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A Review of Minority Stress as a Risk Factor for Cognitive Decline in Lesbian, Gay, Bisexual, and Transgender (LGBT) Elders

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Abstract

Lesbian, gay, bisexual, and transgender (LGBT) older adults comprise a unique and growing subset of the aging population. The historical context in which they came of age was imbued with victimization and discrimination. These experiences are subjectively stressful and collectively known as minority stress. Older LGBT adults continue to face stressors related to their gender and sexual identities in their daily lives. Importantly, chronic minority stress (CMS), like other forms of chronic stress, is harmful to health and well-being. CMS contributes to

LGBT health disparities, including cardiovascular disease and depression, conditions that in turn increase risk for premature cognitive decline. Furthermore, long-term exposure to stress hormones is associated with accelerated brain aging. Yet, the cognitive functioning of LGBT elders and the influence of CMS on their cognition is all but unexplored. In this review, we examine the influences of CMS in LGBT elders and connect those influences to existing research on stress and cognitive aging. We propose a testable model describing how CMS in LGBT elders heightens risk for premature cognitive aging and how ameliorating factors may help protect from CMS risk. Research is desperately needed to calibrate this model toward improving LGBT quality of life and mental health practices.

Keywords

Gay, Lesbian, Bisexual & Transgender, Health Disparities, Cognition

Social, economic, and environmental factors impact health ("Healthy People 2020," 2012), and the differences in health among disadvantaged groups compared to most of the population are defined as health disparities (Carter-Pokras & Baquet, 2002). Racial minorities have health disparities that are predicated by race-related stressors, including discrimination and internalized racism (Merritt, Bennett, Williams, Edwards, & Sollers, 2006; Utsey & Hook, 2007). Over the lifespan, chronic stress stemming from social inequality leads to physiological deterioration and accelerated aging (Geronimus, 1992; McEwen & Gianaros, 2010). This mechanism applies to other forms of social inequality such as ethnic discrimination (Lauderdale, 2006) and ageism (Allen, 2016).

Lesbian, gay, bisexual, and transgender (LGBT) older adults¹ are another health disparate population. They are at an elevated risk for developing cardiovascular diseases and other metabolic disorders (Fredriksen-Goldsen, Emler, et al., 2013; Fredriksen-Goldsen, Kim, Barkan, Muraco, & Hoy-Ellis, 2013; Lick, Durso, & Johnson, 2013). These diseases can be attributed to chronic exposure to minority stress, which is the specific set of stressors conferred based on one's actual or perceived social identities (Hendricks & Testa, 2012; Meyer, 2003, 2015). Protracted exposure to stress hormones (e.g., cortisol) damages the structures and functions of numerous body systems. Also, social inequality can impede access to adequate and affirmative healthcare opportunities (Ferraro & Shippee, 2009).

Elevated levels of stress hormones are associated with accelerated brain aging and cognitive decline (Lupien, McEwen, Gunnar, & Heim, 2009). Thus, LGBT elders experiencing chronic minority stress (CMS) may be at elevated risk of cognitive decline (Fredriksen-Goldsen et al., 2017; Hatzenbuehler, 2016). Yet, little is known about cognitive aging for LGBT elders as compared to heterosexual older adults, much less about LGBT subgroups and the mechanisms underlying such developmental changes. Geriatric health care and mental health care cannot be comprehensively informed without greater knowledge of minority groups and subgroups, including LGBT elders. Therefore, the objectives of this article are twofold: 1) detail what is directly and indirectly known about the risks for cognitive decline that LGBT elders may incur and 2) propose an introductory model to guide future research and clinical practice.

Studies of LGBT Cognition

Typically, older adulthood is associated with declines in cognitive abilities. The experiences of cognitive aging for LGBT elders specifically have only recently been documented. Older adults who either self-identified as LGBT or reported engaging in same-sex sexual behavior, having romantic relationship(s) with someone of the same sex or gender, or having an attraction to someone with the same sex or gender endorse having mild to moderate cognitive difficulties (Fredriksen-Goldsen, Jen, Bryan, & Goldsen, 2016). In a separate sample, 23% of adults age 50 and older who identify as LGBT reported significant cognitive declines in memory and at least one other

cognitive function (Flatt et al., 2018). Of the 1.1 million LGBT adults age 65 and older, general population estimates (Alzheimer's Association, 2016; Hebert, Weuve, Scherr, & Evans, 2013) suggest that roughly 121,000 (11%) would currently be living with Alzheimer's disease, or AD, (Fredriksen-Goldsen, 2016; Fredriksen-Goldsen et al., 2016). Another estimate puts the prevalence of all-cause dementia for self-identifying LGBT older adults at 23% (McGovern, 2014). One recent examination of mild cognitive impairment and all-cause dementia diagnoses indicates no differences between adults age 55 and older in same-sex versus opposite-sex relationships (Perales-Puchalt et al., 2019). Yet, these estimates are not based on objective assessment; there are currently no studies directly examining dementia prevalence or cognitive functioning in self-identified LGBT older adults regardless of relationship status.

Neurocognitive studies of sexual orientation, as measured by participants' self-identification and sexual attractions, have thus far focused on early adulthood (Rahman, Abrahams, & Wilson, 2003; Rahman, Andersson, & Govier, 2005; Rahman, Sharp, McVeigh, & Ho, 2017; Rahman & Wilson, 2003; Rahman, Wilson, & Abrahams, 2003, 2004a, 2004b; Xu, Norton, & Rahman, 2017), concluding that cognition is generally intact in non-heterosexual adults, but with sex-atypicality reflecting a "cross-sex shift" (Willmott & Brierley, 1984; Xu et al., 2017), wherein cognitive abilities in gay men are comparable to heterosexual women, and lesbian women's abilities are commensurate with heterosexual men.

To date only one cross-sectional study has investigated cognitive abilities and sexual orientation in adults of more advanced age (Maylor et al., 2007). Yet, it examined age only from 20 to 65, precluding evaluation of later adulthood. Overall, women outperformed men on category fluency and spatial memory, while men outperformed women on visuospatial tasks. Moreover, cognitive performance was poorer with greater age, as is typically found. When sexual orientation was also considered, the cross-sex shift was apparent but without a meaningful pattern of interaction with age, suggesting little impact of sexual orientation on cognition through middle adulthood. No studies of LGBT older adults in such a context yet exist. Thus, the cognitive abilities of LGBT elders are unknown.

Minority Stress and Its Mechanisms

LGBT older adults came of age during an era of repression when non-heterosexuality was pathologized and criminalized (Fredriksen-Goldsen & Muraco, 2010). For instance, for decades, LGBT adults have been barred from marrying or adopting children. Homosexuality has been pathologized and was included in the American Psychiatric Association's *Diagnostic and Statistical Manual for Mental Disorders (DSM)* until 1973. Still today, actual or threatened violence, discrimination, and hate speech are frequent (D'Augelli & Grossman, 2001; Huebner, Rebhook, & Kegeles, 2004; Woodford, Howell, Silverschanz, & Yu, 2012). Moreover, policies in public and private sectors can intentionally or unintentionally burden LGBT individuals' resources and well-being and place them at social disadvantages (Hatzenbuehler, 2014). For example, in many U.S. states, sexual identity is not included as a protected identity, and employment may be terminated because of individuals' sexual orientation (e.g., "Zarda & Moore, Jr. v. Altitude Express, Inc.," 2017). Furthermore, LGBT people have been discriminated from obtaining housing or appropriate healthcare. Due to their age and the era in which they came of age, older LGBT adults have been chronically exposed to an array of identity-related stressors (Fredriksen-Goldsen & Muraco, 2010; Kertzner, Meyer, Frost, & Stirratt, 2009). These stressors may negatively impact the way in which LGBT adults age.

The minority stress model (Meyer, 1995, 2003) postulates that a unique set of distal and proximal stressors experienced by LGBT individuals increases their risk for physical and mental health disorders. Distal stressors are objectively stressful, external events that happen to an individual or other people that the individual learns

about. On the other hand, proximal stressors are personal and psychological; they are the appraisals and internalization of distal stressors (i.e., internalized stigma²). Both distal and proximal stressors contribute to negative views of the self and maladaptive psychological phenomena that can trigger physical and mental health disorders (Cox, Dewaele, van Houtte, & Vincke, 2011; Hatzenbuehler, 2009; Newcomb & Mustanski, 2010). For example, LGBT individuals frequently internalize society's negative attitudes against non-heterosexuality (Meyer & Dean, 1998; Walch, Ngamake, Bovornusvakool, & Walker, 2016), which can be experienced as shame, self-hatred, and poor self-esteem (Brubaker, Garrett, & Dew, 2009; Herek, Gillis, & Cogan, 2009). Internalized stigma also contributes to discomfort in disclosing one's sexual or gender identity, feeling disconnected from other LGBT individuals, and being uncomfortable with same-sex romantic relationships and sexual activities (Newcomb & Mustanski, 2010). Through these mechanisms, sexual stigma negatively impacts the mental health of LGBT people.

Anticipating confrontation or discrimination places an individual in a state of hypervigilance and arousal, thereby activating stress responses (Brosschot, Pieper, & Thayer, 2005). While stress responses are adaptive in the short-term, protracted stress activation can lead to "allostatic load," which is the set of physiological changes causing functional and structural damage throughout the body (Cohen, Janicki-Deverts, & Miller, 2007; Epel et al., 2004; McEwen & Stellar, 1993), including excessive circulation of stress hormones that trigger immune responses and chronic inflammation (Segerstrom & Miller, 2004). Moreover, protracted stress can cause hypertension, place strain on the cardiovascular system, and increase risk for myocardial infarctions (i.e., heart attacks; McEwen, 1998a; Muller, Tofler, & Stone, 1989). Lifetime exposure to identity-related stigma alters cortisol levels, cortisol regulation, and hypothalamic-pituitary-adrenal (HPA) axis function, and these mechanisms are thought to underlie many stress-related sexual and gender minority health disparities (Fredriksen-Goldsen & Kim, 2017; Hatzenbuehler & McLaughlin, 2014; Hoy-Ellis & Fredriksen-Goldsen, 2016; Huebner & Davis, 2005; Juster, Smith, Ouellet, Sindi, & Lupien, 2013; Meyer, 2003; Pascoe & Smart Richman, 2009) through heightened allostatic load (Cohen et al., 2007; McEwen & Stellar, 1993).

LGBT Health Disparities and Cognitive Aging

Social inequality is stressful, and throughout one's lifespan, inequality confers significant health risks that alter aging trajectories and increase mortality (Ferraro & Shippee, 2009). Heterosexism creates a stressful social environment that LGBT individuals navigate across a lifetime, and chronic minority stress (CMS) has significant consequences on LGBT elders' physical and mental health. Late adulthood is typified by gradual declines in cognitive abilities and based on a lifetime of social inequality in conjunction with known health disparities, LGBT individuals may be at risk of having accelerated cognitive declines (cf. Ferraro & Shippee, 2009). Cognitive aging in the LGBT population has been infrequently examined, and the specific impact of minority stress on cognition for LGBT individuals is currently unknown.

Historical oppression has shaped the healthcare utilization of individuals from victimized backgrounds, including LGBT people (Brotman, Ryan, Jalbert, & Rowe, 2002; Fredriksen-Goldsen et al., 2016; Fredriksen-Goldsen, Kim, et al., 2013). Many LGBT adults are concerned about being treated poorly by their healthcare providers (Espinoza, 2014), and those who fear disclosing their sexual/gender minority status to healthcare providers are more likely to delay routine care and examinations, especially if they have previously encountered homophobia or transphobia from providers (Brotman et al., 2002). Clearly, stigma impacts the way LGBT people access healthcare, and as such, sexual orientation and gender identity/variance are critical social variables that affect health outcomes ("Healthy People 2020," 2012; Institute of Medicine, 2011; Logie, 2012).

In addition to barriers to accessing healthcare, minority stress specifically impacts health outcomes for LGBT adults aged 50 years or greater. Lifetime victimization and internalized stigma predict poor general health for LGBT elders, and internalized heterosexism increases the number of chronic health conditions (e.g., angina, arthritis, congestive heart failure, diabetes, heart attack, high cholesterol, hypertension, osteoporosis, and stroke) that LGBT adults aged 50 and older endorse (Fredriksen-Goldsen, Emler, et al., 2013; see also, Lick et al., 2013). Moreover, negative experiences of minority stress are associated with greater “disability” (i.e., functional impairment stemming from physical, mental, or emotional conditions). Ultimately, lifetime victimization and discrimination are negatively associated with elders’ reports of physical health quality of life, which suggests that CMS impedes successful aging (Fredriksen-Goldsen, Kim, Shiu, Goldsen, & Emler, 2015).

The negative consequences of sexual minority stress are not limited to physical health; they also extend to mental health (King & Richardson, 2016). Internalized homophobia increases symptoms of anxiety and depression, and age exacerbates the relationship between internalized heterosexism and mental health problems (Newcomb & Mustanski, 2010). Recent studies of participants 50 and older showed that those who reported greater sexual minority stress also reported more symptoms of major depressive disorder (Fredriksen-Goldsen, Emler, et al., 2013; Hoy-Ellis & Fredriksen-Goldsen, 2016). Older adults who identify as lesbian, gay, or bisexual are more likely to smoke cigarettes and engage in excessive drinking compared to heterosexual elders (Fredriksen-Goldsen, Kim, et al., 2013). Through the minority stress model, mental health disparities among LGBT individuals are the consequence of identity-related prejudice, discrimination, and stigma (Meyer, 2003).

Psychological disorders and chronic stress are known to increase risk for dementia (Diniz, Butters, Albert, Dew, & Reynolds, 2013; Lathe, Sapronova, & Kotelevtsev, 2014; Muela et al., 2017; Ownby, Crocco, Acevedo, John, & Loewenstein, 2006), likely via HPA axis impairments and chronic exposure to cortisol (Simard, Hudon, & van Reekum, 2009; Sotiropoulos et al., 2008). Indeed, major depressive disorders, which LGBT people have to a greater degree than heterosexuals, place older adults in the general population at heightened risk for cognitive impairment, vascular dementia, and AD (Caraci, Copani, Nicoletti, & Drago, 2010; Diniz et al., 2013; Houde, Bergman, Whitehead, & Chertkow, 2008; Modrego & Ferrandez, 2004; Ownby et al., 2006; Sotiropoulos et al., 2008). Specifically, prolonged exposure to cortisol during adulthood is associated with damage to age- and dementia-vulnerable neural networks, including reductions in hippocampal function and volume via cell death (Lupien et al., 1998; Lupien, Maheu, Tu, Fiocco, & Schramek, 2007; Lupien et al., 2009; McEwen, 1998b), hippocampal dendritic arbor retraction (Ulrich-Lai & Herman, 2009), disrupted dendritic connections between the hippocampus and the prefrontal cortex (Arnsten, 2009; Cerqueira, Mailliet, Almeida, Jay, & Sousa, 2007), and suppressed neurogenesis (McEwen, 2007). Elevated cortisol levels may be one pathophysiological cause of Alzheimer’s disease (Landfield, Blalock, Chen, & Porter, 2007). In fact, animals exposed to frequent stress have more neuropathology that is comparable to the plaques and tangles found in the brains of humans with AD (Green, Billings, Roozendaal, McGaugh, & LaFerla, 2006). Further, allostatic load increases risk for cardiovascular diseases, chronic inflammation, and vulnerability to pathogenic infection (McEwen & Stellar, 1993), which can be further exacerbated by poor health behaviors such as lack of exercise and substance use (Conron, Mimiaga, & Landers, 2010). These health consequences exacerbate typical brain aging processes, specifically within the hippocampus, amygdala, and prefrontal cortex, and contribute to all-cause cognitive decline (Garrido, 2011; Lupien et al., 2009). Although cognitive functioning in LGBT elders is as yet unexplored, their exposure to CMS suggests that their cognitive functions, most specifically memory and executive functioning, may be particularly vulnerable to accelerated aging and dementia (Arnsten, 2009; Roozendaal, 2002; Sapolsky, Krey, & McEwen, 1986).

Conceptual Model of Cognitive Aging for LGBT Older Adults

The size of the LGBT population is underappreciated and growing. By 2060, there will be an estimated 2.2 million LGBT older adults in the U.S. alone (Fredriksen-Goldsen et al., 2016; Fredriksen-Goldsen & Kim, 2017). Minority stress will continue to impact their mental health and healthcare utilization, which may alter their aging trajectory (Ferraro & Shippee, 2009). Aging trajectories are shaped by environmental and social systems, and these systems are imbued with advantages and disadvantages based on one's position within society. Successful aging is impeded in individuals whose identities like race, gender, and sexual orientation are dissimilar from the group(s) with the most social power. Specifically, inequality confers disadvantages via exposure to risk and the absence of opportunity. The consequences of inequality accumulate across the lifespan and thereby burden typical aging processes (Ferraro & Shippee, 2009). Thus, stress mechanisms underlying health disparities in minority populations may contribute to premature cognitive aging because chronic stress is a risk factor for accelerated aging and Alzheimer's disease (Sotiropoulos et al., 2008). Coping mechanisms, specifically social support and LGBT identity disclosure, are expected to mitigate the effects of CMS by modulating stress hormone exposure and improving quality of life.

Specific studies examining the neuropsychological abilities of LGBT adults through late-life have not been conducted. Although LGBT aging research is increasing, cognitive outcomes have not been reported. Nevertheless, LGBT older adults may be at an increased risk for cognitive impairment and dementia because of their long-term exposure to minority stress, which elevates their rate of health conditions, including substance use, and all-cause dementia risks (Center for Disease Control and Prevention, 2011; Fredriksen-Goldsen et al., 2016; Fredriksen-Goldsen, Kim, et al., 2013; McGovern, 2014). Furthermore, lack of attention to and underreporting of sexual identity in longitudinal research prevents discernment of typical and pathological LGBT cognitive aging trajectories relative to their heterosexual counterparts. Even if such studies ultimately reveal comparable risk profiles (cf. Perales-Puchalt et al., 2019), history of discrimination for LGBT elders may hinder their pursuit of early interventions, contributing to poorer cognitive outcomes (Gardner, de Vries, & Mockus, 2014; McGovern, 2014). Thus, specific studies examining the cognitive functioning of LGBT adults through late-life and their patterns and rates of decline are critically needed.

LGBT Minority Stress and Cognition

We propose an introductory conceptual model of minority stress-related cognitive decline in LGB elders for the purpose of compelling and guiding critically important future research (see Figure 1). Line A represents the typical cognitive aging trajectory whereby all-cause brain and cognitive functioning gradually decline across older adulthood. Line B is the theoretical average all-cause decline for LGBT older adults. This cognitive trajectory is theoretically modifiable by minority stress (i.e., shaded region below) and resilience (i.e., shaded and stippled region above). Line B has a steeper slope than Line A because lifelong exposure to stress hormones contributes to deficits in neurocognitive functioning (Lupien et al., 1998; Lupien et al., 2009; Sapolsky et al., 1986). The mechanisms by which stress accelerates decline include the neurotoxic effects of stress hormones on the hippocampus and prefrontal cortex as well as metabolic disruptions that harm general brain functioning (Arnsten, 2009; de la Torre, 2012; Lupien et al., 1998; Lupien et al., 2009; McEwen, Nasca, & Gray, 2016; Muela et al., 2017; Raz & Rodrigue, 2006; Stefanidis, Askew, Greaves, & Summers, 2017). Cognitive consequences would therefore be particularly evident in learning, memory, and executive functions.

Importantly, social systems, one's position in society, and location apportion exposure to risks and access to resources (Brotman et al., 2002; Ferraro & Shippee, 2009). Health disparities are a manifestation of social inequality as people from various minority backgrounds are at elevated risks for health complications. As such, many LGBT individuals may ultimately face other forms of oppression in addition to heterosexism (Bowleg, Huang, Brooks, Black, & Burkholder, 2003; Kertzner et al., 2009; Kim & Fredriksen-Goldsen, 2017; Kum, 2017;

Veenstra, 2011). Stigma-related stress is typically multi-faceted, likely accumulating to compound risks for detrimental aging (Ferraro & Shippee, 2009; Meyer, 2015). This is accounted for by the gray area below Line B. Notably, LGBT health disparities research samples tend to include mostly White, healthy, educated, and “out” participants. It is therefore imperative that future research specifically examine discrete identities as well as the interacting effects of oppression/privilege associated with individuals’ unique identities (Kertzner et al., 2009). This will necessitate multilevel predictive modeling and examination of mediating and moderating factors. For example, transgender older adults have poorer health outcomes than non-transgender sexual minorities, which is indirectly mediated by the impact of a transgender identity on healthcare access, physical activity, minority stress, and social support, in addition to other mediators such as obesity and disability (Fredriksen-Goldsen et al., 2014).

Protective Factors

Resource mobilization, human agency, environmental enrichment (e.g., social support), and early intervention are factors that mitigate the negative effects of early disadvantage (Ferraro & Shippee, 2009; Lupien et al., 2009). Thus, cognitive decline for LGBT elders is likely modifiable by protective factors such as: social support, LGBT community engagement, and disclosure of one’s identity (Burton, Bonanno, & Hatzenbuehler, 2014; Butler, 2004; Caceres & Frank, 2016; Fredriksen-Goldsen, Emler, et al., 2013; Fredriksen-Goldsen et al., 2015; Hoy-Ellis & Fredriksen-Goldsen, 2016; Hsieh, 2014; Kim, Fredriksen-Goldsen, Bryan, & Muraco, 2017; Lyons & Pepping, 2017; Masini & Barrett, 2008; Walch et al., 2016). These variables likely moderate the stress-related aging trajectories in Figure 1 by modulating cortisol responses (Burton et al., 2014) in an additive manner (Kremen, Lachman, Pruessner, Sliwinski, & Wilson, 2012). For example, in adults³ 24-75 years of age, protective factors had an additive effect toward protecting cognition over the next decade (Agrigoroaei & Lachman, 2011).

Implications and Recommendations

The U.S. economy and healthcare system may be impacted by the ability of current scientists and healthcare providers to discover and eliminate health disparities experienced by LGBT older adults (“Healthy People 2020,” 2012). Currently, there are over 3 million LGBT people age 55 and older (Espinoza, 2014; Fredriksen-Goldsen et al., 2016), and the LGBT population is projected to double by 2040 (Espinoza, 2014). With discrepant prevalence rates of physical and mental health conditions compared to their heterosexual counterparts, LGBT elders’ care will require disparately more resources (Fredriksen-Goldsen et al., 2016; Fredriksen-Goldsen & Kim, 2017). Given their particularly high risk for exposure to stress, pathological aging risk might be exacerbated in LGBT elders. As such, understanding of their risks for cognitive decline and dementia and the potential avenues to prevent their particular risks is critically needed.

Sexual and gender identities are important considerations in clinical and cognitive evaluations of older adults, both to better address potential risks and to better target and afford access to LGBT-affirmative services (Gardner et al., 2014). Healthcare providers and aging researchers are uniquely positioned to provide recommendations to enhance health and wellbeing. Examples include offering or providing referrals to culturally sensitive interventions, recommending interactions with LGBT community organizations and social support groups, and encouraging engagement in supportive social networks. Finally, research on the cognitive impact and mechanisms of lifelong minority stress is essential to the mitigation and prevention of disease and healthcare costs and to maintain quality of life for LGBT elders (Meyer, 2015).

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Footnotes

- 1 Definitions of older adulthood vary across the literature and in popular culture. Although research on LGBT aging tends to focus on those age 50+ (cf. Fredriksen-Goldsen & Muraco, 2010), studies vary, with some focusing on age 65+ and others on ages 45-75. Herein "older adult" and "elder" are synonymous and defined as age 65 and older.

2 Internalized stigma has also been described as “self-stigma,” “internalized homophobia,” “internalized heterosexism,” and “internalized homonegativity.”

3 Sexual identity was not reported.

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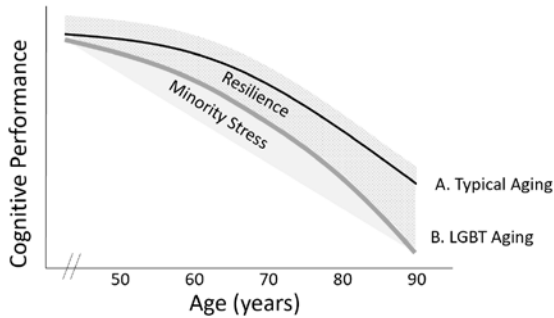


Figure 1. Theoretical trajectory of cognitive decline for LGBT older adults.

Cognitive decline is accelerated in LGBT aging (Line B) relative to typical aging (Line A) due to the degree of chronic minority stress, which increases physical and mental health risk factors (de la Torre, 2012; Diniz et al., 2013; Fredriksen-Goldsen, Emler, et al., 2013; Fredriksen-Goldsen et al., 2016; Ownby et al., 2006; Simard et al., 2009; Sotiropoulos et al., 2008; Stefanidis et al., 2017) and neurotoxic effects of stress hormones on brain structure and function (Lupien et al., 2009). Neuropsychological consequences include learning, memory, and executive functioning. Factors such as discrimination and social inequality accumulate to modify the trajectory (Ferraro & Shippee, 2009) in an additive manner (Minority Stress shaded area). Protective factors (e.g., social support) theoretically promote resilience to cognitive aging (Resilience shaded and stippled area) (Fredriksen-Goldsen, Emler, et al., 2013; Fredriksen-Goldsen et al., 2015; Meyer, 2015). Protective factors also include those beneficial to typical older adults, including education, socioeconomic status, and physical activity (Alzheimer's Association, 2016). Genetics can be additive or subtractive but are excluded from the model for simplicity.