roller rinks, etc. than might be available within the bounds of the census tract (Cassarino & Setti, 2015; Kearns & Parkinson, 2001). Further supporting this notion was the finding that the distal measurement of rurality was a significant negative predictor of engagement in hobbies that were rated in terms of cognitive demands, indicative of cognitive stimulation. Again, more urban areas provide more opportunities for engagement in hobbies that have greater cognitive demands, such as book clubs or attending classes. The findings of Study 1 suggest activity engagement may be influenced by levels of rurality and these influences may vary by whether proximal or distal levels are more meaningful. Findings of this study have a particular significance to potentially inform activity engagement interventions, especially for sedentary activity. With proximal measures being the most important predictor for sedentary activities, interventions may benefit from a focus on neighborhood-level out-reach and educational programs to inform about the negative health impacts of sedentary activity, as well as evaluate the specific neighborhood conditions which may create barriers for engaging in the neighborhood and thus, adopting pernicious sedentary behaviors (Jakicic et al., 1999; Kaushal & Rhodes, 2014; Khalil et al., 2012; Moore et al., 2009; Vestergaard et al., 2008).

Study 2 evaluated the geographic differences in social capital as well as the how social capital may influence physical health. Similar to Study 1, this study utilized both proximal (individual-level social capital facets such as social support and social network engagement) as well as distal (county-level social capital index (SCI)) measures of social capital, and used these proximal and distal measures of social capital to further evaluate the relationship between social capital and physical health. The proximal level of social capital was the SCI which combines the county's number of available membership organizations, with population, and voter/census response rates to create a scale of social capital (Northeast Regional Center for Rural Development, 2019; Rupasingha et al., 2006). Individual level measures of social capital included social capital facets such as number of close friends, contact frequency with friends, perceived social support, etc. Because the SCI was created for analysis at the county level and was the only geographically informed measure of social capital, we evaluated geographic differences in social capital using only the county-level measure of IRR. Models suggested that the more rural a county is, the higher the social capital, consistent with prior literature (Beaudoin & Thorson, 2004; Fischer, 1982; Onyx & Bullen, 2000; Sørensen, 2016; Ziersch et al., 2009).

Results from Study 2 showed few relationships with IRR and individual-level (proximal) social capital facets. In evaluating the self-reported number of close friends, IRRcounty was a significant predictor of the number of close friends' with the more rural the county, the fewer number of close friends' participants reported. This finding was consistent with prior literature that suggests that individuals in rural areas display smaller networks than urban dwellers. Still, the depth and value of the relationships in rural areas are more meaningful for rural dwellers, while urban relationships are more likely to include acquaintanceships (Beggs et al., 1996; Sørensen, 2012). Similarly, results suggested that IRRcounty was predictive to the contact frequency with friends, with less frequency reported in rural areas than in urban areas. Again, this finding aligns with prior work that suggests that often times, individuals residing in urban areas are further away from family members and rely on contact with friends for social support; whereas rural residing individuals are likely to have more frequent contact with family members than with friends (Amato, 1993b; Hofferth & Iceland, 1998; Key, 1961; Sørensen, 2012). These findings may inform health interventions. Research suggests that social engagement may have direct and indirect effects on physical and mental health, regardless of the geographic location (Beaudoin & Thorson, 2004; Franks et al., 1992; Reeves et al., 2014; Sørensen, 2012, 2016). Interestingly, however, Study 2 showed no differences in rural and urban residing individuals for other proximal measures of social capital, including perceived social support (appraisal, tangible, belonging), family contact frequency, family support, and family strain. Although these findings were inconsistent with prior literature (Hofferth & Iceland, 1998; Key, 1961), the findings are important for interventions regarding health behaviors as both the family and friends (regardless of geographic location) play important roles in supporting positive health behaviors.

Study 2 found no geographic differences for any of the three health measures used in the study (somatic complaints, number of illness endorsed, and self-rated health). Moreover, Study 2 found no associations with the distal measure of social capital and the three health measures. Associations were observed for some of the individual-level measures of social capital (number of friends, friend contact frequency, and family contact frequency) and health. However, all individual-level measures of social capital were negatively associated with self-rated health, with the exception of family strain, which was positively associated with self-rated health (c.f., Table 2.7). The number of friends was additionally associated with fewer somatic complaints, and contact frequency with friends was additionally associated with fewer illness endorsements.

Leveraging what we learned from Study 2, it is difficult to say with confidence that examining social capital facets independently are informative to interventions. In this sample, although IRR was associated with the size of the social network (e.g. rural individuals had a smaller "close friend" networks than urban individuals), the social network (i.e. the number of close friends) was an important predictor of physical health, irrespective of geographic location. Indeed, studies investigating the role of social support to engagement in positive health behaviors (e.g. physical activity engagement, healthy eating, etc.), have noted that individuals who report greater amounts of social support show greater engagement and adherence to positive health behaviors (Eyler & Vest, 2002; Parks et al., 2003; Sanderson et al., 2002). A possible limitation of this study is that we did not have a social capital index that could be applied to evaluate the relationship to physical health at the proximal tract level. We were able utilize some individual level facets of social capital such as perceived support and number of close friends, but other facets of social capital such as measures of trust could have offered additional insight into the relationship between social capital and physical health. Follow up studies would benefit from examining social capital across a number of facets and across a number of geographic levels.

Study 3 built upon Studies 1 and 2 by examining how geographic differences, social capital, and activity engagement influenced cognitive performance. Moreover, Study 3 also controls for well-documented effects of educational and occupational attainment on activity engagement and cognitive performance (Cassarino & Setti, 2015; Gatz et al., 2006; Glymour & Manly, 2008; Katzman, 2004; Martin & Zimprich, 2005; Richards & Wadsworth, 2004; Salthouse, 2009; Wahl et al., 2012). Educational attainment but not occupational attainment was an important predictor of cognitive performance in all models for Study 3. In the first part of Study 3, we evaluated how geographic differences were associated with cognitive performance (measured by IQ). Correlations indicated possible associations between IRRcounty with Full Scale IQ (FSIQ) and Verbal IQ (VIQ), where individuals living in areas that are more rural had lower scores. Using multilevel models that accounted for sibling structure reduced the observed associations to nonsignificance. Accounting for sibling structure allows for the deeper examination of possible selection effects of contexts and behaviors with the outcome of interest. Moreover, in evaluating individual differences in IQ, accounting for sibling similarities was more salient than geographic location, not surprisingly. In fact, intraclass correlations demonstrated that more than one-third of the total variance in IQ was attributable to the sibling structure. This was evidenced by conforming to behavioral genetic models, with adoptive individuals showing the lowest between sibling variance followed by DZ twins (which are no more similar genetically than regular siblings) and control siblings showing similar ICCs, which were about half as that observed for MZ twins (Knopik et al., 2017). This finding has implications for future research, when evaluating geographic differences in cognitive performance because some of the associations found between 'place' and cognitive performance may be due to environmental selection (Laidley et al., 2019).

Next, Study 3 tested for main effects between activity engagement and social capital to evaluate possible mediation effects of social capital on activity engagement to cognitive performance. Only hours per week spent on cognitive activities and having hobbies that were rated to be cognitively demanding were found to be significant main effects on IQ, and other activities (social or physical) and social capital were not significant predictors. Moreover, there does not appear to be direct mediation of the cognitive activities and hobbies with social capital on cognitive performance. Further investigation of the relationship between activity engagement and social capital is warranted. Areas that are high in social capital have been shown to have residents who have higher levels of social trust, greater community and neighborhood participation, and stronger family ties (Beaudoin & Thorson, 2004; Hofferth & Iceland, 1998; Onyx & Bullen, 2000; Sørensen, 2012). These characteristics may create environments that encourage activity engagement of all types. Exploring individual level, social capital facets, such as social support/networks may better elucidate any potential mediations between activity engagement and cognitive performance.

Finally, Study 3 evaluated if the associations between activity engagement and cognitive performance, as mediated by social capital, would differ geographically. Results suggested that there were main effects of hours per week on cognitive activities or having cognitive hobbies and social capital as well as an interaction between social capital and IRR. These findings suggest that the status of IQ performance functions by the index of relative rurality and level of social individuals, with individuals who reside in more urban areas that are low in social capital display lower scores on FSIQ compared to their rural residing counterparts, while individuals in urban areas with high levels of social capital show higher scores on FSIQ compared to rural individuals with the same level of social capital. Specifically, social capital plays a more important role in moderating the relationship between cognitive activity engagement or cognitively demanding hobbies on FSIQ for urban dwellers than for rural dwellers. Moreover, prior literature suggests that individuals residing in urban areas often have higher educational attainment due to the increased occupational opportunities available for those with higher educational attainment in urban areas (Saenz et al., 2018; Sanchez & Pacheco, 2012). Similarly, there are often more opportunities for cognitive activity engagement or having cognitive hobbies in urban areas such as going to museums, being in book clubs or attending courses through the local schools. Urban residing individuals can take advantage of these social capital resources that foster cognitive activity engagement. However, limited social capital in urban areas can be more detrimental than in rural areas because people live in denser, more populated area but don't have resources to actively engage in the community. Considering these points, it is possible that engaging in cognitive activities or hobbies in urban areas may increase the social capital for the area which is suggestive of environmental selection (Laidley et al., 2019). Additionally, residents can modify their environment whereby individuals who are interested in engaging in certain activities or hobbies could increase the community social capital by encouraging others to engage as well. In this dissertation we were able to account for possible selection effects by accounting for sibling structure and were still able to find some support for associations between cognitive activity engagement and IQ although this finding was independent of the rurality by social capital interaction. This finding aligns with prior research which is suggestive that some benefit of cognitive activity engagement that is likely only partially due to reverse causation (Sajeev et al., 2016).

Strengths and Limitations

This dissertation has many strengths including being the first to: (1) evaluate adapt the Index of Relative Rurality (IRR) to the tract level, (2) evaluate geographic differences in social capital and social support on a continuous scale of rurality, (3) explore associations between social capital and cognitive performance, and (4) the first to explore the associations between activity engagement and cognitive performance as mediated by social capital. These evaluations help to address gaps in several literature domains, including assessing the relationship between social capital and cognition, as well as geographic differences in cognitive performance through activity engagement. This dissertation is also able to expand on past research as many studies are not able to evaluate outcomes of interest at the individual level, which is an important level of measurement available in the current three studies. Particularly for studies evaluating geographic differences in physical health, many rely on county-level measures and cannot evaluate effects at the individual-level. Overall, this is an important developmental study that emphasizes the necessity of including ecologically relevant measures to explore how contextual factors within a person's environment could impact key facets of health salient behaviors, health status, and cognitive aging. This study was able to not only look at regional differences in outcomes of interest such as activity engagement or cognitive performance, but was also able to leverage the sibling structure to be able to look at the potential for selection into environments and selection into the behaviors of interest such as activity engagement. Accounting for sibling similarities in models us to be able to look at the individuals situated within their environment. Although we did not do formal modeling to test how similar the different sibling types were, the multilevel models did account for the similarities in sibling types. To the extent that you see sibling similarities at all, suggests that there may be some selection factoring into geographic location. Finding greater sibling similarity for MZ than for DZ twins, suggests there may be genetic factors involved in this geographic selection. While we did find geographic associations at the fixed effects level for some of the outcomes, suggesting that geography was salient, it was often the case that family structure was more important to account for in models. It becomes obvious then that it is not just that the environment that is impacting an individual, but that individuals have agency so there becomes some potential for how individuals construct their environments or find themselves in certain environments that are similar to their siblings, even when the siblings don't live together.

This dissertation had several limitations that should be addressed. To begin, it is worth acknowledging that this sample is relatively homogeneous (about 92% white) which makes it difficult to generalize to other racial or ethnic groups, but it is important to note that while this sample is limited in racial or ethnic diversity, there is substantial diversity in other socioeconomic variables such as age, partnership status, educational attainment, and occupational attainment. Similarly, this sample has slightly higher educational attainment and IQ scores than what would be expected in the general population. Again, it is worth noting, however, that we do see distributions in this sample of educational attainment that would be representative of the general population. An additional limitation of this dissertation is that we were unable to estimate random effects for family and spatial clustering. Because of the vast geographic spread of individuals residing outside of Colorado, models were only able to estimate random effects for family clustering. In addition, this dissertation focused on an individual's engagement in activities and the influences of the environment at one point in the lifespan and cannot speak to how these patterns may change across time or pass mid-life. While it has been shown that engagement in activities can have lasting effects on cognition, Salthouse et al. (2002) points out, our engagement with activities changes as our physical and cognitive abilities change with age. For example, in mid-life, one may spend a few hours per week on household chores with relatively little physical demands. In late life, however, the same individual may need to spend several more hours on household chores, which are now much more physically demanding due to the physical aging and frailty of the body. Further, we were unable to include the duration that participants had resided at the current address. It is possible that the duration of time an individual at a current residence will vary with some who recently moved or others that have lived majority of their life at same or near their current location. Thus, the engagement with the proximal environment may be quite different for someone who recently moved to a location than someone who has lived in the same neighborhood their entire life. Lastly, this dissertation used only one of the multiple methods employed for coding the qualitative activity engagement data (i.e. the weighting of activities in cognitive, social, and physical demand). Further exploration into the qualitative data is warranted to better understand participants' engagement with, and perceptions of, their proximal environment.

Future Directions

The present study is a cross-sectional examination of geographic differences in activity engagement, social capital, physical health, and cognitive performance. As Katzman first points out in his 2004 study, both genetic an early life environmental factors can benefit or hinder healthy cognitive aging in later life (Katzman, 2004). Katzman (2004), details how early life environmental factors such as nutrition and socioeconomic status, as well as, how mid-life environmental factors such as educational attainment, occupational attainment and leisure activities can influence clinical expression of dementia in later life. Utilizing twin methodology, other studies have bolstered Katzman's findings by evaluating activity engagement and late life cognitive performance through the evaluation of discordant twins (Crowe et al., 2003). Evaluating same sex twins who are discordant for dementia (i.e. one twin has dementia and the other doesn't), and after controlling for educational attainment, Crowe et al., (2003) find those who reported greater activity engagement 20 years prior, were at lower risk for all dementia and Alzheimer's disease. Similarly, other work has evaluated mid-life environmental factors (educational attainment, higher occupational attainment and activity engagement) and the associations with late life dementia risk (Gatz et al., 2006). Gatz et al., (2006) reported that within-twin pair differences in educational attainment predicted a greater dementia risk in the twin partner with lower education; moreover, in evaluating twin pairs who were discordant on educational attainment, the twin who had higher educational attainment unsurprisingly had higher occupational attainment but interestingly, this twin also reported more engagement with cognitively stimulating activities in mid-life. These studies demonstrate how engagement with the environment, even in early or midlife life, may have impacts to later life cognition. At this time, geospatial data is available for CATSLife participants' current address but is being prepared for age and study enrollment (year 1) and later ages. In future work, it will be possible to align geospatial data with assessments of cognitive performance and activity engagement from the previous waves of data collection from CAP and LTS. This will allow for a cumulative analysis of activity engagement and cognitive performance from early life to mid-life and further inform the literature regarding lifespan environmental factors affecting cognitive development.

Additionally, CATSLife participants responded to twelve open-ended items that corresponded to the activity engagement items. This dissertation utilized two of the twelve open-ended questions: "What clubs do you belong to" and "What hobbies do you have". Furthermore, analyses in this dissertation utilized only one coding technique for qualitative data (how cognitively, socially, or physically demanding the hobby is). Prior work evaluating activity engagement often places activities into one of the traditional domains of cognitive, social or physica***l*** (Bennett et al., 2006; Scarmeas et al., 2001; Sofi et al., 2011; Taaffe et al., 2008; Wang et al., 2002b; Robert S. Wilson et al., 2013b; R.S. Wilson et al., 2003)**.** In future work, the qualitative data will be evaluated using the other methods of coding which included an assignment coding strategy where raters classified the club or hobby into one of eight categories including Physical Activity, Making &

Tinkering, Relaxation, Passive entertainment, Active entertainment, Sensory Stimulation, Creative, or Casual Volunteering/Altruism (Flatt et al., 2015; R. Stebbins, 2017). Evaluating activity engagement on a more diverse set of domains may lead to better understanding of not only the geographic differences in the types of activities individual engage in, but also may provide a more holistic view of how a person spends their free time and how that may affect cognitive functioning.

Conclusion

The current dissertation study illuminates the interplay between the individual and their environment and the implications for human development. Moreover, it demonstrates how engagement in leisure time activities differ geographically, while highlighting that some activities may have implications to engagement at a more proximal level (e.g. sedentary activities), while others have implications to engagement that are more distally-influenced (e.g. family and cognitive activities). Collectively, this study addressed several gaps in the literature concerning activity engagement and the relation to social capital, social capital and the relation to cognition, and what can be gained by evaluating environmental effects on activity engagement and cognition from proximal and distal regional measures.

References

Amato, P. R. (1993). Urban-Rural Differences in Helping Friends and Family Members. *Social Psychology Quarterly*, *56*(4), 249–262. JSTOR. https://doi.org/10.2307/2786662

Arai, S., & Pedlar, A. (2003). Moving beyond individualism in leisure theory: A critical analysis of concepts of community and social engagement. *Leisure Studies*, *22*(3), 185–202. https://doi.org/10.1080/026143603200075489

Aronson, R. E., & Oman, R. F. (2004). Views on Exercise and Physical Activity Among Rural-Dwelling Senior Citizens. *The Journal of Rural Health*, *20*(1), 76–79. https://doi.org/10.1111/j.1748-0361.2004.tb00010.x

Barnes, L. L., De Leon, C. M., Wilson, R. S., Bienias, J. L., & Evans, D. A. (2004). Social resources and cognitive decline in a population of older African Americans and whites. *Neurology*, *63*(12), 2322–2326.

Bassuk, S. S., Glass, T. A., & Berkman, L. F. (1999). Social disengagement and incident cognitive decline in community-dwelling elderly persons. *Annals of Internal Medicine*, *131*(3), 165–173.

Beaudoin, C. E., & Thorson, E. (2004). Social Capital in Rural and Urban Communities: Testing Differences in Media Effects and Models. *Journalism & Mass Communication Quarterly*, *81*(2), 378–399. https://doi.org/10.1177/107769900408100210

Beggs, J. J., Haines, V. A., & Hurlbert, J. S. (1996). Revisiting the Rural-Urban Contrast: Personal Networks in Nonmetropolitan and Metropolitan Settings1. *Rural Sociology*, *61*(2), 306–325. https://doi.org/10.1111/j.1549-0831.1996.tb00622.x

Bennett, D. A., Schneider, J. A., Tang, Y., Arnold, S. E., & Wilson, R. S. (2006). The effect of social networks on the relation between Alzheimer's disease pathology and level of cognitive function in old people: A longitudinal cohort study. *The Lancet Neurology*, *5*(5), 406–412.

Bot, S. D., Mackenbach, J. D., Nijpels, G., & Lakerveld, J. (2016). Association between Social Network Characteristics and Lifestyle Behaviours in Adults at Risk of Diabetes and Cardiovascular Disease. *PLOS ONE*, *11*(10), e0165041. https://doi.org/10.1371/journal.pone.0165041

Bourassa, K. J., Memel, M., Woolverton, C., & Sbarra, D. A. (2017). Social participation predicts cognitive functioning in aging adults over time: Comparisons with physical health, depression, and physical activity. *Aging & Mental Health*, *21*(2), 133–146.

Bronfenbrenner, U. (1979). *The Ecology of Human Development*. Harvard University Press.

Bronfenbrenner, U., & Ceci, S. J. (1994). Nature-nuture reconceptualized in developmental perspective: A bioecological model. *Psychological Review*, *101*(4), 568–586. https://doi.org/10.1037/0033-295X.101.4.568

Cassarino, M., & Setti, A. (2015). Environment as 'Brain Training': A review of geographical and physical environmental influences on cognitive ageing. *Ageing Research Reviews*, *23*, 167–182. https://doi.org/10.1016/j.arr.2015.06.003

Chan, T., Parisi, J. M., Moored, K. D., & Carlson, M. C. (2018). Variety of Enriching Early Life Activities Linked to Late Life Cognitive Functioning in Urban Community-Dwelling African Americans. *The Journals of Gerontology: Series B*.

Churchill, S. L., Clark, V. L. P., Prochaska-Cue, K., Creswell, J. W., & Ontai-Grzebik, L. (2007). How Rural Low-Income Families Have Fun: A Grounded Theory Study. *Journal of Leisure Research*, *39*(2), 271–294. https://doi.org/10.1080/00222216.2007.11950108

Clark, A. (1999). An embodied cognitive science? *Trends in Cognitive Sciences*, *3*(9), 345–351. https://doi.org/10.1016/S1364-6613(99)01361-3

Clark, B. K., Sugiyama, T., Healy, G. N., Salmon, J., Dunstan, D. W., Shaw, J. E., Zimmet, P. Z., & Owen, N. (2010). Socio-demographic correlates of prolonged television viewing time in Australian men and women: The AusDiab study. *Journal of Physical Activity and Health*, *7*(5), 595–601.

Cotman, C. W., & Engesser-Cesar, C. (2002). Exercise enhances and protects brain function. *Exercise and Sport Sciences Reviews*, *30*(2), 75–79.

Crowe, M., Andel, R., Pedersen, N. L., Johansson, B., & Gatz, M. (2003). Does participation in leisure activities lead to reduced risk of Alzheimer's disease? A prospective study of Swedish twins. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *58*(5), P249–P255.

Debertin, D. L., & Goetz, S. J. (1996). A comparison of social capital in rural and urban settings. *University of Kentucky*.

Deng, Y., & Paul, D. R. (2018). The Relationships Between Depressive Symptoms, Functional Health Status, Physical Activity, and the Availability of Recreational Facilities: A Rural-Urban Comparison in Middle-Aged and Older Chinese Adults. *International Journal of Behavioral Medicine*, *25*(3), 322–330. https://doi.org/10.1007/s12529-018-9714-3

Dyck, D. V., Barnett, A., Cauwenberg, J. V., Zhang, C. J. P., Sit, C. H. P., & Cerin, E. (2020). Main and interacting effects of physical activity and sedentary time on older adults' BMI: The moderating roles of socio-demographic and environmental attributes. *PLOS ONE*, *15*(7), e0235833. https://doi.org/10.1371/journal.pone.0235833

Eberhardt, M. S., & Pamuk, E. R. (2004). The Importance of Place of Residence: Examining Health in Rural and Nonrural Areas. *American Journal of Public Health*, *94*(10), 1682–1686. https://doi.org/10.2105/AJPH.94.10.1682

Ertel, K. A., Glymour, M. M., & Berkman, L. F. (2008). Effects of social integration on preserving memory function in a nationally representative US elderly population. *American Journal of Public Health*, *98*(7), 1215–1220.

Eyler, A. A., & Vest, J. R. (2002). Environmental and Policy Factors Related to Physical Activity in Rural White Women. *Women & Health*, *36*(2), 109–119. https://doi.org/10.1300/J013v36n02_08

Fan, J. X., Wen, M., & Kowaleski-Jones, L. (2014). Rural–Urban Differences in Objective and Subjective Measures of Physical Activity: Findings From the National Health and Nutrition Examination Survey (NHANES) 2003–2006. *Preventing Chronic Disease*, *11*. https://doi.org/10.5888/pcd11.140189

Fan, Y., & Khattak, A. J. (2009). Does urban form matter in solo and joint activity engagement? *Landscape and Urban Planning*, *92*(3), 199–209. https://doi.org/10.1016/j.landurbplan.2009.05.006

Fischer, C. S. (1982). *To Dwell Among Friends: Personal Networks in Town and City*. University of Chicago Press.

Flatt, J. D., Hughes, T. F., Documét, P. I., Lingler, J. H., Trauth, J. M., & Albert, S. M. (2015). A Qualitative Study on the Types and Purposes of Social Activities in Late Life. *Activities, Adaptation & Aging*, *39*(2), 109–132. https://doi.org/10.1080/01924788.2015.1024485

Franks, P., Campbell, T. L., & Shields, C. G. (1992). Social relationships and health: The relative roles of family functioning and social support. *Social Science & Medicine*, *34*(7), 779–788. https://doi.org/10.1016/0277-9536(92)90365-W

Gatz, M., Prescott, C. A., & Pedersen, N. L. (2006). Lifestyle risk and delaying factors. *Alzheimer Disease & Associated Disorders*, *20*, S84–S88.

Glymour, M. M., & Manly, J. J. (2008). Lifecourse social conditions and racial and ethnic patterns of cognitive aging. *Neuropsychology Review*, *18*(3), 223–254.

Gow, A. J., Corley, J., Starr, J. M., & Deary, I. J. (2012). Reverse causation in activity-cognitive ability associations: The Lothian Birth Cohort 1936. *Psychology and Aging*, *27*(1), 250.

Gow, A. J., Pattie, A., & Deary, I. J. (2017). Lifecourse Activity Participation From Early, Mid, and Later Adulthood as Determinants of Cognitive Aging: The Lothian Birth Cohort 1921. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *72*(1), 25–37. https://doi.org/10.1093/geronb/gbw124

Harris, J. K., Beatty, K., Leider, J. P., Knudson, A., Anderson, B. L., & Meit, M. (2016). The Double Disparity Facing Rural Local Health Departments. *Annual Review of Public Health*, *37*(1), 167–184. https://doi.org/10.1146/annurev-publhealth-031914-122755

Hoang, T. D., Reis, J., Zhu, N., Jacobs, D. R., Launer, L. J., Whitmer, R. A., Sidney, S., & Yaffe, K. (2016). Effect of early adult patterns of physical activity and television viewing on midlife cognitive function. *JAMA Psychiatry*, *73*(1), 73–79.

Hofferth, S. L., & Iceland, J. (1998). Social Capital in Rural and Urban Communities1. *Rural Sociology*, *63*(4), 574–598. https://doi.org/10.1111/j.1549-0831.1998.tb00693.x

Holtzman, R. E., Rebok, G. W., Saczynski, J. S., Kouzis, A. C., Wilcox Doyle, K., & Eaton, W. W. (2004). Social network characteristics and cognition in middle-aged and older adults. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *59*(6), P278–P284.

Jakicic, J. M., Winters, C., Lang, W., & Wing, R. R. (1999). Effects of Intermittent Exercise and Use of Home Exercise Equipment on Adherence, Weight Loss, and Fitness in Overweight Women: A Randomized Trial. *JAMA*, *282*(16), 1554–1560. https://doi.org/10.1001/jama.282.16.1554

Karp, A., Paillard-Borg, S., Wang, H.-X., Silverstein, M., Winblad, B., & Fratiglioni, L. (2006). Mental, physical and social components in leisure activities equally contribute to decrease dementia risk. *Dementia and Geriatric Cognitive Disorders*, *21*(2), 65–73.

Katzman, R. (2004). A neurologist's view of Alzheimer's disease and dementia. *International Psychogeriatrics*, *16*(3), 259–273. https://doi.org/10.1017/S1041610204000456

Kaushal, N., & Rhodes, R. E. (2014). The home physical environment and its relationship with physical activity and sedentary behavior: A systematic review. *Preventive Medicine*, *67*, 221–237. https://doi.org/10.1016/j.ypmed.2014.07.026

Kearns, A., & Parkinson, M. (2001). The Significance of Neighbourhood. *Urban Studies*, *38*(12), 2103–2110. https://doi.org/10.1080/00420980120087063

Key, W. H. (1961). Rural-Urban Differences and the Family. *The Sociological Quarterly*, *2*(1), 49–56. https://doi.org/10.1111/j.1533-8525.1961.tb01484.x

Khalil, H., Quinn, L., van Deursen, R., Martin, R., Rosser, A., & Busse, M. (2012). Adherence to Use of a Home-Based Exercise DVD in People With Huntington Disease: Participants' Perspectives. *Physical Therapy*, *92*(1), 69–82. https://doi.org/10.2522/ptj.20100438

Knopik, V. S., Neiderhiser, J. M., DeFries, J. C., & Plomin, R. (2017). *Behavioral genetics* (Seventh edition. ed.). Worth Publishers, Macmillan Learning.

Laidley, T., Vinneau, J., & Boardman, J. D. (2019). Individual and Social Genomic Contributions to Educational and Neighborhood Attainments: Geography, Selection, and Stratification in the United States. *Sociological Science*, *6*, 580–608. https://doi.org/10.15195/v6.a22

Mannarini, T., & Fedi, A. (2009). Multiple senses of community: The experience and meaning of community. *Journal of Community Psychology*, *37*(2), 211–227. https://doi.org/10.1002/jcop.20289

Martin, M., & Zimprich, D. (2005). Cognitive development in midlife. *Middle Adulthood: A Lifespan Perspective*, 179–206.

Matz, C. J., Stieb, D. M., & Brion, O. (2015). Urban-rural differences in daily time-activity patterns, occupational activity and housing characteristics. *Environmental Health*, *14*(1). https://doi.org/10.1186/s12940-015-0075-y

Moore, J., Fiddler, H., Seymour, J., Grant, A., Jolley, C., Johnson, L., & Moxham, J. (2009). Effect of a home exercise video programme in patients with chronic obstructive pulmonary disease. *Journal of Rehabilitation Medicine*, *41*(3), 195–200. https://doi.org/10.2340/16501977-0308

Northeast Regional Center for Rural Development, S. C. V. for 2014. (2019). *Social Capital Variables for 2014 (Northeast Regional Center for Rural Development)*. Northeast Regional Center for Rural Development (Penn State University). https://aese.psu.edu/nercrd/community/social-capital-resources/social-capital-variables-for-2014

Onyx, J., & Bullen, P. (2000). Measuring Social Capital in Five Communities. *The Journal of Applied Behavioral Science*, *36*(1), 23–42. https://doi.org/10.1177/0021886300361002

Paluska, S. A., & Schwenk, T. L. (2000). Physical activity and mental health. *Sports Medicine*, *29*(3), 167–180.

Parks, S. E., Housemann, R. A., & Brownson, R. C. (2003). Differential correlates of physical activity in urban and rural adults of various socioeconomic backgrounds in the United States. *Journal of Epidemiology & Community Health*, *57*(1), 29–35. https://doi.org/10.1136/jech.57.1.29

Patterson, P. D., Moore, C. G., Probst, J. C., & Shinogle, J. A. (2004). Obesity and Physical Inactivity in Rural America. *The Journal of Rural Health*, *20*(2), 151–159. https://doi.org/10.1111/j.1748-0361.2004.tb00022.x

Probst, J. C., Moore, C. G., Baxley, E. G., & Lammie, J. J. (2002). Rural-Urban Differences in Visits to Primary Care Physicians. *Family Medicine*, *34*(8), 609–615.

Reeves, D., Blickem, C., Vassilev, I., Brooks, H., Kennedy, A., Richardson, G., & Rogers, A. (2014). The Contribution of Social Networks to the Health and Self-Management of Patients with Long-Term Conditions: A Longitudinal Study. *PLOS ONE*, *9*(6), e98340. https://doi.org/10.1371/journal.pone.0098340

Richards, M., & Wadsworth, M. (2004). Long term effects of early adversity on cognitive function. *Archives of Disease in Childhood*, *89*(10), 922–927.

Rupasingha, A., Goetz, S. J., & Freshwater, D. (2006). The production of social capital in US counties. *The Journal of Socio-Economics*, *35*(1), 83–101. https://doi.org/doi:10.1016/j.socec.2005.11.001

Saenz, J. L., Downer, B., Garcia, M. A., & Wong, R. (2018). Cognition and Context: Rural–Urban Differences in Cognitive Aging Among Older Mexican Adults. *Journal of Aging and Health*, *30*(6), 965–986. https://doi.org/10.1177/0898264317703560

Sajeev, G., Weuve, J., Jackson, J. W., VanderWeele, T. J., Bennett, D. A., Grodstein, F., & Blacker, D. (2016). Late-life cognitive activity and dementia: A systematic review and bias analysis. *Epidemiology (Cambridge, Mass.)*, *27*(5), 732.

Salthouse, T. A. (2009). When does age-related cognitive decline begin? *Neurobiology of Aging*, *30*(4), 507–514.

Salthouse, T. A., Berish, D. E., & Miles, J. D. (2002). The role of cognitive stimulation on the relations between age and cognitive functioning. *Psychology and Aging*, *17*(4), 548–557. https://doi.org/10.1037/0882-7974.17.4.548

Salvo, G., Lashewicz, B. M., Doyle-Baker, P. K., & McCormack, G. R. (2018). Neighbourhood Built Environment Influences on Physical Activity among Adults: A Systematized Review of Qualitative Evidence. *International Journal of Environmental Research and Public Health*, *15*(5), 897. https://doi.org/10.3390/ijerph15050897

Sampaio, P. Y. S., Ito, E., & Carvalho Sampaio, R. A. (2013). The association of activity and participation with quality of life between Japanese older adults living in rural and urban areas. *Journal of Clinical Gerontology and Geriatrics*, *4*(2), 51–56. https://doi.org/10.1016/j.jcgg.2012.11.004

Sanchez, L., & Pacheco, E. (2012). Rural Population Trends in Mexico: Demographic and Labor Changes. In L. J. Kulcsár & K. J. Curtis (Eds.), *International Handbook of Rural Demography* (pp. 155–168). Springer Netherlands. https://doi.org/10.1007/978-94-007-1842-5_12

Sanderson, B., Littleton, M., & Pulley, L. V. (2002). Environmental, Policy, and Cultural Factors Related to Physical Activity Among Rural, African American Women. *Women & Health*, *36*(2), 73–88. https://doi.org/10.1300/J013v36n02_06

Scarmeas, N., Levy, G., Tang, M.-X., Manly, J., & Stern, Y. (2001). Influence of leisure activity on the incidence of Alzheimer's disease. *Neurology*, *57*(12), 2236–2242.

Sharp, E. S., & Gatz, M. (2011). Relationship Between Education and Dementia: An Updated Systematic Review. *Alzheimer Disease & Associated Disorders*, *25*(4), 289–304. https://doi.org/10.1097/WAD.0b013e318211c83c

Singh, G. K., & Siahpush, M. (2014). Widening Rural–Urban Disparities in Life Expectancy, U.S., 1969–2009. *American Journal of Preventive Medicine*, *46*(2), e19–e29. https://doi.org/10.1016/j.amepre.2013.10.017

Sofi, F., Valecchi, D., Bacci, D., Abbate, R., Gensini, G. F., Casini, A., & Macchi, C. (2011). Physical activity and risk of cognitive decline: A meta-analysis of prospective studies. *Journal of Internal Medicine*, *269*(1), 107–117.

Sørensen, J. F. L. (2012). Testing the Hypothesis of Higher Social Capital in Rural Areas: The Case of Denmark. *Regional Studies*, *46*(7), 873–891. https://doi.org/10.1080/00343404.2012.669471

Sørensen, J. F. L. (2016). Rural–Urban Differences in Bonding and Bridging Social Capital. *Regional Studies*, *50*(3), 391–410. https://doi.org/10.1080/00343404.2014.918945

Stebbins, R. (2017). *Serious Leisure: A Perspective for Our Time (paperback edition)*. Routledge.

Stern, Y. (2012). Cognitive reserve in ageing and Alzheimer's disease. *The Lancet Neurology*, *11*(11), 1006–1012. https://doi.org/10.1016/S1474-4422(12)70191-6

Taaffe, D. R., Irie, F., Masaki, K. H., Abbott, R. D., Petrovitch, H., Ross, G. W., & White, L. R. (2008). Physical activity, physical function, and incident dementia in elderly men: The Honolulu–Asia Aging Study. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *63*(5), 529–535.

Trivedi, T., Liu, J., Probst, J., Merchant, A., Jones, S., & Martin, A. (2015). Obesity and obesity-related behaviors among rural and urban adults in the USA. *Rural Remote Health*, *15*(4), 11.

Uijtdewilligen, L., Twisk, J. W., Singh, A. S., Chinapaw, M. J., van Mechelen, W., & Brown, W. J. (2014). Biological, socio-demographic, work and lifestyle determinants of sitting in young adult women: A prospective cohort study. *International Journal of Behavioral Nutrition and Physical Activity*, *11*(1), 7.

Valenzuela, M., & Sachdev, P. (2009). Can Cognitive Exercise Prevent the Onset of Dementia? Systematic Review of Randomized Clinical Trials with Longitudinal Follow-up. *The American Journal of Geriatric Psychiatry*, *17*(3), 179–187. https://doi.org/10.1097/JGP.0b013e3181953b57

Van Uffelen, J. G., Heesch, K. C., & Brown, W. (2012). Correlates of sitting time in working age Australian women: Who should be targeted with interventions to decrease sitting time? *Journal of Physical Activity and Health*, *9*(2), 270–287.

Vestergaard, S., Kronborg, C., & Puggaard, L. (2008). Home-based video exercise intervention for community-dwelling frail older women: A randomized controlled trial. *Aging Clinical and Experimental Research*, *20*(5), 479–486. https://doi.org/10.1007/BF03325155

Vogelsang, E. M. (2016). Older adult social participation and its relationship with health: Rural-urban differences. *Health & Place*, *42*, 111–119. https://doi.org/10.1016/j.healthplace.2016.09.010

Wahl, H.-W., Iwarsson, S., & Oswald, F. (2012). Aging well and the environment: Toward an integrative model and research agenda for the future. *The Gerontologist*, *52*(3), 306–316.

Wang, H.-X., Karp, A., Winblad, B., & Fratiglioni, L. (2002). Late-Life Engagement in Social and Leisure Activities Is Associated with a Decreased Risk of Dementia: A Longitudinal Study from the Kungsholmen Project. *American Journal of Epidemiology*, *155*(12), 1081–1087. https://doi.org/10.1093/aje/155.12.1081

Wang, H.-X., MacDonald, S. W. S., Dekhtyar, S., & Fratiglioni, L. (2017). Association of lifelong exposure to cognitive reserve-enhancing factors with dementia risk: A community-based cohort study. *PLOS Medicine*, *14*(3), e1002251. https://doi.org/10.1371/journal.pmed.1002251

Weden, M. M., Shih, R. A., Kabeto, M. U., & Langa, K. M. (2018). Secular Trends in Dementia and Cognitive Impairment of U.S. Rural and Urban Older Adults. *American Journal of Preventive Medicine*, *54*(2), 164–172. https://doi.org/10.1016/j.amepre.2017.10.021

Weeks, W. B., Kazis, L. E., Shen, Y., Cong, Z., Ren, X. S., Miller, D., Lee, A., & Perlin, J. B. (2004). Differences in health-related quality of life in rural and urban veterans. *American Journal of Public Health*, *94*(10), 1762–1767. https://doi.org/10.2105/AJPH.94.10.1762

Wen, M., Fan, J. X., Kowaleski-Jones, L., & Wan, N. (2018). Rural–urban disparities in obesity prevalence among working age adults in the United States: Exploring the mechanisms. *American Journal of Health Promotion*, *32*(2), 400–408. https://doi.org/DOI: 10.1177/0890117116689488

Wilcox, S., Castro, C., King, A., Housemann, R., & Brownson, R. (2000). Determinants of leisure time physical activity in rural compared with urban older and ethnically diverse women in the United States. *Journal of Epidemiology & Community Health*, *54*(9), 667–672. https://doi.org/10.1136/jech.54.9.667

Wilson, Robert S., Boyle, P. A., Yu, L., Barnes, L. L., Schneider, J. A., & Bennett, D. A. (2013). Life-span cognitive activity, neuropathologic burden, and cognitive aging. *Neurology*, *81*(4), 314–321. https://doi.org/10.1212/WNL.0b013e31829c5e8a

Wilson, R.S., Bennett, D. A., Bienias, J. L., Mendes de Leon, C. F., Morris, M. C., & Evans, D. A. (2003). Cognitive activity and cognitive decline in a biracial community population. *Neurology*, *61*(6), 812–816. https://doi.org/10.1212/01.WNL.0000083989.44027.05

Wu, Y.-T., Prina, A. M., & Brayne, C. (2015). The association between community environment and cognitive function: A systematic review. *Social Psychiatry and Psychiatric Epidemiology*, *50*(3), 351–362. https://doi.org/10.1007/s00127-014-0945-6

Wu, Y.-T., Prina, A. M., Jones, A., Matthews, F. E., & Brayne, C. (2017). The Built Environment and Cognitive Disorders: Results From the Cognitive Function and Ageing Study II. *American Journal of Preventive Medicine*, *53*(1), 25–32. https://doi.org/10.1016/j.amepre.2016.11.020

Yankeelov, P. A., Faul, A. C., D'Ambrosio, J. G., Collins, W. L., & Gordon, B. (2015). "Another Day in Paradise": A Photovoice Journey of Rural Older Adults Living With Diabetes. *Journal of Applied Gerontology*, *34*(2), 199–218. https://doi.org/10.1177/0733464813493136

Ziersch, A. M., Baum, F., Darmawan, I. G. N., Kavanagh, A. M., & Bentley, R. J. (2009). Social capital and health in rural and urban communities in South Australia. *Australian and New Zealand Journal of Public Health*, *33*(1), 7–16. https://doi.org/10.1111/j.1753-6405.2009.00332.x

Full References

Ainsworth, B. E., Haskell, W. L., Leon, A. S., Jacobs, D. R. J., Montoye, H. J., Sallis, J. F., & Paffenbarger, R. S. J. (1993). Compendium of Physical Activities: Classification of energy costs of human physical activities. *Medicine & Science in Sports & Exercise*, *25*(1), 71–80.

Ainsworth, B. E., Haskell, W. L., Whitt, M. C., Irwin, M. L., Swartz, A. M., Strath, S. J., O Brien, W. L., Bassett, D. R., Schmitz, K. H., Emplaincourt, P. O., Jacobs, D. R., & Leon, A. S. (2000). Compendium of Physical Activities: An update of activity codes and MET intensities: *Medicine & Science in Sports & Exercise*, *32*(Supplement), S498–S516. https://doi.org/10.1097/00005768-200009001-00009

Aldrich, H., Zimmer, C., Sexton, D., & Smilor, R. (1986). The art and science of entrepreneurship. *Ballinger, Cambridge, MA*, 3–23.

Alesina, A., & La Ferrara, E. (2000). Participation in Heterogeneous Communities. *The Quarterly Journal of Economics*, *115*(3), 847–904. https://doi.org/10.1162/003355300554935

Amato, P. R. (1993). Urban-Rural Differences in Helping Friends and Family Members. *Social Psychology Quarterly*, *56*(4), 249–262. JSTOR. https://doi.org/10.2307/2786662

Annear, M., Keeling, S., Wilkinson, T., Cushman, G., Gidlow, B., & Hopkins, H. (2014). Environmental influences on healthy and active ageing: A systematic review. *Ageing & Society*, *34*(4), 590–622.

Arai, S., & Pedlar, A. (2003). Moving beyond individualism in leisure theory: A critical analysis of concepts of community and social engagement. *Leisure Studies*, *22*(3), 185–202. https://doi.org/10.1080/026143603200075489

Aronson, R. E., & Oman, R. F. (2004). Views on Exercise and Physical Activity Among Rural-Dwelling Senior Citizens. *The Journal of Rural Health*, *20*(1), 76–79. https://doi.org/10.1111/j.1748-0361.2004.tb00010.x

Ashida, S., & Heaney, C. A. (2008). Differential Associations of Social Support and Social Connectedness With Structural Features of Social Networks and the Health Status of Older Adults. *Journal of Aging and Health*, *20*(7), 872–893. https://doi.org/10.1177/0898264308324626

Bae, J. B., Kim, Y. J., Han, J. W., Kim, T. H., Park, J. H., Lee, S. B., Lee, J. J., Jeong, H. G., Kim, J. L., Jhoo, J. H., Yoon, J. C., & Kim, K. W. (2015). Incidence of and

Risk Factors for Alzheimer's Disease and Mild Cognitive Impairment in Korean Elderly. *Dementia and Geriatric Cognitive Disorders*, *39*(1–2), 105–115. https://doi.org/10.1159/000366555

Barber, C. E. (2013). Perceptions of Aging-Friendly Community Characteristics: Does County Rurality Make a Difference? *Online Journal of Rural Research & Policy*, *8*(2). https://doi.org/10.4148/ojrrp.v8i2.1944

Barnes, L. L., De Leon, C. M., Wilson, R. S., Bienias, J. L., & Evans, D. A. (2004). Social resources and cognitive decline in a population of older African Americans and whites. *Neurology*, *63*(12), 2322–2326.

Bassuk, S. S., Glass, T. A., & Berkman, L. F. (1999). Social disengagement and incident cognitive decline in community-dwelling elderly persons. *Annals of Internal Medicine*, *131*(3), 165–173.

Beal, D. J. (2007). Information criteria methods in SAS for multiple linear regression models. *15th Annual SouthEast SAS Users Group (SESUG) Proceedings, South Carolina, Paper SA05*.

Beaudoin, C. E., & Thorson, E. (2004). Social Capital in Rural and Urban Communities: Testing Differences in Media Effects and Models. *Journalism & Mass Communication Quarterly*, *81*(2), 378–399. https://doi.org/10.1177/107769900408100210

Befort, C. A., Nazir, N., & Perri, M. G. (2012). Prevalence of obesity among adults from rural and urban areas of the United States: Findings from NHANES (2005-2008). *The Journal of Rural Health*, *28*(4), 392–397.

Beggs, J. J., Haines, V. A., & Hurlbert, J. S. (1996). Revisiting the Rural-Urban Contrast: Personal Networks in Nonmetropolitan and Metropolitan Settings1. *Rural Sociology*, *61*(2), 306–325. https://doi.org/10.1111/j.1549-0831.1996.tb00622.x

Behringer, B., Friedell, G. H., Dorgan, K. A., Hutson, S. P., Naney, C., Phillips, A., & Cantrell, E. (2007). Understanding the challenges of reducing cancer in Appalachia: Addressing a place-based health disparity population. *Californian Journal of Health Promotion*, *5*, 40–49.

Bennett, D. A., Schneider, J. A., Tang, Y., Arnold, S. E., & Wilson, R. S. (2006). The effect of social networks on the relation between Alzheimer's disease pathology and level of cognitive function in old people: A longitudinal cohort study. *The Lancet Neurology*, *5*(5), 406–412.

Berardi, N., Braschi, C., Capsoni, S., Cattaneo, A., & Maffei, L. (2007). Environmental enrichment delays the onset of memory deficits and reduces neuropathological hallmarks in a mouse model of Alzheimer-like neurodegeneration. *Journal of Alzheimer's Disease*, *11*(3), 359–370.

Berkman, L. F. (1984). Assessing the Physical Health Effects of Social Networks and Social Support. *Annual Review of Public Health*, *5*(1), 413–432. https://doi.org/10.1146/annurev.pu.05.050184.002213

Biswas, A., Oh, P. I., Faulkner, G. E., Bajaj, R. R., Silver, M. A., Mitchell, M. S., & Alter, D. A. (2015). Sedentary Time and Its Association With Risk for Disease Incidence, Mortality, and Hospitalization in Adults. *Annals of Internal Medicine*, *162*(2), 123–132. https://doi.org/10.7326/M14-1651

Bøen, H., Dalgard, O. S., & Bjertness, E. (2012). The importance of social support in the associations between psychological distress and somatic health problems and socio-economic factors among older adults living at home: A cross sectional study. *BMC Geriatrics*, *12*(1), 27. https://doi.org/10.1186/1471-2318-12-27

Bolin, K., Lindgren, B., Lindström, M., & Nystedt, P. (2003). Investments in social capital—Implications of social interactions for the production of health. *Social Science & Medicine*, *56*(12), 2379–2390. https://doi.org/10.1016/S0277-9536(02)00242-3

Bot, S. D., Mackenbach, J. D., Nijpels, G., & Lakerveld, J. (2016). Association between Social Network Characteristics and Lifestyle Behaviours in Adults at Risk of Diabetes and Cardiovascular Disease. *PLOS ONE*, *11*(10), e0165041. https://doi.org/10.1371/journal.pone.0165041

Bourassa, K. J., Memel, M., Woolverton, C., & Sbarra, D. A. (2017). Social participation predicts cognitive functioning in aging adults over time: Comparisons with physical health, depression, and physical activity. *Aging & Mental Health*, *21*(2), 133–146.

Bourdieu, P., & Richardson, J. G. (1986). The forms of capital. In *Handbook of Theory and Research for the Sociology of Education.* (pp. 241–258). Westport: Greenwood Press.

Brehm, J., & Rahn, W. (1997). Individual-level evidence for the causes and consequences of social capital. *American Journal of Political Science*, 999–1023.

Brim, O., Baltes, P., Bumpass, L., Cleary, P., Featherman, D., Hazzard, W., & Shweder, R. (2007). *Midlife in the United States (MIDUS 1), 1995-1996. Inter-university Consortium for Political and Social Research [distributor].*

Bronfenbrenner, U. (1979). *The Ecology of Human Development*. Harvard University Press.

Bronfenbrenner, U., & Ceci, S. J. (1994). Nature-nuture reconceptualized in developmental perspective: A bioecological model. *Psychological Review*, *101*(4), 568–586. https://doi.org/10.1037/0033-295X.101.4.568

Brownstein, N., Kalsbeek, W. D., Tabor, J. W., Entzel, P., Daza, E., & Harris, K. M. (2018). *Non-Response in Wave IV of the National Longitudinal Study of Adolescent Health*. https://doi.org/10.17615/c6zq0q

Buffel, T., Phillipson, C., Scharf, T., Warburton, J., Ng, S. H., & Shardlow, S. M. (2012). Experiences of neighbourhood exclusion and inclusion among older people living in deprived inner-city areas in Belgium and England. *Ageing and Society*, *33*(1), 89.

Bureau, U. C. (n.d.). *Welcome to Geocoder*. Retrieved June 4, 2020, from https://geocoding.geo.census.gov/geocoder/locations/addressbatch?form

Bureau, U. C. (2003). *Core-Based Statistical Areas*. The United States Census Bureau. https://www.census.gov/topics/housing/housing-patterns/about/core-based-statistical-areas.html

Bureau, U. C. (2010). *2010 Census Urban and Rural Classification and Urban Area Criteria*. The United States Census Bureau. https://www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural/2010-urban-rural.html

Bureau, U. C. (2020). *Understanding Geographic Identifiers (GEOIDs)*. The United States Census Bureau. https://www.census.gov/programs-surveys/geography/guidance/geo-identifiers.html

Burnham, K. P., & Anderson, D. R. (2002). A practical information-theoretic approach. *Model Selection and Multimodel Inference, 2nd Ed. Springer, New York*, *2*.

Burnham, K. P., & Anderson, D. R. (2003). *Model selection and multimodel inference: A practical information-theoretic approach*. Springer Science & Business Media.

Cahill, S., O’Shea, E., & Pierce, M. (2012). *Creating excellence in dementia care: A research review for Ireland’s national dementia strategy*.

Canter, D. V., & Craik, K. H. (1981). Environmental psychology. *Journal of Environmental Psychology*, *1*(1), 1–11. https://doi.org/10.1016/S0272-4944(81)80013-8

Carlson, M. C., Saczynski, J. S., Rebok, G. W., Seeman, T., Glass, T. A., McGill, S., Tielsch, J., Frick, K. D., Hill, J., & Fried, L. P. (2008). Exploring the Effects of an "Everyday" Activity Program on Executive Function and Memory in Older Adults: Experience Corps®. *The Gerontologist*, *48*(6), 793–801. https://doi.org/10.1093/geront/48.6.793

Cassarino, M., & Setti, A. (2015). Environment as 'Brain Training': A review of geographical and physical environmental influences on cognitive ageing. *Ageing Research Reviews*, *23*, 167–182. https://doi.org/10.1016/j.arr.2015.06.003

Chan, T., Parisi, J. M., Moored, K. D., & Carlson, M. C. (2018). Variety of Enriching Early Life Activities Linked to Late Life Cognitive Functioning in Urban Community-Dwelling African Americans. *The Journals of Gerontology: Series B*.

Chen, S.-T., Hyun, J., Graefe, A. R., Mowen, A. J., Almeida, D. M., & Sliwinski, M. J. (2020). The Influence of Leisure Engagement on Daily Emotional Well-Being. *Leisure Sciences*, *0*(0), 1–18. https://doi.org/10.1080/01490400.2020.1757537

Christakis, N. A., & Fowler, J. H. (2008). The Collective Dynamics of Smoking in a Large Social Network. *New England Journal of Medicine*, *358*(21), 2249–2258. https://doi.org/10.1056/NEJMsa0706154

Churchill, S. L., Clark, V. L. P., Prochaska-Cue, K., Creswell, J. W., & Ontai-Grzebik, L. (2007). How Rural Low-Income Families Have Fun: A Grounded Theory Study. *Journal of Leisure Research*, *39*(2), 271–294. https://doi.org/10.1080/00222216.2007.11950108

Clark, A. (1999). An embodied cognitive science? *Trends in Cognitive Sciences*, *3*(9), 345–351.

Clarke, P. J., Ailshire, J. A., House, J. S., Morenoff, J. D., King, K., Melendez, R., & Langa, K. M. (2011). Cognitive function in the community setting: The neighbourhood as a source of 'cognitive reserve'? *Journal of Epidemiology & Community Health*, jech–2010.

Clarke, B. L., Koziol, N. A., & Sheridan, S. M. (2017). The Effects of Rurality on Parents' Engagement in Children's Early Literacy. In G. C. Nugent, G. M. Kunz, S. M. Sheridan, T. A. Glover, & L. L. Knoche (Eds.), *Rural Education Research in the United States: State of the Science and Emerging Directions* (pp. 231–250). Springer International Publishing. https://doi.org/10.1007/978-3-319-42940-3_12

Clark, B. K., Sugiyama, T., Healy, G. N., Salmon, J., Dunstan, D. W., Shaw, J. E., Zimmet, P. Z., & Owen, N. (2010). Socio-demographic correlates of prolonged television viewing time in Australian men and women: The AusDiab study. *Journal of Physical Activity and Health*, *7*(5), 595–601.

Cohen, G. (2006). Research on Creativity and Aging: The Positive Impact of the Arts on Health and Illness. *Generations*, *30*(1), 7–15.

Cohen, S. A., Cook, S. K., Kelley, L., Foutz, J. D., & Sando, T. A. (2017). A Closer Look at Rural-Urban Health Disparities: Associations Between Obesity and Rurality Vary by Geospatial and Sociodemographic Factors. *The Journal of Rural Health*, *33*(2), 167–179.

Cohen, D. A., McKenzie, T. L., Sehgal, A., Williamson, S., Golinelli, D., & Lurie, N. (2007). Contribution of public parks to physical activity. *American Journal of Public Health*, *97*(3), 509–514.

Cohen, S., Mermelstein, R., Kamarck, T., & Hoberman, H. M. (1985). Measuring the functional components of social support. In *Social support: Theory, research and applications* (pp. 73–94). Springer.

Cole, S. W., Shanahan, M. J., Gaydosh, L., & Harris, K. M. (2020). Population-based RNA profiling in Add Health finds social disparities in inflammatory and antiviral gene regulation to emerge by young adulthood. *Proceedings of the National Academy of Sciences*, *117*(9), 4601–4608.

Coleman, J. (1990). *Foundations of social theory. Cambridge, MA: Belknap Press of Harvard University Press*.

Coleman, J. S. (1988). Social Capital in the Creation of Human Capital. *American Journal of Sociology*, *94*, S95–S120. https://doi.org/10.1086/228943

Contador, I., Bermejo-Pareja, F., & Benito-Leon, V. P.-M. and J. (2015, May 1). *Childhood and Adulthood Rural Residence Increases the Risk of Dementia: NEDICES Study*. Current Alzheimer Research. https://www.eurekaselect.com/129746/article

Cotman, C. W., & Engesser-Cesar, C. (2002). Exercise enhances and protects brain function. *Exercise and Sport Sciences Reviews*, *30*(2), 75–79.

Cramm, J. M., van Dijk, H. M., & Nieboer, A. P. (2013). The Importance of Neighborhood Social Cohesion and Social Capital for the Well Being of Older Adults in the Community. *The Gerontologist*, *53*(1), 142–152. https://doi.org/10.1093/geront/gns052

Crowe, M., Andel, R., Pedersen, N. L., Johansson, B., & Gatz, M. (2003). Does participation in leisure activities lead to reduced risk of Alzheimer's disease? A prospective study of Swedish twins. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *58*(5), P249–P255.

Davis, S., Crothers, N., Grant, J., Young, S., & Smith, K. (2012). Being involved in the country: Productive ageing in different types of rural communities. *Journal of Rural Studies*, *28*(4), 338–346.

Debertin, D. L., & Goetz, S. J. (1996). A comparison of social capital in rural and urban settings. *University of Kentucky*.

De Carolis, D. M., Litzky, B. E., & Eddleston, K. A. (2009). Why Networks Enhance the Progress of New Venture Creation: The Influence of Social Capital and Cognition. *Entrepreneurship Theory and Practice*, *33*(2), 527–545. https://doi.org/10.1111/j.1540-6520.2009.00302.x

De Carolis, D. M., & Saparito, P. (2006). Social Capital, Cognition, and Entrepreneurial Opportunities: A Theoretical Framework. *Entrepreneurship Theory and Practice*, *30*(1), 41–56. https://doi.org/10.1111/j.1540-6520.2006.00109.x

De Fockert, J. W., Caparos, S., Linnell, K. J., & Davidoff, J. (2011). Reduced distractibility in a remote culture. *PLoS One*, *6*(10), e26337.

De Montis, A., Caschili, S., & Trogu, D. (2012, June 13). *Accessibility, Rurality and Remoteness: An Investigation on the Island of Sardinia, Italy. In Planning Support Tools: Policy Analysis, Implementation and Evaluation.* Proceedings of the Seventh International Conference on Informatics and Urban and Regional Planning INPUT2012: 155.

Deng, Y., & Paul, D. R. (2018). The Relationships Between Depressive Symptoms, Functional Health Status, Physical Activity, and the Availability of Recreational Facilities: A Rural-Urban Comparison in Middle-Aged and Older Chinese Adults. *International Journal of Behavioral Medicine*, *25*(3), 322–330. https://doi.org/10.1007/s12529-018-9714-3

Dyck, D. V., Barnett, A., Cauwenberg, J. V., Zhang, C. J. P., Sit, C. H. P., & Cerin, E. (2020). Main and interacting effects of physical activity and sedentary time on older adults' BMI: The moderating roles of socio-demographic and environmental attributes. *PLOS ONE*, *15*(7), e0235833. https://doi.org/10.1371/journal.pone.0235833

Eaton, C. B., Nafziger, A. N., Strogatz, D. S., & Pearson, T. A. (1994). Self-reported physical activity in a rural county: A New York county health census. *American Journal of Public Health*, *84*(1), 29–32. https://doi.org/10.2105/AJPH.84.1.29

Eberhardt, M. S., & Pamuk, E. R. (2004). The Importance of Place of Residence: Examining Health in Rural and Nonrural Areas. *American Journal of Public Health*, *94*(10), 1682–1686. https://doi.org/10.2105/AJPH.94.10.1682

Elder Jr, G. H., & Conger, R. D. (2014). *Children of the land: Adversity and success in rural America*. University of Chicago Press.

Emmons, K. M., Barbeau, E. M., Gutheil, C., Stryker, J. E., & Stoddard, A. M. (2007). Social Influences, Social Context, and Health Behaviors Among Working-Class, Multi-Ethnic Adults. *Health Education & Behavior*, *34*(2), 315–334. https://doi.org/10.1177/1090198106288011

ESRI. (2018). *ArcMap* (10.6.1) [Computer software]. http://desktop.arcgis.com/en/arcmap/

Ertel, K. A., Glymour, M. M., & Berkman, L. F. (2008). Effects of social integration on preserving memory function in a nationally representative US elderly population. *American Journal of Public Health*, *98*(7), 1215–1220.

Eyler, A. A., & Vest, J. R. (2002). Environmental and Policy Factors Related to Physical Activity in Rural White Women. *Women & Health*, *36*(2), 109–119. https://doi.org/10.1300/J013v36n02_08

Fan, J. X., Wen, M., & Kowaleski-Jones, L. (2014). Rural–Urban Differences in Objective and Subjective Measures of Physical Activity: Findings From the National Health and Nutrition Examination Survey (NHANES) 2003–2006. *Preventing Chronic Disease*, *11*. https://doi.org/10.5888/pcd11.140189

Fan, Y., & Khattak, A. J. (2009). Does urban form matter in solo and joint activity engagement? *Landscape and Urban Planning*, *92*(3), 199–209. https://doi.org/10.1016/j.landurbplan.2009.05.006

Felmlee, D., & Muraco, A. (2009). Gender and Friendship Norms Among Older Adults. *Research on Aging*, *31*(3), 318–344. https://doi.org/10.1177/0164027508330719

Fischer, C. S. (1982). *To Dwell Among Friends: Personal Networks in Town and City*. University of Chicago Press.

Fisher, B. J., & Specht, D. K. (1999). Successful Aging And Creativity In Later Life. *Journal of Aging Studies*, *13*(4), 457–472. https://doi.org/10.1016/S0890-4065(99)00021-3

Flatt, J. D., Hughes, T. F., Documét, P. I., Lingler, J. H., Trauth, J. M., & Albert, S. M. (2015). A Qualitative Study on the Types and Purposes of Social Activities in Late Life. *Activities, Adaptation & Aging*, *39*(2), 109–132. https://doi.org/10.1080/01924788.2015.1024485

Fors, S., Lennartsson, C., & Lundberg, O. (2009). Childhood living conditions, socioeconomic position in adulthood, and cognition in later life: Exploring the associations. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *64*(6), 750–757.

Franks, P., Campbell, T. L., & Shields, C. G. (1992). Social relationships and health: The relative roles of family functioning and social support. *Social Science & Medicine*, *34*(7), 779–788. https://doi.org/10.1016/0277-9536(92)90365-W

Fukuyama, F. (1995). *Trust: The social virtues and the creation of prosperity* (Vol. 99). Free press New York.

Gallardo, R., & Scammahorn, R. (2011). Determinants of innovative versus non-innovative entrepreneurs in three southern states. *Review of Regional Studies*, *41*(2, 3), 103–117.

Gatz, M., Prescott, C. A., & Pedersen, N. L. (2006). Lifestyle risk and delaying factors. *Alzheimer Disease & Associated Disorders*, *20*, S84–S88.

Gavrila, D., Antunez, C., Tormo, M., Carles, R., Garcia Santos, J., Parrilla, G., Fortuna, L., Jiménez, J., Salmerón, D., & Navarro, C. (2009). Prevalence of dementia and cognitive impairment in Southeastern Spain: The Ariadna study. *Acta Neurologica Scandinavica*, *120*(5), 300–307.

Giannetti, V. J., Reynolds, J., & Rihn, T. (1985). Factors which differentiate smokers from ex-smokers among cardiovascular patients: A discriminant analysis. *Social Science & Medicine*, *20*(3), 241–245. https://doi.org/10.1016/0277-9536(85)90237-0

Gibson, E. J. (1991). *The ecological approach: A foundation for environmental psychology.*

Glaeser, E. L., Laibson, D., & Sacerdote, B. (2002). An economic approach to social capital. *The Economic Journal*, *112*(483), F437–F458.

Glymour, M. M., & Manly, J. J. (2008). Lifecourse social conditions and racial and ethnic patterns of cognitive aging. *Neuropsychology Review*, *18*(3), 223–254.

Gottlieb, B. H. (1981a). *Social networks and social support* (Vol. 4). Sage Publications, Inc.

Gottlieb, B. H. (1981b). Social networks and social support in community mental health. *Social Networks and Social Support*, *4*, 11–42.

Gow, A. J., Corley, J., Starr, J. M., & Deary, I. J. (2012). Reverse causation in activity-cognitive ability associations: The Lothian Birth Cohort 1936. *Psychology and Aging*, *27*(1), 250.

Gow, A. J., Pattie, A., & Deary, I. J. (2017). Lifecourse Activity Participation From Early, Mid, and Later Adulthood as Determinants of Cognitive Aging: The Lothian Birth

Cohort 1921. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *72*(1), 25–37. https://doi.org/10.1093/geronb/gbw124

Griep, Y., Hanson, L. M., Vantilborgh, T., Janssens, L., Jones, S. K., & Hyde, M. (2017). Can volunteering in later life reduce the risk of dementia? A 5-year longitudinal study among volunteering and non-volunteering retired seniors. *PLoS One*, *12*(3), e0173885.

Haberstick, B. C., Zeiger, J. S., & Corley, R. P. (2014). Genetic and environmental influences on the allocation of adolescent leisure time activities. *BioMed Research International*, *2014*.

Handy, S. L., Boarnet, M. G., Ewing, R., & Killingsworth, R. E. (2002). How the built environment affects physical activity: Views from urban planning. *American Journal of Preventive Medicine*, *23*(2), 64–73.

Harati, H., Majchrzak, M., Cosquer, B., Galani, R., Kelche, C., Cassel, J.-C., & Barbelivien, A. (2011). Attention and memory in aged rats: Impact of lifelong environmental enrichment. *Neurobiology of Aging*, *32*(4), 718–736.

Harris, K. M. (2013). *The Add Health Study: Design and Accomplishments*.

Harris, J. K., Beatty, K., Leider, J. P., Knudson, A., Anderson, B. L., & Meit, M. (2016). The Double Disparity Facing Rural Local Health Departments. *Annual Review of Public Health*, *37*(1), 167–184. https://doi.org/10.1146/annurev-publhealth-031914-122755

Heflin, C., & Miller, K. (2012). The geography of need: Identifying human service needs in rural America. *Journal of Family Social Work*, *15*(5), 359–374.

Henning-Smith, C., & Lahr, M. (2018). Rural-Urban Difference in Workplace Supports and Impacts for Employed Caregivers: Rural-Urban Differences in Employed Caregivers. *The Journal of Rural Health*, *0*, 1–9. https://doi.org/10.1111/jrh.12309

Hoang, T. D., Reis, J., Zhu, N., Jacobs, D. R., Launer, L. J., Whitmer, R. A., Sidney, S., & Yaffe, K. (2016). Effect of early adult patterns of physical activity and television viewing on midlife cognitive function. *JAMA Psychiatry*, *73*(1), 73–79.

Hofferth, S. L., & Iceland, J. (1998). Social Capital in Rural and Urban Communities. *Rural Sociology*, *63*(4), 574–598. https://doi.org/10.1111/j.1549-0831.1998.tb00693.x

Holtzman, R. E., Rebok, G. W., Saczynski, J. S., Kouzis, A. C., Wilcox Doyle, K., & Eaton, W. W. (2004). Social network characteristics and cognition in middle-aged and older adults. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *59*(6), P278–P284.

House, J. S. (1981). Work stress and social support reading. *MA: Addison-Wesley*.

Hubach, R. D., Dodge, B., Cola, T., Battani, P. R., & Reece, M. (2014). *Assessing the Sexual Health Needs of Men Who Have Sex with Men (MSM) Residing in Rural and Mixed Rural Areas*. *31*(2), 7.

Huffman, M. K., & Amireault, S. (2019). INDEX OF RELATIVE RURALITY AS A PREDICTOR OF PHYSICAL ACTIVITY CORRELATES FOR OLDER ADULTS. *Innovation in Aging*, *3*(Supplement_1), S521–S521. https://doi.org/10.1093/geroni/igz038.1920

Inagami, S., Gao, S., Karimi, H., Shendge, M. M., Probst, J. C., & Stone, R. A. (2016). Adapting the Index of Relative Rurality (IRR) to Estimate Rurality at the ZIP Code Level: A Rural Classification System in Health Services Research: Adapting the Index of Relative Rurality. *The Journal of Rural Health*, *32*(2), 219–227. https://doi.org/10.1111/jrh.12148

Infurna, F. J., Gerstorf, D., & Lachman, M. E. (2020). Midlife in the 2020s: Opportunities and challenges. *American Psychologist*, *75*(4), 470–485. https://doi.org/10.1037/amp0000591

Israel, B. A. (1982). Social networks and health status: Linking theory, research, and practice. *Patient Counselling and Health Education*, *4*(2), 65–79. https://doi.org/10.1016/S0190-2040(82)80002-5

Jakicic, J. M., Winters, C., Lang, W., & Wing, R. R. (1999). Effects of Intermittent Exercise and Use of Home Exercise Equipment on Adherence, Weight Loss, and Fitness in Overweight Women: A Randomized Trial. *JAMA*, *282*(16), 1554–1560. https://doi.org/10.1001/jama.282.16.1554

Jankowsky, J. L., Melnikova, T., Fadale, D. J., Xu, G. M., Slunt, H. H., Gonzales, V., Younkin, L. H., Younkin, S. G., Borchelt, D. R., & Savonenko, A. V. (2005).

Environmental enrichment mitigates cognitive deficits in a mouse model of Alzheimer's disease. *Journal of Neuroscience*, *25*(21), 5217–5224.

Jefferson, A. L., Gibbons, L. E., Rentz, D. M., Carvalho, J. O., Manly, J., Bennett, D. A., & Jones, R. N. (2011). A life course model of cognitive activities, socioeconomic status, education, reading ability, and cognition. *Journal of the American Geriatrics Society*, *59*(8), 1403–1411.

Jessor, R., & Jessor, S. L. (1977). *Problem behavior and psychosocial development: A longitudinal study of youth.*

Jones, N. L., Gilman, S. E., Cheng, T. L., Drury, S. S., Hill, C. V., & Geronimus, A. T. (2019). Life course approaches to the causes of health disparities. *American Journal of Public Health*, *109*(S1), S48–S55.

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, *15*(3), 169–182.

Karp, A., Paillard-Borg, S., Wang, H.-X., Silverstein, M., Winblad, B., & Fratiglioni, L. (2006). Mental, physical and social components in leisure activities equally contribute to decrease dementia risk. *Dementia and Geriatric Cognitive Disorders*, *21*(2), 65–73.

Katzman, R. (2004). A neurologist's view of Alzheimer's disease and dementia. *International Psychogeriatrics*, *16*(3), 259–273. https://doi.org/10.1017/S1041610204000456

Kaufman, A. S., Raiford, S. E., & Coalson, D. L. (2015). *Intelligent Testing with the WISC-V*. John Wiley & Sons.

Kaushal, N., & Rhodes, R. E. (2014). The home physical environment and its relationship with physical activity and sedentary behavior: A systematic review. *Preventive Medicine*, *67*, 221–237. https://doi.org/10.1016/j.ypmed.2014.07.026

Kawachi, I. (1999). Social capital and community effects on population and individual health. *Annals of the New York Academy of Sciences*, *896*(1), 120–130.

Kawachi, I. (2006). Commentary: Social capital and health: making the connections one step at a time. *International Journal of Epidemiology*, *35*(4), 989–993. https://doi.org/10.1093/ije/dyl117

Kawachi, I., Kennedy, B. P., & Glass, R. (1999). Social capital and self-rated health: A contextual analysis. *American Journal of Public Health*, *89*(8), 1187–1193. https://doi.org/10.2105/AJPH.89.8.1187

Kaza, N. (2013). The changing urban landscape of the continental United States. *Landscape and Urban Planning*, *110*, 74–86. https://doi.org/10.1016/j.landurbplan.2012.10.015

Kearns, A., & Parkinson, M. (2001). The Significance of Neighbourhood. *Urban Studies*, *38*(12), 2103–2110. https://doi.org/10.1080/00420980120087063

Keay, L., Jasti, S., Munoz, B., Turano, K. A., Munro, C. A., Duncan, D. D., Baldwin, K., Bandeen-Roche, K. J., Gower, E. W., & West, S. K. (2009). Urban and rural differences in older drivers' failure to stop at stop signs. *Accident Analysis & Prevention*, *41*(5), 995–1000.

Kelly, M. E., Duff, H., Kelly, S., McHugh Power, J. E., Brennan, S., Lawlor, B. A., & Loughrey, D. G. (2017). The impact of social activities, social networks, social support and social relationships on the cognitive functioning of healthy older adults: A systematic review. *Systematic Reviews*, *6*(1), 259. https://doi.org/10.1186/s13643-017-0632-2

Kerr, J., Rosenberg, D., & Frank, L. (2012). The role of the built environment in healthy aging: Community design, physical activity, and health among older adults. *Journal of Planning Literature*, *27*(1), 43–60.

Key, W. H. (1961). Rural-Urban Differences and the Family. *The Sociological Quarterly*, *2*(1), 49–56. https://doi.org/10.1111/j.1533-8525.1961.tb01484.x

Khalil, H., Quinn, L., van Deursen, R., Martin, R., Rosser, A., & Busse, M. (2012). Adherence to Use of a Home-Based Exercise DVD in People With Huntington Disease: Participants' Perspectives. *Physical Therapy*, *92*(1), 69–82. https://doi.org/10.2522/ptj.20100438

Knopik, V. S., Neiderhiser, J. M., DeFries, J. C., & Plomin, R. (2017). *Behavioral genetics* (Seventh edition. ed.). Worth Publishers, Macmillan Learning.

Krabbendam, L., & Van Os, J. (2005). Schizophrenia and urbanicity: A major environmental influence—conditional on genetic risk. *Schizophrenia Bulletin*, *31*(4), 795–799.

Krueger, K. R., Wilson, R. S., Kamenetsky, J. M., Barnes, L. L., Bienias, J. L., & Bennett, D. A. (2009). Social engagement and cognitive function in old age. *Experimental Aging Research*, *35*(1), 45–60.

Kuiper, J. S., Zuidersma, M., Voshaar, R. C. O., Zuidema, S. U., van den Heuvel, E. R., Stolk, R. P., & Smidt, N. (2015). Social relationships and risk of dementia: A systematic review and meta-analysis of longitudinal cohort studies. *Ageing Research Reviews*, *22*, 39–57.

Kuiper, J. S., Zuidersma, M., Zuidema, S. U., Burgerhof, J. G., Stolk, R. P., Oude Voshaar, R. C., & Smidt, N. (2016). Social relationships and cognitive decline: A systematic review and meta-analysis of longitudinal cohort studies. *International Journal of Epidemiology*, *45*(4), 1169–1206.

Kweon, B.-S., Sullivan, W. C., & Wiley, A. R. (1998). Green common spaces and the social integration of inner-city older adults. *Environment and Behavior*, *30*(6), 832–858.

Laidley, T., Vinneau, J., & Boardman, J. D. (2019). Individual and Social Genomic Contributions to Educational and Neighborhood Attainments: Geography, Selection, and Stratification in the United States. *Sociological Science*, *6*, 580–608. https://doi.org/10.15195/v6.a22

Lambert, D. M., Wilcox, M. D., Clark, C. D., Murphy, B., & Park, W. M. (2010). Is growth in the health sector correlated with later-life migration? In *Progress in Spatial Analysis* (pp. 381–403). Springer.

Lampard, J. E., Voigt, M., & Bornstein, M. H. (2000). Urban and rural parenting. *Parenthood in America: An Encyclopedia*, *2*, 442–444.

Langa, K. M., Larson, E. B., Crimmins, E. M., Faul, J. D., Levine, D. A., Kabeto, M. U., & Weir, D. R. (2017). A comparison of the prevalence of dementia in the United States in 2000 and 2012. *JAMA Internal Medicine*, *177*(1), 51–58.

Langa, K. M., Larson, E. B., Karlawish, J. H., Cutler, D. M., Kabeto, M. U., Kim, S. Y., & Rosen, A. B. (2008). Trends in the prevalence and mortality of cognitive impairment in the United States: Is there evidence of a compression of cognitive morbidity? *Alzheimer's & Dementia*, *4*(2), 134–144.

Lawrence, E., Hummer, R. A., & Harris, K. M. (2017). The cardiovascular health of young adults: Disparities along the urban-rural continuum. *The Annals of the American Academy of Political and Social Science*, *672*(1), 257–281.

Leavy, R. L. (1983). Social support and psychological disorder: A review. *Journal of Community Psychology*, *11*(1), 3–21. https://doi.org/10.1002/1520-6629(198301)11:1<3::AID-JCOP2290110102>3.0.CO;2-E

Lee, C.-J., & Kim, D. (2013). A Comparative Analysis of the Validity of US State- and County-Level Social Capital Measures and Their Associations with Population Health. *Social Indicators Research*, *111*(1), 307–326. https://doi.org/10.1007/s11205-012-0007-y

Lee, Y., Chi, I., & Palinkas, L. A. (2019). Retirement, Leisure Activity Engagement, and Cognition Among Older Adults in the United States. *Journal of Aging and Health*, *31*(7), 1212–1234. https://doi.org/10.1177/0898264318767030

Lee, S., Kawachi, I., Berkman, L. F., & Grodstein, F. (2003). Education, other socioeconomic indicators, and cognitive function. *American Journal of Epidemiology*, *157*(8), 712–720.

Letellier, N., Carrière, I., Cadot, E., Berkman, L., Goldberg, M., Zins, M., & Berr, C. (2020). Individual and neighbourhood socioeconomic inequalities in cognitive impairment: Cross-sectional findings from the French CONSTANCES cohort. *BMJ Open*, *10*(3), e033751. https://doi.org/10.1136/bmjopen-2019-033751

Levasseur, M., Cohen, A. A., Dubois, M.-F., Généreux, M., Richard, L., Therrien, F.-H., & Payette, H. (2015). Environmental Factors Associated With Social Participation of Older Adults Living in Metropolitan, Urban, and Rural Areas: The NuAge Study. *American Journal of Public Health*, *105*(8), 1718–1725. https://doi.org/10.2105/AJPH.2014.302415

Lin, N. (2001b). Building a Network Theory of Social Capital. In N. Lin, R. Cook, & S. Burt, (Eds.), *Social Capital: Theory and Research.* Aldine de Gruyter.

Lin, N. (2002a). *Social Capital: A Theory of Social Structure and Action*. Cambridge University Press.

Lin, N. (1982). Social Resources and Instrumental Action. In P. V. Marsden & N. Lin (Eds.), *Social Structure and Network Analysis.* (pp. 131–145). Sage. https://scholar.google.com/scholar_lookup?title=Social%20resources%20and%20instrumental%20action&author=N.%20Lin&pages=131-145&publication_year=1982

Lin, Nan, & Dumin, M. (1986). Access to occupations through social ties. *Social Networks*, *8*(4), 365–385.

Lindström, M. (2004). Social capital, the miniaturisation of community and self-reported global and psychological health. *Social Science & Medicine*, *59*(3), 595–607. https://doi.org/10.1016/j.socscimed.2003.11.006

Linnell, K. J., Caparos, S., de Fockert, J. W., & Davidoff, J. (2013). Urbanization decreases attentional engagement. *Journal of Experimental Psychology: Human Perception and Performance*, *39*(5), 1232.

Litwin, H., & Stoeckel, K. J. (2015). Social Network, Activity Participation, and Cognition: A Complex Relationship. *Research on Aging*, *38*(1), 76–97. https://doi.org/10.1177/0164027515581422

Liu, Y., Wang, R., Xiao, Y., Huang, B., Chen, H., & Li, Z. (2019). Exploring the linkage between greenness exposure and depression among Chinese people: Mediating roles of physical activity, stress and social cohesion and moderating role of urbanicity. *Health & Place*, *58*, 102168.

Lochner, K., Kawachi, I., & Kennedy, B. P. (1999). Social Capital: A guide to its measurement. *Health & Place*, *5*, 259–270. https://doi.org/10.1016/S1353-8292(99)00016-7

Lövdén, M., Bäckman, L., Lindenberger, U., Schaefer, S., & Schmiedek, F. (2010). A theoretical framework for the study of adult cognitive plasticity. *Psychological Bulletin*, *136*(4), 659.

Lövdén, M., Schellenbach, M., Grossman-Hutter, B., Krüger, A., & Lindenberger, U. (2005). Environmental topography and postural control demands shape aging-associated decrements in spatial navigation performance. *Psychology and Aging*, *20*(4), 683–694. https://doi.org/10.1037/0882-7974.20.4.683

Lynch, J., Smith, G. D., Hillemeier, M., Shaw, M., Raghunathan, T., & Kaplan, G. (2001). Income inequality, the psychosocial environment, and health: Comparisons of wealthy nations. *The Lancet*, *358*(9277), 194–200. https://doi.org/10.1016/S0140-6736(01)05407-1

Maas, J., Van Dillen, S. M., Verheij, R. A., & Groenewegen, P. P. (2009). Social contacts as a possible mechanism behind the relation between green space and health. *Health & Place*, *15*(2), 586–595.

Mainous, A. G., & Kohrs, F. P. (1995). A comparison of health status between rural and urban adults. *Journal of Community Health*, *20*(5), 423–431.

Mammen, S., Lawrence, F. C., Marie, P. S., Berry, A. A., & Knight, S. E. (2011). The earned income tax credit and rural families: Differences between non-participants and participants. *Journal of Family and Economic Issues*, *32*(3), 461–472.

Mannarini, T., & Fedi, A. (2009). Multiple senses of community: The experience and meaning of community. *Journal of Community Psychology*, *37*(2), 211–227. https://doi.org/10.1002/jcop.20289

Martin, M., & Zimprich, D. (2005). Cognitive development in midlife. *Middle Adulthood: A Lifespan Perspective*, 179–206.

Marttinen, R., Simon, M., Phillips, S., & Fredrick, R. N. (2020). Latina Elementary School Girls' Experiences in an Urban After-School Physical Education and Literacy Program. *Journal of Teaching in Physical Education*, *1*(aop), 1–10. https://doi.org/10.1123/jtpe.2019-0211

Matz, C. J., Stieb, D. M., & Brion, O. (2015). Urban-rural differences in daily time-activity patterns, occupational activity and housing characteristics. *Environmental Health*, *14*(1). https://doi.org/10.1186/s12940-015-0075-y

McCall-Hosenfeld, J. S., Mukherjee, S., & Lehman, E. B. (2014). The Prevalence and Correlates of Lifetime Psychiatric Disorders and Trauma Exposures in Urban and Rural Settings: Results from the National Comorbidity Survey Replication (NCS-R). *PLoS ONE*, *9*(11), e112416. https://doi.org/10.1371/journal.pone.0112416

Michael, Y. L., & Yen, I. H. (2014). *Aging and place—Neighborhoods and health in a world growing older*. *26*(8), 1251–1260.

Mitchell, R. E., & Trickett, E. J. (1980). Task force report: Social networks as mediators of social support. *Community Mental Health Journal*, *16*(1), 27–44. https://doi.org/10.1007/BF00780665

Meng, T., & Chen, H. (2014). A multilevel analysis of social capital and self-rated health: Evidence from China. *Health & Place*, *27*, 38–44. https://doi.org/10.1016/j.healthplace.2014.01.009

Moffat, S. D., & Resnick, S. M. (2002). Effects of age on virtual environment place navigation and allocentric cognitive mapping. *Behavioral Neuroscience*, *116*(5), 851.

Mohnen, S. M., Groenewegen, P. P., Völker, B., & Flap, H. (2011). Neighborhood social capital and individual health. *Social Science & Medicine*, *72*(5), 660–667.

Moore, J., Fiddler, H., Seymour, J., Grant, A., Jolley, C., Johnson, L., & Moxham, J. (2009). Effect of a home exercise video programme in patients with chronic obstructive pulmonary disease. *Journal of Rehabilitation Medicine*, *41*(3), 195–200. https://doi.org/10.2340/16501977-0308

Mueller, K. D., Norton, D., Koscik, R. L., Morris, M. C., Jonaitis, E. M., Clark, L. R., Fields, T., Allison, S., Berman, S., Kraning, S., Zuelsdorff, M., Okonkwo, O., Chin, N.,

Carlsson, C. M., Bendlin, B. B., Hermann, B. P., & Johnson, S. C. (2020). Self-reported health behaviors and longitudinal cognitive performance in late middle age: Results from the Wisconsin Registry for Alzheimer's Prevention. *PLOS ONE*, *15*(4), e0221985. https://doi.org/10.1371/journal.pone.0221985

Murayama, H., Nishi, M., Matsuo, E., Nofuji, Y., Shimizu, Y., Taniguchi, Y., Fujiwara, Y., & Shinkai, S. (2013). Do bonding and bridging social capital affect self-rated health, depressive mood and cognitive decline in older Japanese? A prospective cohort study. *Social Science & Medicine*, *98*, 247–252. https://doi.org/10.1016/j.socscimed.2013.09.026

Murayama, H., Sugiyama, M., Inagaki, H., Okamura, T., Miyamae, F., Ura, C., Edahiro, A., Motokawa, K., & Awata, S. (2018). Is community social capital associated with subjective symptoms of dementia among older people? A cross-sectional study in Japan: Social capital and dementia symptoms. *Geriatrics & Gerontology International*. https://doi.org/10.1111/ggi.13519

Michael, Y. L., Green, M. K., & Farquhar, S. A. (2006). Neighborhood design and active aging. *Health & Place*, *12*(4), 734–740.

Nahapiet, J., & Ghoshal, S. (1998). Social Capital, Intellectual Capital, and the Organizational Advantage. *The Academy of Management Review*, *23*(2), 242–266. JSTOR. https://doi.org/10.2307/259373

Northeast Regional Center for Rural Development, S. C. V. for 2014. (2019). *Social Capital Variables for 2014 (Northeast Regional Center for Rural Development)*. Northeast Regional Center for Rural Development (Penn State University). https://aese.psu.edu/nercrd/community/social-capital-resources/social-capital-variables-for-2014

Nunes, B., Silva, R. D., Cruz, V. T., Roriz, J. M., Pais, J., & Silva, M. C. (2010). Prevalence and pattern of cognitive impairment in rural and urban populations from Northern Portugal. *BMC Neurology*, *10*(1), 42. https://doi.org/10.1186/1471-2377-10-42

Onyx, J., & Bullen, P. (2000). Measuring Social Capital in Five Communities. *The Journal of Applied Behavioral Science*, *36*(1), 23–42. https://doi.org/10.1177/0021886300361002

Offer, S., & Schneider, B. (2007). Children's Role in Generating Social Capital. *Social Forces*, *85*(3), 1125–1142. JSTOR.

Paluska, S. A., & Schwenk, T. L. (2000). Physical activity and mental health. *Sports Medicine*, *29*(3), 167–180.

Pandey, A., Salahuddin, U., Garg, S., Ayers, C., Kulinski, J., Anand, V., Mayo, H., Kumbhani, D. J., de Lemos, J., & Berry, J. D. (2016). Continuous dose-response association between sedentary time and risk for cardiovascular disease: A meta-analysis. *JAMA Cardiology*, *1*(5), 575–583.

Parks, S. E., Housemann, R. A., & Brownson, R. C. (2003). Differential correlates of physical activity in urban and rural adults of various socioeconomic backgrounds in the United States. *Journal of Epidemiology & Community Health*, *57*(1), 29–35. https://doi.org/10.1136/jech.57.1.29

Park, J. Z., & Smith, C. (2000). 'To Whom Much Has Been Given...': Religious Capital and Community Voluntarism Among Churchgoing Protestants. *Journal for the Scientific Study of Religion*, *39*(3), 272–286.

Patterson, P. D., Moore, C. G., Probst, J. C., & Shinogle, J. A. (2004). Obesity and Physical Inactivity in Rural America. *The Journal of Rural Health*, *20*(2), 151–159. https://doi.org/10.1111/j.1748-0361.2004.tb00022.x

Paúl, C., Fonseca, A. M., Martín, I., & Amado, J. (2003). Psychosocial profile of rural and urban elders in Portugal. *European Psychologist*, *8*(3), 160.

Pedersen, N. L. (2015). *Swedish Adoption/Twin Study on Aging (SATSA), 1984, 1987, 1990, 1993, 2004, 2007, and 2010*. Inter-university Consortium for Political and Social Research [distributor]. https://doi.org/10.3886/ICPSR03843.v2

Peen, J., Schoevers, R. A., Beekman, A. T., & Dekker, J. (2010). The current status of urban-rural differences in psychiatric disorders. *Acta Psychiatrica Scandinavica*, *121*(2), 84–93. https://doi.org/10.1111/j.1600-0447.2009.01438.x

Petrou, S., & Kupek, E. (2008). Social capital and its relationship with measures of health status: Evidence from the Health Survey for England 2003. *Health Economics*, *17*(1), 127–143. https://doi.org/10.1002/hec.1242

Phansikar, M., & Mullen, S. P. (2019). Exploring Active Travel and Leisure-Time Physical Activity Relationships With Cognition Among Older Adults. *Journal of Aging and Physical Activity*, *1*(aop), 1–8. https://doi.org/10.1123/japa.2019-0125

Pinillos-Franco, S., & Kawachi, I. (2018). The relationship between social capital and self-rated health: A gendered analysis of 17 European countries. *Social Science & Medicine*, *219*, 30–35. https://doi.org/10.1016/j.socscimed.2018.10.010

Plomin, R., & DeFries, J. C. (1983). The Colorado adoption project. *Child Development*, 276–289.

Poortinga, W. (2006). Social capital: An individual or collective resource for health? *Social Science & Medicine*, *62*(2), 292–302. https://doi.org/10.1016/j.socscimed.2005.06.008

Probst, J. C., Moore, C. G., Baxley, E. G., & Lammie, J. J. (2002). Rural-Urban Differences in Visits to Primary Care Physicians. *Family Medicine*, *34*(8), 609–615.

Putnam, R. D. (1995). Tuning in, tuning out: The strange disappearance of social capital in America. *PS: Political Science & Politics*, *28*(4), 664–683.

Putnam, R. D. (2000). Bowling alone: The Collapse and Revival of American Community. In *Bowling alone: The Collapse and Revival of American Community*. Simon & Schuster.

Putnam, R. D., Leonardi, R., & Nanetti, R. Y. (1994). *Making democracy work: Civic traditions in modern Italy*. Princeton university press.

Queen, T. L., Butner, J., Berg, C. A., & Smith, J. (2019). Activity Engagement Among Older Adult Spousal Caregivers. *The Journals of Gerontology: Series B*, *74*(7), 1278–1282. https://doi.org/10.1093/geronb/gbx106

Raftery, A. E. (1995). Bayesian Model Selection in Social Research. *Sociological Methodology*, *25*, 111–163. https://doi.org/10.2307/271063

Reis, J. P., Bowles, H. R., Ainsworth, B. E., Dubose, K. D., Smith, S., & Laditka, J. N. (2004). Nonoccupational physical activity by degree of urbanization and U.S. geographic region. *Medicine and Science in Sports and Exercise*, *36*(12), 2093—2098. https://doi.org/10.1249/01.mss.0000147589.98744.85

Reeves, D., Blickem, C., Vassilev, I., Brooks, H., Kennedy, A., Richardson, G., & Rogers, A. (2014). The Contribution of Social Networks to the Health and Self-Management of Patients with Long-Term Conditions: A Longitudinal Study. *PLOS ONE*, *9*(6), e98340. https://doi.org/10.1371/journal.pone.0098340

Rhea, S.-A., Bricker, J. B., Wadsworth, S. J., & Corley, R. P. (2013). The Colorado Adoption Project. *Twin Research and Human Genetics*, *16*(01), 358–365. https://doi.org/10.1017/thg.2012.109

Rhea, S.-A., Bricker, J. B., Wadsworth, S. J., & Corley, R. P. (2013). The Colorado Adoption Project. *Twin Research and Human Genetics: The Official Journal of the International Society for Twin Studies*, *16*(1), 358–365. https://doi.org/10.1017/thg.2012.109

Rhea, S.-A., Gross, A. A., Haberstick, B. C., & Corley, R. P. (2013). Colorado Twin Registry—An Update. *Twin Research and Human Genetics : The Official Journal of the International Society for Twin Studies*, *16*(1). https://doi.org/10.1017/thg.2012.93

Richards, M., & Wadsworth, M. (2004). Long term effects of early adversity on cognitive function. *Archives of Disease in Childhood*, *89*(10), 922–927.

Robertson, M. C., Song, J., Taylor, W. C., Durand, C. P., & Basen-Engquist, K. M. (2018). Urban-Rural Differences in Aerobic Physical Activity, Muscle Strengthening Exercise, and Screen-Time Sedentary Behavior: Urban-Rural Differences in Physical Activity. *The Journal of Rural Health*, *00*, 1–10. https://doi.org/10.1111/jrh.12295

Romans, S., Cohen, M., & Forte, T. (2011). Rates of depression and anxiety in urban and rural Canada. *Social Psychiatry and Psychiatric Epidemiology*, *46*(7), 567–575.

Romans, S. E., Walton, V. A., Herbison, G. P., & Mullen, P. E. (1992). Social Networks and Psychiatric Morbidity in New Zealand Women. *Australian and New Zealand Journal of Psychiatry*, *26*(3), 485–492. https://doi.org/10.3109/00048679209072075

Romans-Clarkson, S., E., Walton, V., A., Herbison, P., & Mullen, P. (1990). *Psychiatric Morbidity among Women in Urban and Rural New Zealand: Psycho-social Correlates - ProQuest*. https://search.proquest.com/openview/253655a5b652cd8eb52b9cb15d33e3cb/1/advanced

Roscigno, V. J., Tomaskovic-Devey, D., & Crowley, M. (2005). Education and the Inequalities of Place. *Social Forces*, *84*(4), 2121–2146.

Rosenquist, J. N., Murabito, J., Fowler, J. H., & Christakis, N. A. (2010). The Spread of Alcohol Consumption Behavior in a Large Social Network. *Annals of Internal Medicine*, *152*(7), 426–433. https://doi.org/10.7326/0003-4819-152-7-201004060-00007

Rupasingha, A., Goetz, S. J., & Freshwater, D. (2006). The production of social capital in US counties. *The Journal of Socio-Economics*, *35*(1), 83–101. https://doi.org/doi:10.1016/j.socec.2005.11.001

Russ, T. C., Batty, G. D., Hearnshaw, G. F., Fenton, C., & Starr, J. M. (2012). Geographical variation in dementia: Systematic review with meta-analysis. *International Journal of Epidemiology*, *41*(4), 1012–1032. https://doi.org/10.1093/ije/dys103

Saelens, B. E., & Handy, S. L. (2008). Built environment correlates of walking: A review. *Medicine and Science in Sports and Exercise*, *40*(7 Suppl), S550.

Saenz, J. L., Downer, B., Garcia, M. A., & Wong, R. (2018). Cognition and Context: Rural–Urban Differences in Cognitive Aging Among Older Mexican Adults. *Journal of Aging and Health*, *30*(6), 965–986. https://doi.org/10.1177/0898264317703560

Sajeev, G., Weuve, J., Jackson, J. W., VanderWeele, T. J., Bennett, D. A., Grodstein, F., & Blacker, D. (2016). Late-life cognitive activity and dementia: A systematic review and bias analysis. *Epidemiology (Cambridge, Mass.)*, *27*(5), 732.

Sallis, J. F., Bowles, H. R., Bauman, A., Ainsworth, B. E., Bull, F. C., Craig, C. L., Sjöström, M., De Bourdeaudhuij, I., Lefevre, J., Matsudo, V., Matsudo, S., Macfarlane, D. J., Gomez, L. F., Inoue, S., Murase, N., Volbekiene, V., McLean, G., Carr, H., Heggebo, L. K., … Bergman, P. (2009). Neighborhood Environments and Physical Activity Among Adults in 11 Countries. *American Journal of Preventive Medicine*, *36*(6), 484–490. https://doi.org/10.1016/j.amepre.2009.01.031

Salthouse, T. A. (2009). When does age-related cognitive decline begin? *Neurobiology of Aging*, *30*(4), 507–514.

Salthouse, T. A., Berish, D. E., & Miles, J. D. (2002). The role of cognitive stimulation on the relations between age and cognitive functioning. *Psychology and Aging*, *17*(4), 548–557. https://doi.org/10.1037/0882-7974.17.4.548

Salvo, G., Lashewicz, B. M., Doyle-Baker, P. K., & McCormack, G. R. (2018). Neighbourhood Built Environment Influences on Physical Activity among Adults: A Systematized Review of Qualitative Evidence. *International Journal of Environmental Research and Public Health*, *15*(5), 897. https://doi.org/10.3390/ijerph15050897

Sampaio, P. Y. S., Ito, E., & Carvalho Sampaio, R. A. (2013). The association of activity and participation with quality of life between Japanese older adults living in rural and urban areas. *Journal of Clinical Gerontology and Geriatrics*, *4*(2), 51–56. https://doi.org/10.1016/j.jcgg.2012.11.004

Sampson, R. J. (1988). Local Friendship Ties and Community Attachment in Mass Society: A Multilevel Systemic Model. *American Sociological Review*, *53*(5), 766–779. https://doi.org/10.2307/2095822

Sanchez, L., & Pacheco, E. (2012). Rural Population Trends in Mexico: Demographic and Labor Changes. In L. J. Kulcsár & K. J. Curtis (Eds.), *International Handbook of Rural Demography* (pp. 155–168). Springer Netherlands. https://doi.org/10.1007/978-94-007-1842-5_12

Sanderson, B., Littleton, M., & Pulley, L. V. (2002). Environmental, Policy, and Cultural Factors Related to Physical Activity Among Rural, African American Women. *Women & Health*, *36*(2), 73–88. https://doi.org/10.1300/J013v36n02_06

Scarmeas, N., Levy, G., Tang, M.-X., Manly, J., & Stern, Y. (2001). Influence of leisure activity on the incidence of Alzheimer's disease. *Neurology*, *57*(12), 2236–2242.

Schaie, K. W., Willis, S. L., Knight, B. G., Levy, B., & Park, D. C. (Eds.). (2016). *Handbook of the Psychology of Aging* (7 edition). Academic Press.

Sharifian, N., Gu, Y., Manly, J. J., Schupf, N., Mayeux, R., Brickman, A. M., & Zahodne, L. B. (2020). Linking depressive symptoms and cognitive functioning: The mediating role of leisure activity. *Neuropsychology*, *34*(1), 107–115. https://doi.org/10.1037/neu0000595

Sharp, E. S., & Gatz, M. (2011). Relationship Between Education and Dementia: An Updated Systematic Review. *Alzheimer Disease & Associated Disorders*, *25*(4), 289–304. https://doi.org/10.1097/WAD.0b013e318211c83c

Shelton, R. C., McNeill, L. H., Puleo, E., Wolin, K. Y., Emmons, K. M., & Bennett, G. G. (2011). The Association Between Social Factors and Physical Activity Among Low-Income Adults Living in Public Housing. *American Journal of Public Health*, *101*(11), 2102–2110. https://doi.org/10.2105/AJPH.2010.196030

Singh, G. K., & Siahpush, M. (2014). Widening Rural–Urban Disparities in Life Expectancy, U.S., 1969–2009. *American Journal of Preventive Medicine*, *46*(2), e19–e29. https://doi.org/10.1016/j.amepre.2013.10.017

Singh-Manoux, A., Richards, M., & Marmot, M. (2005). Socioeconomic position across the lifecourse: How does it relate to cognitive function in mid-life? *Annals of Epidemiology*, *15*(8), 572–578. https://doi.org/10.1016/j.annepidem.2004.10.007

Smidt, C. (1999). Religion and civic engagement: A comparative analysis. *The Annals of the American Academy of Political and Social Science*, *565*(1), 176–192.

Smith, K. B., Humphreys, J. S., & Wilson, M. G. (2008). Addressing the health disadvantage of rural populations: How does epidemiological evidence inform rural health policies and research? *Australian Journal of Rural Health*, *16*(2), 56–66. https://doi.org/doi: 10.1111/j.1440-1584.2008.00953.x

Snidjers, T. A. B. (1999). Prologue to the measurement of social capital. *La Revue Tocqueville/The Toc*.

Sofi, F., Valecchi, D., Bacci, D., Abbate, R., Gensini, G. F., Casini, A., & Macchi, C. (2011). Physical activity and risk of cognitive decline: A meta-analysis of prospective studies. *Journal of Internal Medicine*, *269*(1), 107–117.

Song, L., Son, J., & Lin, N. (2013). *Social capital and health* (W. C. Cockerham, Ed.). Springer.

Sørensen, J. F. L. (2012). Testing the Hypothesis of Higher Social Capital in Rural Areas: The Case of Denmark. *Regional Studies*, *46*(7), 873–891. https://doi.org/10.1080/00343404.2012.669471

Sørensen, J. F. L. (2016). Rural–Urban Differences in Bonding and Bridging Social Capital. *Regional Studies*, *50*(3), 391–410. https://doi.org/10.1080/00343404.2014.918945

Spanier, P. A., & Allison, K. R. (2001). General Social Support and Physical Activity: An Analysis of the Ontario Health Survey. *Canadian Journal of Public Health*, *92*(3), 210–213. https://doi.org/10.1007/BF03404308

Spencer, J. C., Wheeler, S. B., Rotter, J. S., & Holmes, G. M. (2018). Decomposing Mortality Disparities in Urban and Rural U.S. Counties. *Health Services Research*. https://doi.org/10.1111/1475-6773.12982

Stebbins, R. A. (2015). *Between Work and Leisure: The Common Ground of Two Separate Worlds*. Transaction Publishers.

Stebbins, R. (2017). *Serious Leisure: A Perspective for Our Time (paperback edition)*. Routledge.

Stepankova Georgi, H., Frydrychova, Z., Horakova Vlckova, K., Vidovicova, L., Sulc, Z., & Lukavsky, J. (2019). Young-Old City-Dwellers Outperform Village Counterparts in Attention and Verbal Control Tasks. *Frontiers in Psychology*, *10*, 1224. https://doi.org/10.3389/fpsyg.2019.01224

Stern, Y. (2012). Cognitive reserve in ageing and Alzheimer's disease. *The Lancet Neurology*, *11*(11), 1006–1012. https://doi.org/10.1016/S1474-4422(12)70191-6

Stern, C., & Munn, Z. (2010). Cognitive leisure activities and their role in preventing dementia: A systematic review. *International Journal of Evidence-Based Healthcare*, *8*(1), 2–17. https://doi.org/10.1111/j.1744-1609.2010.00150.x

Stewart, L. A., & Lambert, D. M. (2008). *Factors determining corn-based ethanol plant site selection, 2000-2007*.

Suherman, A., Jajat, Rahayu, N. I., Sultoni, K., Risma, R., & Agust, K. (2020). *Early Childhood Physical Activity and Sedentary Behavior in Indonesia: Objectively Measure Using Accelerometer*. 426–428. https://doi.org/10.2991/ahsr.k.200214.114

Subramanian, S. V., Kawachi, I., & Kennedy, B. P. (2001). Does the state you live in make a difference? Multilevel analysis of self-rated health in the US. *Social Science & Medicine*, *53*(1), 9–19. https://doi.org/10.1016/S0277-9536(00)00309-9

Sundquist, K., Frank, G., & Sundquist, J. A. N. (2004). Urbanisation and incidence of psychosis and depression: Follow-up study of 4.4 million women and men in Sweden. *The British Journal of Psychiatry*, *184*(4), 293–298.

Svedberg, P., Gatz, M., Lichtenstein, P., Sandin, S., & Pedersen, N. L. (2005). Self-Rated Health in a Longitudinal Perspective: A 9-Year Follow-Up Twin Study. *The Journals of Gerontology: Series B*, *60*(6), S331–S340. https://doi.org/10.1093/geronb/60.6.S331

Taaffe, D. R., Irie, F., Masaki, K. H., Abbott, R. D., Petrovitch, H., Ross, G. W., & White, L. R. (2008). Physical activity, physical function, and incident dementia in elderly men: The Honolulu–Asia Aging Study. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *63*(5), 529–535.

Tang, F., Zhang, W., Chi, I., Li, M., & Dong, X. Q. (2020). Importance of Activity Engagement and Neighborhood to Cognitive Function Among Older Chinese Americans. *Research on Aging*, 0164027520917064. https://doi.org/10.1177/0164027520917064

Therrien, F.-H., & Desrosiers, J. (2010). Participation of metropolitan, urban and rural community-dwelling older adults. *Archives of Gerontology and Geriatrics*, *51*(3), e52–e56. https://doi.org/10.1016/j.archger.2009.11.017

Trivedi, T., Liu, J., Probst, J., Merchant, A., Jones, S., & Martin, A. (2015). Obesity and obesity-related behaviors among rural and urban adults in the USA. *Rural Remote Health*, *15*(4), 11.

Tulin, M., Lancee, B., & Volker, B. (2018). Personality and Social Capital. *Social Psychology Quarterly*, *81*(4), 295–318. https://doi.org/10.1177/0190272518804533

Uijtdewilligen, L., Twisk, J. W., Singh, A. S., Chinapaw, M. J., van Mechelen, W., & Brown, W. J. (2014). Biological, socio-demographic, work and lifestyle determinants of sitting in young adult women: A prospective cohort study. *International Journal of Behavioral Nutrition and Physical Activity*, *11*(1), 7.

US Department of Commerce, N. O. and A. A. (2018). *North American Datum of 1983 (NAD 83)—Horizontal and Geometric Datums—Datums—National Geodetic Survey*. https://www.ngs.noaa.gov/datums/horizontal/north-american-datum-1983.shtml

USDA, E. (2010). *USDA ERS - Rural-Urban Commuting Area Codes*. Rural-Urban Commuting Area Codes. https://www.ers.usda.gov/data-products/rural-urban-commuting-area-codes/

USDA, E. (2013). *USDA ERS - Rural-Urban Continuum Codes*. https://www.ers.usda.gov/data-products/rural-urban-continuum-codes/

Valenzuela, M., & Sachdev, P. (2009). Can Cognitive Exercise Prevent the Onset of Dementia? Systematic Review of Randomized Clinical Trials with Longitudinal Follow-up. *The American Journal of Geriatric Psychiatry*, *17*(3), 179–187. https://doi.org/10.1097/JGP.0b013e3181953b57

Van Cauwenberg, J., De Bourdeaudhuij, I., De Meester, F., Van Dyck, D., Salmon, J., Clarys, P., & Deforche, B. (2011). Relationship between the physical environment and physical activity in older adults: A systematic review. *Health & Place*, *17*(2), 458–469.

Van der Gaag, M., Snijders, T. A., & Flap, H. D. (2008). *Position generator measures and their relationship to other social capital measures* (Nan Lin & B. Erickson H., Eds.). Oxford University Press USA.

Van der Linden, J., Drukker, M., Gunther, N., Feron, F., & Van Os, J. (2003). Children's mental health service use, neighbourhood socioeconomic deprivation, and social capital. *Social Psychiatry and Psychiatric Epidemiology*, *38*(9), 507–514. https://doi.org/10.1007/s00127-003-0665-9

Van Uffelen, J. G., Heesch, K. C., & Brown, W. (2012). Correlates of sitting time in working age Australian women: Who should be targeted with interventions to decrease sitting time? *Journal of Physical Activity and Health*, *9*(2), 270–287.

Verghese, J., Lipton, R. B., Katz, M. J., Hall, C. B., Derby, C. A., Kuslansky, G., Ambrose, A. F., Sliwinski, M., & Buschke, H. (2003). Leisure activities and the risk of dementia in the elderly. *New England Journal of Medicine*, *348*(25), 2508–2516.

Vestergaard, S., Kronborg, C., & Puggaard, L. (2008). Home-based video exercise intervention for community-dwelling frail older women: A randomized controlled trial. *Aging Clinical and Experimental Research*, *20*(5), 479–486. https://doi.org/10.1007/BF03325155

Vogelsang, E. M. (2016). Older adult social participation and its relationship with health: Rural-urban differences. *Health & Place*, *42*, 111–119. https://doi.org/10.1016/j.healthplace.2016.09.010

Wadsworth, S. J., Corley, R. P., Munoz, E., Trubenstein, B. P., Knaap, E., DeFries, J. C., Plomin, R., Reynolds, C. A., & The CATSLife Team. (2019a). CATSLife: A Study of Lifespan Behavioral Development and Cognitive Functioning. *Twin Research and Human Genetics*, *22*(6), 695–706. https://doi.org/10.1017/thg.2019.49

Wadsworth, S. J., Corley, R. P., Munoz, E., Trubenstein, B. P., Knaap, E., DeFries, J. C., Plomin, R., Reynolds, C. A., & The CATSLife Team. (2019b). CATSLife: A Study of Lifespan Behavioral Development and Cognitive Functioning – Corrigendum. *Twin Research and Human Genetics*, *22*(6), 829–829. https://doi.org/10.1017/thg.2019.126

Wahl, H.-W., Iwarsson, S., & Oswald, F. (2012). Aging well and the environment: Toward an integrative model and research agenda for the future. *The Gerontologist*, *52*(3), 306–316.

Waldorf, B. (2006). *A Continuous Multi-Dimensional Measure of Rurality: Moving Beyond Threshold Measures*. Selected Paper, Annual Meetings of the Association of Agricultural Economics, Long Beach, CA, July 2006.

Waldorf, B., & Ayoung, K. (2015). *Defining And Measuring Rurality in the US: From Typologies to Continuous Indices*. 26. https://doi.org/doi:10.4231/R7959FS8

Walker, K. N., MacBride, A., & Vachon, M. L. S. (1977). Social support networks and the crisis of bereavement. *Social Science & Medicine (1967)*, *11*(1), 35–41. https://doi.org/10.1016/0037-7856(77)90143-3

Wang, H.-X., Karp, A., Winblad, B., & Fratiglioni, L. (2002). Late-life engagement in social and leisure activities is associated with a decreased risk of dementia: A longitudinal study from the Kungsholmen project. *American Journal of Epidemiology*, *155*(12), 1081–1087.

Wang, H.-X., MacDonald, S. W., Dekhtyar, S., & Fratiglioni, L. (2017). Association of lifelong exposure to cognitive reserve-enhancing factors with dementia risk: A community-based cohort study. *PLoS Medicine*, *14*(3), e1002251.

Wanless, D., Mitchell, B. A., & Wister, A. V. (2010). Social determinants of health for older women in Canada: Does rural–urban residency matter? *Canadian Journal on Aging/La Revue Canadienne Du Vieillissement*, *29*(2), 233–247.

Ware, J. E., & Sherbourne, C. D. (1992). The MOS 36-Item Short-Form Health Survey (SF-36): I. Conceptual Framework and Item Selection. *Medical Care*, *30*(6), 473–483. JSTOR.

Waverijn, G., Wolfe, M. K., Mohnen, S., Rijken, M., Spreeuwenberg, P., & Groenewegen, P. (2014). A prospective analysis of the effect of neighbourhood and individual social capital on changes in self-rated health of people with chronic illness. *BMC Public Health*, *14*(1), 675.

Weaver, K. E., Palmer, N., Lu, L., Case, L. D., & Geiger, A. M. (2013). Rural–urban differences in health behaviors and implications for health status among US cancer survivors. *Cancer Causes & Control*, *24*(8), 1481–1490. https://doi.org/10.1007/s10552-013-0225-x

Wechsler, D. (1997). WAIS-III administration and scoring manual. San Antonio, TX: The Psychological Corporation.

Weden, M. M., Shih, R. A., Kabeto, M. U., & Langa, K. M. (2018). Secular Trends in Dementia and Cognitive Impairment of U.S. Rural and Urban Older Adults. *American Journal of Preventive Medicine*, *54*(2), 164–172. https://doi.org/10.1016/j.amepre.2017.10.021

Weeks, W. B., Kazis, L. E., Shen, Y., Cong, Z., Ren, X. S., Miller, D., Lee, A., & Perlin, J. B. (2004). Differences in health-related quality of life in rural and urban veterans. *American Journal of Public Health*, *94*(10), 1762–1767. https://doi.org/10.2105/AJPH.94.10.1762

Wen, M., Browning, C. R., & Cagney, K. A. (2003). Poverty, affluence, and income inequality: Neighborhood economic structure and its implications for health. *Social Science & Medicine*, *57*(5), 843–860. https://doi.org/10.1016/S0277-9536(02)00457-4

Wen, M., Fan, J. X., Kowaleski-Jones, L., & Wan, N. (2018). Rural–urban disparities in obesity prevalence among working age adults in the United States: Exploring the mechanisms. *American Journal of Health Promotion*, *32*(2), 400–408. https://doi.org/DOI: 10.1177/0890117116689488

Wilcox, S., Castro, C., King, A., Housemann, R., & Brownson, R. (2000). Determinants of leisure time physical activity in rural compared with urban older and ethnically diverse women in the United States. *Journal of Epidemiology & Community Health*, *54*(9), 667–672. https://doi.org/10.1136/jech.54.9.667

Williams, A. W., Ware Jr, J. E., & Donald, C. A. (1981). A model of mental health, life events, and social supports applicable to general populations. *Journal of Health and Social Behavior*, 324–336.

Wilson, R., Bennett, D., Bienias, J., Aggarwal, N., De Leon, C. M., Morris, M., Schneider, J., & Evans, D. (2002). Cognitive activity and incident AD in a population-based sample of older persons. *Neurology*, *59*(12), 1910–1914.

Wilson, R.S., Bennett, D. A., Bienias, J. L., Mendes de Leon, C. F., Morris, M. C., & Evans, D. A. (2003). Cognitive activity and cognitive decline in a biracial community population. *Neurology*, *61*(6), 812–816. https://doi.org/10.1212/01.WNL.0000083989.44027.05

Wilson, Robert S., Boyle, P. A., Yu, L., Barnes, L. L., Schneider, J. A., & Bennett, D. A. (2013). Life-span cognitive activity, neuropathologic burden, and cognitive aging. *Neurology*, *81*(4), 314–321. https://doi.org/10.1212/WNL.0b013e31829c5e8a

Wilson, J., & Musick, M. (1997). Who cares? Toward an integrated theory of volunteer work. *American Sociological Review*, *62*, 694–713. https://doi.org/10.2307/2657355

Wilson, R., Scherr, P., Schneider, J., Tang, Y., & Bennett, D. (2007). Relation of cognitive activity to risk of developing Alzheimer disease. *Neurology*, *69*(20), 1911–1920.

Wirth, L. (1938). Urbanism as a Way of Life. *American Journal of Sociology*, *44*(1), 1–24. JSTOR.

Wu, Y.-T., Prina, A. M., & Brayne, C. (2015). The association between community environment and cognitive function: A systematic review. *Social Psychiatry and Psychiatric Epidemiology*, *50*(3), 351–362. https://doi.org/10.1007/s00127-014-0945-6

Wu, Y.-T., Prina, A. M., Jones, A., Barnes, L. E., Matthews, F. E., & Brayne, C. (2017). Micro-scale environment and mental health in later life: Results from the Cognitive Function and Ageing Study II (CFAS II). *Journal of Affective Disorders*, *218*, 359–364. https://doi.org/10.1016/j.jad.2017.05.001

Wu, Y.-T., Prina, A. M., Jones, A. P., Barnes, L. E., Matthews, F. E., & Brayne, C. (2015). Community environment, cognitive impairment and dementia in later life: Results from the Cognitive Function and Ageing Study. *Age and Ageing*, *44*(6), 1005–1011.

Wu, Y.-T., Prina, A. M., Jones, A., Matthews, F. E., & Brayne, C. (2017). The Built Environment and Cognitive Disorders: Results From the Cognitive Function and Ageing Study II. *American Journal of Preventive Medicine*, *53*(1), 25–32. https://doi.org/10.1016/j.amepre.2016.11.020

Xiang, Y., Zare, H., Guan, C., & Gaskin, D. (2018). The impact of rural-urban community settings on cognitive decline: Results from a nationally-representative sample of seniors in China. *BMC Geriatrics*, *18*(1), 323. https://doi.org/10.1186/s12877-018-1003-0

Yang, T.-C., Jensen, L., & Haran, M. (2011). Social capital and human mortality: Explaining the rural paradox with county-level mortality data. *Rural Sociology*, *76*(3), 347–374. https://doi.org/10.1111/j.1549-0831.2011.00055.x

Yankeelov, P. A., Faul, A. C., D'Ambrosio, J. G., Collins, W. L., & Gordon, B. (2015). "Another Day in Paradise": A Photovoice Journey of Rural Older Adults Living With Diabetes. *Journal of Applied Gerontology*, *34*(2), 199–218. https://doi.org/10.1177/0733464813493136

Yeh, S.-C. J., & Liu, Y.-Y. (2003). Influence of social support on cognitive function in the elderly. *BMC Health Services Research*, *3*(1), 9. https://doi.org/10.1186/1472-6963-3-9

Zhai, L., Zhang, Y., & Zhang, D. (2015). Sedentary behaviour and the risk of depression: A meta-analysis. *British Journal of Sports Medicine*, *49*(11), 705–709.

Zhang, M. (2005). Exploring the relationship between urban form and nonwork travel through time use analysis. *Landscape and Urban Planning*, *73*(2), 244–261. https://doi.org/10.1016/j.landurbplan.2004.11.008

Ziersch, A. M., Baum, F., Darmawan, I. G. N., Kavanagh, A. M., & Bentley, R. J. (2009). Social capital and health in rural and urban communities in South Australia. *Australian and New Zealand Journal of Public Health*, *33*(1), 7–16. https://doi.org/10.1111/j.1753-6405.2009.00332.x

Zimmerman, S., Scott, A. C., Park, N. S., Hall, S. A., Wetherby, M. M., Gruber-Baldini, A. L., & Morgan, L. A. (2003). Social engagement and its relationship to service provision in residential care and assisted living. *Social Work Research*, *27*(1), 6–18. https://doi.org/10.1093/swr/27.1.6

Zimmerman, S., Sloane, P., & Eckert, J. (2001). Emerging issues in residential care/assisted living. *Assisted Living: Needs, Practices, and Policies in Residential Care for the Elderly*, 317–331.

Appendix 1

Club/Hobby Rating Instructions for Research Assistants:

The first coding system had raters select the category (from a provided list of types of activity categories) that best represented the participants listed response. Specific coding instructions provided to raters were: "For each of the following clubs [hobbies] you will code the club [hobby] in multiple ways. First, in the domain box, choose the one domain of activity that best describes the club [hobby]." Raters placed the club or hobby into one of the following categories that were informed by prior literature (Flatt et al., 2015; R. Stebbins, 2017). Raters were instructed to "Select the activity type from the list below that the club [hobby] best fits into. 1 = Physical Activity (e.g., gym membership, physical games like basketball); 2 = Making & Tinkering (e.g., mechanical work, wood working, quilting, dog training); 3 = Relaxation (e.g., sitting, napping, strolling); 4 = Passive entertainment (e.g., watching TV, reading books, listening to music); 5 = Active entertainment (e.g., playing games, solving puzzles, playing cards, bingo, crossword puzzles, geocaching, playing music/singing); 6=Sensory Stimulation (e.g., sex, eating, drinking, sight-seeing); 7 = Creative (e.g., painting, drawing, liberal arts pursuits, traveling, being in nature, birding, watching performances); 8 = Casual Volunteering / Altruism (e.g., volunteer for organization, handing out leaflets, educating others, caregiving, getting donations)."

Additionally, clubs and hobbies were flagged if the club or hobby had a religious connotation. Prior work suggests that religious traditions and church participation plays an important role in civic engagement such as volunteering within the community (Park

& Smith, 2000; Smidt, 1999) and may be a beneficial variable to consider in evaluating social capital (J. Wilson & Musick, 1997). Next, if each club/hobby had a religious connotation, the raters were instructed to flag the club/hobby. Specific coding instructions read: “Second, if the club [hobby] has a religious connotation, indicate this by typing yes in the Religious box.”

The second coding system is directly pertinent to the current study. Specifically, raters were instructed to rate each club/hobby to indicate the degree to which the club/hobby entailed cognitive, social, or physical demands. Specific coding instructions read: “Each type of club [hobby] may have varying levels of demand with cognitive, social and physical types of engagement. Indicate the level of demand for each club in each of these domains by selecting from the provided options below.” Raters provided a value based on the following instructions: “Rate how cognitively, socially, and physically demanding you feel each club [hobby] is on a 5-point scale where:1 = absolutely no cognitive demand (sleeping), no social demand (home alone), no physical demands (meditation); 2 = some cognitive, social, or physical demands; 3 = moderate cognitive demand (reading newspaper), moderate social demand (visiting with a friend), moderate physical demands (hiking); 4 = a lot of cognitive, social, or physical demands; 5 = high cognitive demand (completing a tax form), high social demand (dinner party), high physical demands (competitive kayaking).” To see a copy of the rater sheet that was provided to Research assistants, see Figure SF1.1.

Club/Hobby Consensus Rating Description:

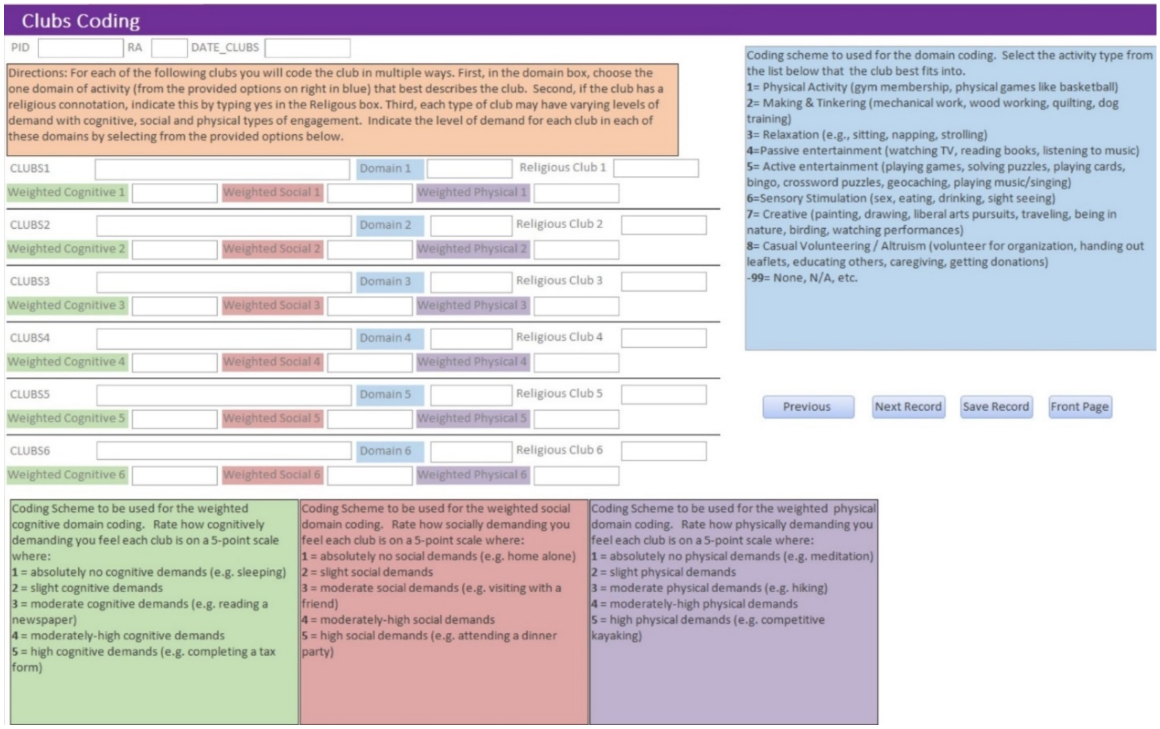
To address discrepancies in the rating of clubs and hobbies as to social, physical and cognitive demands, consensus meetings were held with a separate set of raters who established further criteria for distinguishing cognitive, social and physical demands. Consensus raters were shown what values previous raters had assigned for each club [hobby] as well as the instructions provided to the raters (described above) and made decisions for final scale assignment.

For ratings of the cognitive domain, research assistants rated clubs [hobbies] as 1 if the clubs [hobby] had absolutely no cognitive demands (e.g. sleeping) and the consensus raters included activities such as yoga and hookah in this category. Research assistants rated clubs [hobbies] as a 2 if the clubs [hobby] had slight cognitive demands and consensus raters included activities such as watching TV, housework, gardening or shopping in this category. Research assistants rated clubs [hobbies] as a 3 if the clubs [hobby] had moderate cognitive demands (e.g. reading a newspaper) and the consensus raters included activities such as reading novels, making meals, driving, volunteering, watching news, playing bridge, attending meetings, attending social events, playing music, and general computer use. Research assistants rated clubs [hobbies] as a 4 if the clubs [hobby] had moderately high cognitive demands and the consensus raters included activities such as writing, reading, supervising, writing, handling finances, reading nonfiction, completing puzzles or attending classes. Research assistants rated clubs [hobbies] as a 5 if the clubs [hobby] had high cognitive demands (e.g. completing a tax form) and the consensus raters included activities such as business ownership, computer programming, app development, and writing music.

For rating of social domain, research assistants rated clubs [hobbies] as a 1 if the clubs [hobby] had absolutely no social demands (e.g. home alone) and the consensus raters included activities such as unspecified art projects, baking, and cooking. Research assistants rated clubs [hobbies] as a 2 if the clubs [hobby] had slight social demands and the consensus raters included activities such as outdoor activities, engagement with animals or pets, shopping, generally solitary physical activities such as biking, and blogging. Research assistants rated clubs [hobbies] as a 3 if the clubs [hobby] had moderate social demands (e.g. visiting with a friend) and the consensus raters included activities such as unspecified musical activities, going out to events, engagement with family/kids, training animals (horses/dogs). Research assistants rated clubs [hobbies] as a 4 if the clubs [hobby] had moderately-high social demands and the consensus raters included activities such as group musical activities (e.g. band), board games, team sports (e.g. baseball, basketball, soccer) and homeschooling children. Research assistants rated clubs [hobbies] as a 5 if the clubs [hobby] had high social demands (e.g. attending a dinner party) and the consensus raters included activities such as debate and leadership roles such as being a board member on city council.

For weighting of physical domain, research assistants rated clubs [hobbies] as a 1 if the clubs [hobby] had absolutely no physical demands (e.g. meditation) and the consensus raters (informed by MET scoring) included activities that would have a MET range between 1 and 2 which included activities such as reading, computer work (due to time sitting), unspecified art (due to time sitting), and unspecified decorating. Research assistants rated clubs [hobbies] as a 2 if the clubs [hobby] had slight physical demands (e.g. meditation) and the consensus raters included activities that would have a MET range between 2 and 4 which included activities such as unspecified outdoor activities, animal husbandry (caring for pets and animals), and general household work. Research assistants rated clubs [hobbies] as a 3 if the clubs [hobby] had moderate physical demands (e.g. hiking) and the consensus raters included activities that would have a MET range between 4 and 8 which included activities such as biking, dancing, roller derby, slow pitch softball, and general gym memberships. Research assistants rated clubs [hobbies] as a 4 if the clubs [hobby] had moderately-high physical demands and the consensus raters included activities that would have a MET range between 8 and 11 which included activities such as CrossFit, trail running, soccer, and basketball. Research assistants rated clubs [hobbies] as a 5 if the clubs [hobby] had high physical demands (e.g. competitive kayaking) and the consensus raters included activities that would have a MET range between greater than 11 which included activities such as triathlons.

Figure SF1.1: Rater Scoring Sheet for Clubs & Hobbies.


Clubs Coding

PID RA DATE_CLUBS

Directions: For each of the following clubs you will code the club in multiple ways. First, in the domain box, choose the one domain of activity (from the provided options on right in blue) that best describes the club. Second, if the club has a religious connotation, indicate this by typing yes in the Religous box. Third, each type of club may have varying levels of demand with cognitive, social and physical types of engagement. Indicate the level of demand for each club in each of these domains by selecting from the provided options below.

CLUBS1 Domain 1 Religious Club 1
Weighted Cognitive 1 Weighted Social 1 Weighted Physical 1

CLUBS2 Domain 2 Religious Club 2
Weighted Cognitive 2 Weighted Social 2 Weighted Physical 2

CLUBS3 Domain 3 Religious Club 3
Weighted Cognitive 3 Weighted Social 3 Weighted Physical 3

CLUBS4 Domain 4 Religious Club 4
Weighted Cognitive 4 Weighted Social 4 Weighted Physical 4

CLUBS5 Domain 5 Religious Club 5
Weighted Cognitive 5 Weighted Social 5 Weighted Physical 5

CLUBS6 Domain 6 Religious Club 6
Weighted Cognitive 6 Weighted Social 6 Weighted Physical 6

Coding scheme to used for the domain coding. Select the activity type from the list below that the club best fits into.
1= Physical Activity (gym membership, physical games like basketball)
2= Making & Tinkering (mechanical work, wood working, quilting, dog training)
3= Relaxation (e.g., sitting, napping, strolling)
4=Passive entertainment (watching TV, reading books, listening to music)
5= Active entertainment (playing games, solving puzzles, playing cards, bingo, crossword puzzles, geocaching, playing music/singing)
6=Sensory Stimulation (sex, eating, drinking, sight seeing)
7= Creative (painting, drawing, liberal arts pursuits, traveling, being in nature, birding, watching performances)
8= Casual Volunteering / Altruism (volunteer for organization, handing out leaflets, educating others, caregiving, getting donations)
-99= None, N/A, etc.

Previous Next Record Save Record Front Page

Coding Scheme to be used for the weighted cognitive domain coding. Rate how cognitively demanding you feel each club is on a 5-point scale where:
1 = absolutely no cognitive demands (e.g. sleeping)
2 = slight cognitive demands
3 = moderate cognitive demands (e.g. reading a newspaper)
4 = moderately-high cognitive demands
5 = high cognitive demands (e.g. completing a tax form)

Coding Scheme to be used for the weighted social domain coding. Rate how socially demanding you feel each club is on a 5-point scale where:
1 = absolutely no social demands (e.g. home alone)
2 = slight social demands
3 = moderate social demands (e.g. visiting with a friend)
4 = moderately-high social demands
5 = high social demands (e.g. attending a dinner party)

Coding Scheme to be used for the weighted physical domain coding. Rate how physically demanding you feel each club is on a 5-point scale where:
1 = absolutely no physical demands (e.g. meditation)
2 = slight physical demands
3 = moderate physical demands (e.g. hiking)
4 = moderately-high physical demands
5 = high physical demands (e.g. competitive kayaking)

Table ST1.1 Pearson correlations between IRR measures and Hours per Week (HPW) with varying transformations.

	Raw		Square-root	
	IRRcounty	IRRtract	IRRcounty	IRRtract
Sum Social HPW	-0.09	-0.04	-0.10	-0.04
p	0.00	0.18	0.00	0.22
Skew	0.96		0.16	
Kurtosis	1.38		0.06	
Sum Physical HPW	0.02	-0.01	0.02	-0.01
p	0.58	0.80	0.57	0.87
Skew	0.93		0.09	
Kurtosis	0.93		-0.37	
Sum Family HPW	0.12	0.09	0.13	0.10
p	<.0001	0.00	<.0001	0.00
Skew	0.49		0.13	
Kurtosis	-1.07		-1.17	
Sum Sedentary HPW	-0.03	-0.08	-0.03	-0.08
p	0.33	0.01	0.36	0.01
Skew	0.57		-0.03	
Kurtosis	0.06		-0.26	
Sum Cognitive HPW	0.00	0.02	0.00	0.02
p	0.90	0.57	0.95	0.44
Skew	1.29		0.41	
Kurtosis	2.09		-0.06	
Sum Total HPW	0.01	-0.01	0.01	-0.01
p	0.78	0.69	0.78	0.77
Skew	0.31		-0.15	
Kurtosis	-0.01		0.16	

Note: Skew and Kurtosis are referring to the raw and square root transformed activity items and not to IRR.

Table ST1.2: Intraclass correlations (ICCs) from Activity Models

Social Activity (HPW)	Adopted	Control	DZ	MZ
Model 0 (Sociodemographic)	0.18	0.09	0.23	0.14
Model 1 (add IRR covariates)	0.20	0.09	0.20	0.15
Model 2 (add Live Together)	0.20	0.09	0.20	0.14
Model 3 (Drop siblings living together)	0.21	0.11	0.18	0.10
Family Activity (HPW)	**Adopted**	**Control**	**DZ**	**MZ**
Model 0 (Sociodemographic)	0.00	0.11	0.23	0.14
Model 1 (add IRR covariates)	0.00	0.07	0.19	0.13
Model 2 (add Live Together)	0.00	0.07	0.19	0.13
Model 3 (Drop siblings living together)	0.00	0.08	0.16	0.12
Sedentary Activity (HPW)	**Adopted**	**Control**	**DZ**	**MZ**
Model 0 (Sociodemographic)	0.14	0.15	0.14	0.24
Model 1 (add IRR covariates)	0.14	0.16	0.13	0.25
Model 2 (add Live Together)	0.14	0.16	0.12	0.25
Model 3 (Drop siblings living together)	0.15	0.15	0.10	0.22
Physical Activity (HPW)	**Adopted**	**Control**	**DZ**	**MZ**
Model 0 HPW (Sociodemographic)	0.10	0.00	0.11	0.34
Cognitive Activity (HPW)	**Adopted**	**Control**	**DZ**	**MZ**
Model 0 HPW (Sociodemographic)	0.05	0.10	0.13	0.34
Total Activity (HPW)	**Adopted**	**Control**	**DZ**	**MZ**
Model 0 HPW (Sociodemographic)	0.00	0.15	0.05	0.14
Hobby Cognitive ratings	**Adopted**	**Control**	**DZ**	**MZ**
Model 0 Hobby Cognitive ratings	0.00	0.00	0.09	0.37
Model 1 Hobby Cognitive ratings	0.00	0.00	0.07	0.37
Model 2 Hobby Cognitive ratings	0.00	0.00	0.07	0.37

Note: DZ=Dizygotic, MZ=Monozygotic

References

Flatt, J. D., Hughes, T. F., Documét, P. I., Lingler, J. H., Trauth, J. M., & Albert, S. M. (2015). A Qualitative Study on the Types and Purposes of Social Activities in Late Life. *Activities, Adaptation & Aging*, *39*(2), 109–132. https://doi.org/10.1080/01924788.2015.1024485

Park, J. Z., & Smith, C. (2000). 'To Whom Much Has Been Given...': Religious Capital and Community Voluntarism Among Churchgoing Protestants. *Journal for the Scientific Study of Religion*, *39*(3), 272–286.

Smidt, C. (1999). Religion and civic engagement: A comparative analysis. *The Annals of the American Academy of Political and Social Science*, *565*(1), 176–192.

Stebbins, R. (2017). *Serious Leisure: A Perspective for Our Time (paperback edition)*. Routledge.

Wilson, J., & Musick, M. (1997). Who cares? Toward an integrated theory of volunteer work. *American Sociological Review*, *62*, 694–713. https://doi.org/10.2307/2657355

Appendix 2

Supplemental Table ST2.1: ICC's of Social Capital Index (SCI), Close Friends (LN) and Friend Contact Frequency.

	SCI	Close Friends (LN)	Friend Contact Frequency
Model 0 (Sociodemographic)	ICC	ICC	ICC
Adopted	0.13	0.07	0.03
Control	0.09	0.16	0.10
DZ	0.45	0.25	0.03
MZ	0.38	0.30	0.25
Model 1 (add IRR covariates)			
Adopted	0.09	0.08	0.02
Control	0.21	0.14	0.10
DZ	0.47	0.19	0.01
MZ	0.37	0.30	0.25
Model 2 (Exclude Live Together)			
Adopted	0.09	0.08	0.02
Control	0.20	0.14	0.10
DZ	0.46	0.15	0.03
MZ	0.32	0.25	0.29

Note. DZ=dizygotic, MZ=monozygotic; LN = natural log transformed after adding 1.

Supplemental Table ST2.2: Intraclass correlations (ICCs) of Somatic Complaints.

Somatic Complaints	Adopted	Control	DZ	MZ
Model 0 (Sociodemographic)	0.00	0.13	0.06	0.43
Model 1 (add Close Friends LN)	0.00	0.14	0.08	0.43
Model 2 (add IRR)	0.00	0.14	0.08	0.43

Note. DZ=dizygotic, MZ=monozygotic; LN = natural log transformed after adding 1.

Appendix 3

Table ST3.1: Pearson Correlations: check for non-linear associations with IRR^2

		Raw		**Partialed**	
		IRR Tract²	**IRR County²**	**IRR Tract²**	**IRR County²**
FSIQ		-0.02	0.01	-0.02	0.00
	p	0.55	0.78	0.48	0.98
	N	1125	1125	1101	1101
VIQ		-0.03	0.01	-0.03	0.00
	p	0.33	0.81	0.39	0.89
	N	1125	1125	1101	1101
PIQ		0.00	0.01	-0.01	0.00
	p	0.91	0.68	0.81	0.96
	N	1125	1125	1101	1101
SCI		**0.18**	**0.24**	**0.19**	**0.24**
	p	<.0001	<.0001	<.0001	<.0001
	N	1139	1139	1101	1101
Educational Attainment		**-0.06**	-0.03	*-0.06*	-0.04
	p	0.04	0.38	0.05	0.22
	N	1130	1130	1101	1101
Occupational Attainment		-0.04	-0.04	-0.04	-0.04
	p	0.23	0.19	0.16	0.14
	N	1120	1120	1101	1101
HPW Social (LN)		-0.02	0.03	-0.02	0.03
	p	0.51	0.32	0.57	0.25
	N	1127	1127	1101	1101
HPW Physical (LN)		-0.01	-0.01	-0.01	-0.01
	p	0.66	0.73	0.63	0.81
	N	1127	1127	1101	1101
HPW Family (LN)		**0.09**	0.04	**0.07**	0.02
	p	0.00	0.19	0.03	0.43
	N	1127	1127	1101	1101
HPW Sedentary (LN)		-0.05	0.00	*-0.05*	0.00
	p	0.12	0.95	0.07	0.94
	N	1127	1127	1101	1101
HPW Cognitive (LN)		0.02	0.04	0.03	0.05
	p	0.48	0.15	0.29	0.11
	N	1127	1127	1101	1101
Cognitive Hobby (LN)		**-0.08**	-0.06	*-0.08*	-0.06
	p	0.04	0.16	0.06	0.18
	N	592	592	592	592

Table ST3.1: Pearson Correlations: check for non-linear associations with IRR[2]

N Cognitive Hobby (LN)	**0.07**	**0.07**	0.07	0.06
p	0.03	0.02	0.11	0.13
N	969	969	592	592

Note. LN= Natural Log Transformed after adding 1. SCI=Social Capital Index; HPW=Hours per week; FSIQ = Full Scale IQ; VIQ = Verbal IQ; PIQ = Performance IQ. Partial correlations adjusted for female (male=0, female=1), age, project (LTS=0, CAP=1), adopted status (non-adopted=0, adopted=1), Hispanic (0=non-Hispanic, 1=Hispanic), White (0=non-White, 1=White). Bolded correlations are significant $p < .05$; italicized correlations are $p < .10$.

Supplementary Table 3.2: Intraclass correlations (ICCs) from Study 3 Models

FSIQ & IRR.	Adopted	Control	DZ	MZ
Model 0 (IRRcounty)	0.11	0.56	0.51	0.84
Model 1 (add demographic covariates)	0.14	0.46	0.48	0.83
Model 2 (add education)	0.02	0.42	0.36	0.78
Model 3 (add occupation)	0.02	0.42	0.36	0.78
VIQ & IRR.	**Adopted**	**Control**	**DZ**	**MZ**
Model 0 (IRRcounty)	0.10	0.44	0.58	0.84
Model 1 (add demographic covariates)	0.16	0.39	0.57	0.83
Model 2 (add education)	0.05	0.38	0.45	0.78
Model 3 (add occupation)	0.05	0.39	0.46	0.78
FSIQ & HPW Cognitive Activities	**Adopted**	**Control**	**DZ**	**MZ**
Model 0 (HPW Cognitive)	0.00	0.43	0.36	0.76
Model 1 (add Social Capital)	0.00	0.44	0.35	0.77
FSIQ & Cognitively Rated Hobbies	**Adopted**	**Control**	**DZ**	**MZ**
Model 0 (Cognitive Hobby)	0.08	0.35	0.34	0.69
Model 1 (add Social Capital)	0.09	0.34	0.33	0.69
FSIQ & Social Capital*IRR for HPW Cog.	**Adopted**	**Control**	**DZ**	**MZ**
Model 1 (IRRcounty)	0.00	0.44	0.35	0.76
Model 2 (HPW Cognitive *IRRcounty)	0.00	0.44	0.35	0.76
Model 3 (Social Capital*IRRcounty)	0.00	0.44	0.35	0.77
FSIQ & Social Capital*IRR for Cog Hobby.	**Adopted**	**Control**	**DZ**	**MZ**
Model 1 (IRRcounty)	0.09	0.34	0.33	0.69
Model 2 (Cognitive Hobby*IRRcounty)	0.10	0.35	0.33	0.69
Model 3 (Social Capital*IRRcounty)	0.11	0.41	0.31	0.69

Note: FSIQ=Full Scale IQ, IRR=Index of Relative Rurality, HPW=Hours per week.