Social Science & Medicine 172 (2017) 56–63

Contents lists available at ScienceDirect

Social Science & Medicine

journal homepage: www.elsevier.com/locate/socscimed

# Neighborhood social stressors, fine particulate matter air pollution, and cognitive function among older U.S. adults

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ARTICLE INFO

*Article history:*
Received 2 June 2016
Received in revised form
2 October 2016
Accepted 12 November 2016
Available online 14 November 2016

*Keywords:*
Cognitive function
Neighborhoods
Air pollution
Psychosocial stress
USA

ABSTRACT

A growing number of studies have found a link between outdoor air pollution and cognitive function among older adults. Psychosocial stress is considered an important factor determining differential susceptibility to environmental hazards and older adults living in stressful neighborhoods may be particularly vulnerable to the adverse health effects of exposure to hazards such as air pollution. The objective of this study is to determine if neighborhood social stress amplifies the association between fine particulate matter air pollution ($PM_{2.5}$) and poor cognitive function in older, community-dwelling adults. We use data on 779 U.S. adults ages 55 and older from the 2001/2002 wave of the Americans' Changing Lives study. We determined annual average $PM_{2.5}$ concentration in 2001 in the area of residence by linking respondents with EPA air monitoring data using census tract identifiers. Cognitive function was measured using the number of errors on the Short Portable Mental Status Questionnaire (SPMSQ). Exposure to neighborhood social stressors was measured using perceptions of disorder and decay and included subjective evaluations of neighborhood upkeep and the presence of deteriorating/abandoned buildings, trash, and empty lots. We used negative binomial regression to examine the interaction of neighborhood perceived stress and $PM_{2.5}$ on the count of errors on the cognitive function assessment. We found that the association between $PM_{2.5}$ and cognitive errors was stronger among older adults living in high stress neighborhoods. These findings support recent theoretical developments in environmental health and health disparities research emphasizing the synergistic effects of neighborhood social stressors and environmental hazards on residents' health. Those living in socioeconomically disadvantaged neighborhoods, where social stressors and environmental hazards are more common, may be particularly susceptible to adverse health effects of social and physical environmental exposures.


## 1. Introduction

There are significant social, health, and economic costs of cognitive impairment to older adults, their families, and society. Older adults with poor cognitive functioning are at greater risk of poor physical and mental health outcomes (Frisoni et al., 2000; Yaffe et al., 1999) and increased risk of dementia, a disabling condition associated with high caregiving burden and cost (Langa et al., 2001; Hurd et al., 2013). Efforts to identify modifiable risk factors associated with cognitive impairment and decline have largely focused on the role of individual-level risk factors, such as education, smoking, physical activity, and diet (Beydoun et al., 2014). An increasing number of studies have also identified neighborhood-level physical and social stressors that may have an adverse impact on cognitive health in older adults. There is growing evidence, for instance, that older adults living in areas with higher concentrations of outdoor air pollution have worse cognitive function and are at greater risk of cognitive decline (Power et al., 2016). Several studies have also linked neighborhood social stressors, such as poverty and disorder, to poor cognitive function (Wu et al., 2014).

Neighborhood social and environmental stressors, such as socioeconomic disadvantage and air pollution, tend to cluster together geographically (Hajat et al., 2013) and may interact with one another. Acknowledging the potential interrelationships between social and physical environmental hazards, several

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http://dx.doi.org/10.1016/j.socscimed.2016.11.019
0277-9536/

researchers have called for increased attention to identifying the synergistic effects of neighborhood social and physical environmental factors on health (Clougherty and Kubzansky 2009; Gee and Payne-Sturges 2004; McEwen and Tucker, 2011; Morello-Frosch and Shenassa 2006; Wright and Steinbach 2001). Gee and Payne-Sturges (2004) have proposed a conceptual framework for integrating social and environmental exposures that acknowledges psychosocial stress as a "vulnerability factor" linking social conditions and environmental hazards. Community-based social stressors, such as perceptions of disorder and decay, may be considered susceptibility factors because exposure to these stressors often translates into individual psychosocial stress (Hill et al., 2005). Exposure to psychosocial stressors can lower the brain's threshold for neurotoxicity (Lupien et al., 2009), which may increase risk for neurodegeneration and compromised cognitive function from environmental toxicants such as air pollution. Yet, there is little empirical research examining neighborhood social stressors as a vulnerability factor in the relationship between environmental hazards and cognitive function. One prior study found that living in stressful neighborhoods amplified the adverse influence of environmental lead exposure on cognitive function (Glass et al., 2009). To our knowledge, however, no study to date has examined whether the relationship between air pollution and cognitive function is stronger among those living in more stressful neighborhoods.

We used data on adults ages 55 and older from the Americans' Changing Lives Study, a national, population-based sample of community-dwelling adults, to investigate the role of neighborhood stress in the association between outdoor residential air pollution and cognitive function among older adults. Prior research using ACL data demonstrated a link between fine particulate matter air pollution ($PM_{2.5}$) and cognitive function in older adults (Ailshire and Clarke, 2015). The current study builds on this work by determining if the adverse association of $PM_{2.5}$ with cognitive function is stronger among older adults living in more stressful neighborhoods. Understanding how community-based social stressors and environmental hazards interact to influence health may help to identify individuals and communities that are at increased risk for poor cognitive functioning.

## 2. Background

The accumulating evidence suggests ambient air pollution, especially particulate matter, can have adverse consequences for cognitive function among older adults. Fine particulate matter ($PM_{2.5}$) is an air pollutant consisting of small, inhalable particles with aerodynamic diameters less than 2.5 microns (μm) that are produced primarily from combustion and industrial sources. $PM_{2.5}$ is of particular interest for understanding air pollution effects on the aging brain because it is ubiquitous in the air we breath and, once inhaled, fine particles can pass into systemic circulation, leading to increased inflammation, and may ultimately translocate from the lungs into other organ systems such as the brain (Heusinkveld et al., 2016; Peters et al., 2015) where they can cause damage and pathophysiological changes consistent with cognitive decline and impairment. A link between $PM_{2.5}$ and cognitive function has been reported in several recent studies of older adults. For instance, prior research using cross-sectional data has found worse cognitive function among older adults living in areas with higher concentrations of $PM_{2.5}$ (Ailshire and Crimmins, 2014; Ailshire and Clarke, 2015; Gatto et al., 2014; Ranft et al., 2009; Schikowski et al., 2015). The pollution-cognition relationship has also been demonstrated in longitudinal data, with two studies finding an association between $PM_{2.5}$ and greater cognitive decline in older adults (Weuve et al., 2012; Tonne et al., 2014).

Research in animals suggests there are neurodegenerative effects of exposure to particulate matter air pollution. Prior studies have found associations between exposure to high levels of ambient air pollution and increased brain inflammation and accumulation of beta-amyloid, which is implicated in the pathogenesis of Alzheimer's Disease (Calderón-Garcidueñas et al., 2012; Levesque et al., 2011). Researchers have also linked air pollutant-induced inflammation and neurodegeneration to cognitive deficits in humans (Calderón-Garcidueñas et al., 2008). These studies examined the effects of a high dosage of particulate matter exposure, much higher than the concentrations of ambient $PM_{2.5}$ typically found in the United States. However, chronic exposure to even small doses of a pollutant may increase risk for neurodegeneration as individuals age (Bandyopadhyay, 2016). Two recent U.S. studies with neuroimaging data on older adults found an association between living in areas with higher $PM_{2.5}$ concentrations and changes in brain structure, including white matter loss (Chen et al., 2015) and reduced cerebral volume (Wilker et al., 2015).

Neighborhood social stressors have also been linked to differential risk for poor cognitive functioning among community-dwelling older adults. Prior research has found that older U.S. adults living in socioeconomically disadvantaged neighborhoods, where social stressors may be more common, have poorer cognitive function (Aneshensel et al., 2011; Wight et al., 2006) and experience faster rates of cognitive decline (Sheffield and Peek, 2009). Exposure to neighborhood deprivation, which includes social and economic stressors such as housing affordability and crime, has also been linked to worse cognitive function among older adults in England (Lang et al., 2008). Although two studies of older adults living in Chicago, IL found no association between poor neighborhood social conditions and cognitive function, net of individual-level characteristics (Clarke et al., 2011, 2015), those exposed to worse social environments did experience a faster rate of cognitive decline over time. Exposure to neighborhood social stressors may induce a psychosocial stress response that puts individuals at increased risk of experiencing levels of neurodegeneration commonly observed among those with cognitive impairment.

Perceptions of neighborhood problems, such as disorder and decay, can be a source of psychological distress for residents (Steptoe and Feldman, 2001), and chronic exposure to neighborhood stressors may cause a physiological response that results in dysregulation of the systems responsible for the production of stress hormones (Taylor et al., 1997). As the "key target organ" for stress, the brain is of particular interest in the study of the impacts of psychosocial stressors on health (McEwen and Tucker, 2011). The body responds to stress through a series of neural and endocrine reactions that protect the body and promote adaptation. Physiological responses to stress include chronic activation of the hypothalamic-pituitary-adrenal (HPA) axis and immune system, which can culminate in overproduction of glucocorticoid hormones (e.g., cortisol) and cytokines (McEwen and Tucker, 2011). Overproduction of glucocorticoids and cytokines has been linked to damage to the structure and function of the brain consistent with memory impairment and decreased cognitive function (Lupien et al., 2009). Chronic activation of the stress response can also increase risk for hardening of arteries and chronic hypertension, cardiovascular disease risk factors that increase risk for cognitive impairment (Nash and Fillit, 2006). In addition, it has long been hypothesized that prolonged exposure to stress hormones can increase neuronal susceptibility to insults, which can accelerate the rate of neuronal damage from exposure to toxicants (McEwen et al., 1992). Thus, the extent of damage to the brain from environmental toxicants such as air pollution may be amplified by exposure to neighborhood social stressors.

Although Gee and Payne-Sturges (2004) and others have called