Enacted Sexual Minority Stigma, Social Support, and Cognitive Function Among Midlife and Older Men Who Have Sex with Men from the Multicenter AIDS Cohort Study

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Abstract

Men who have sex with men (MSM) in midlife and older adulthood experience many health disparities to their heterosexual peers that can be attributed, in part, to their stigmatized sexual minority identity or behavior. However, how psychosocial factors affect cognitive function among MSM has yet to be explored. This dissertation analyzed data from the *Healthy Aging Study,* a sub-study of the Multicenter AIDS Cohort Study (MACS) to explore the effects of social support and enacted sexual minority stigma on three tests of cognitive function. In the first analysis, social support was associated with a lower Trail Making Test (TMT) Part A score at baseline (b = -2.01, 95% CI = -3.24, -0.77) and across 2 years (b = -1.76, 95% CI = -2.42, -1.10), indicating better psychomotor ability. Social support was also associated with a higher Symbol Digit Modalities Tasks (SDMT) score at baseline (b = 2.28, 95% CI = 0.22, 4.34) and across 2 years (b = 1.05, 95% CI = 0.20, 1.90), indicating better information processing. In the second analysis, at baseline enacted sexual minority stigma was associated with higher TMT Part B/A ratios, indicating worse set-shifting performance (b = 0.14, 95% CI = 0.06, 0.22) and fewer correct answers on the SDMT (b = -1.63, 95% CI = -2.81, -0.44). Longitudinally, enacted sexual minority stigma was associated with higher TMT B/A ratios (b = 0.04, 95% CI = 0.01, 0.07). In the third analysis, experiencing or witnessing enacted sexual minority stigma during adolescence were not associated with cognitive function. However, we observed significant moderating effects of social support at baseline be-

tween witnessing enacted sexual minority stigma in adolescence and the TMT B/A ratio, and enacted sexual minority stigma experienced in adulthood and the SDMT score. Longitudinally, social support moderated the association between adulthood enacted sexual minority stigma and the TMT A and SDMT scores. The public health significance of these analyses shows that psychosocial factors such as sexual minority stigma may contribute to additional risk for poor cognitive function among MSM, and that social support may be an important resource to mitigate negative effects of social stressors.

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Preface

I have had the immense privilege of having so many incredible teachers throughout my entire life both inside and outside of formal education. Each one, in some way, contributed to the execution of this dissertation. I would like to thank my committee members, Drs. Jamie Egan, Robert Coulter, Mackey Friedman, and Andrea Weinstein for their invaluable feedback and mentorship throughout this dissertation process. I am also very grateful for the encouragement I have received from my colleagues in the Center for LGBT Health Research over the past few years. I also wish to thank the people who selflessly gave their time to participating in the Multicenter AIDS Cohort Study (MACS). I have the deepest gratitude for the unwavering support of my family, Mike and Kelly Henderson, Mike Ashcraft and Carrol Davenport, Brittany Ashcraft, and Macie and Ollie. Finally, I wish to thank Judith Lapple for teaching me to play with heart.

1.0 Introduction

In the United States (US), the proportion of older gay, bisexual, and other men who have sex with men (MSM) is rapidly growing. There has been an increase in research efforts to identify and understand health disparities that exist for MSM compared to their older adult peers who identify as heterosexual or exclusively have sexual partners who are cisgender women. Overall, compared to their heterosexual counterparts, older MSM experience poorer general health (1), higher rates HIV (2), and may be at elevated risk of some cancers and cardiovascular disease (CVD) (3, 4). The health disparities among older MSM also extend to mental health conditions including anxiety, depression, and suicidal ideation (4, 5).

Despite the recent attention given to investigating the healthy aging of MSM, less is known about cognitive function, especially for MSM who do not have HIV. Neurocognitive disorders associated with HIV, such as subacute encephalitis, AIDS dementia complex, and HIV encephalopathy, have been researched since the beginning of the HIV epidemic (6-8). However, recent research suggests that MSM living with HIV as well as HIV-negative MSM have a higher prevalence of poor cognitive function relative to the general population (9). To achieve health equity for MSM in older adulthood, further exploration of the mechanisms underlying the development of poor cognitive function is needed, as well as the development and testing of interventions designed to promote healthy cognitive function for this population.

This dissertation explores the impact of enacted sexual minority stigma and social support on cognitive function among a cohort of midlife (40-64 years) and older (65+ years) MSM from the *Healthy Aging Study,* a sub-study of the Multicenter AIDS Cohort Study (MACS) conducted from October 2016 to March 2019 (10). This dissertation includes a discussion of psychosocial

and health disparities that MSM face as they age, an introduction to cognitive health and factors associated with poor cognitive function, and the theoretical approaches used to guide this research. The three analyses that follow contribute to an improved understanding of what, if any, psychosocial factors lead to poor cognitive function among MSM, and provide direction towards ensuring that MSM achieve and maintain healthy cognitive function in midlife and older adulthood.

1.1 Aging of Sexual Minorities in the United States

In the United States (US), the proportion of sexual minority (e.g., lesbian, gay, bisexual) older adults is rapidly growing. Conservative estimates based on population surveillance suggest that 2.4% of the US population age 50 or older, or 2.7 million individuals, openly identify as a sexual minority (11, 12). Of those ages 65 or older, 2.2%, or 1.1 million individuals, identify as a sexual minority (11, 12). By 2060, the estimate of the number of adults 50 or older who identify as sexual minorities is expected to double (11). Furthermore, when considering same-sex behavior, attractions, and romantic relationships, by 2060 the number of sexual minority adults age 50 or older may reach more than 20 million (11). Several factors likely contribute to the apparent growth of the sexual minority older adult population demonstrated in population-based studies, including aging of the population overall, better and more widespread measurement of sexual identity, and an increase in the number of adults who come out later in life.

There is a pressing need to address the healthy aging of sexual minority older adults. Relative to their heterosexual peers, sexual minority adults have poorer general health (1), higher rates of disability and physical limitation (1, 3, 13), and may be at elevated risk of some cancers and cardiovascular disease (CVD) (3, 4). The health disparities among sexual minority older adults

also extend to mental health conditions including anxiety, depression, and suicidal ideation (4, 5). Sexual minority adults, specifically gay and bisexual men, also experience elevated rates of HIV/AIDS relative to heterosexual cisgender men and cisgender women (2). Additionally, current estimates suggest that over 50% of individuals living with HIV are age 50 years or older (14). With increasing efficacy of combination antiretroviral therapy (cART), the shifting of HIV from a disease with high mortality to a chronic disease has implications for the health and well-being of sexual minority men in older adulthood.

1.1.1 Cognitive Health

The Centers for Disease Control and Prevention (CDC) Healthy Brain Initiative defines cognitive health as being able to perform all the mental processes collectively known as cognition – memory, language, attention, executive function, judgement, as well as skills such as driving and the ability to lead a purposeful life – and is viewed along a continuum from optimal functioning to mild cognitive impairment (MCI) to severe cognitive impairment (15). Cognitive impairment is when a person has trouble remembering, learning new things, concentrating, or making decisions, and is a risk factor for developing dementia in later life (15). With mild impairment, individuals may notice changes in cognitive function but remain capable of completing daily activities. Dementia is a severe type of cognitive impairment characterized by a loss of cognitive functioning and behavioral abilities to such an extent that it interferes with a person's daily life and activities (15). Cognitive impairment can be caused by a range of conditions including Alzheimer's disease (AD) and other dementias, traumatic brain injury (TBI), developmental disabilities, or stroke (15).

In the general population, cognitive impairment is a critical public health issue. With currently no cure, AD is the 5th leading cause of death in the US for people age 65 or older. In 2019, an estimated 5.8 million people in the US were living with AD, including 5.6 million age 65 or older (16). AD and other dementias are associated with decreased independence and well-being, and also present a high economic burden. In 2019, the US spent $290 billion on care and treatment of individuals 65 or older with dementia, including 18.5 billion hours of unpaid care valued at $234 billion (16). MCI is more prevalent than dementia (17). Approximately 15 to 20% of people age 65 or older have MCI from any cause (17), and many individuals with MCI progress rapidly to dementia (18).

1.1.2 HIV-Associated Neurocognitive Disorder

Most of what is known regarding cognitive health among sexual minorities has been studied in the context of HIV among MSM given the well-established neurocognitive complications of the disease (19, 20). Neurocognitive disorders associated with HIV, such as subacute encephalitis, AIDS dementia complex, and HIV encephalopathy, have been researched since the beginning of the epidemic (6-8). When left untreated, HIV crosses the blood-brain barrier and enters the central nervous system which results in neuronal damage that affects cognitive health (21). In 2007, Antinori and colleagues established criteria for HIV-associated neurocognitive disorder (HAND) to describe the range of neurological disorders associated with HIV (22). HAND includes three categories: asymptomatic neurocognitive impairment (ANI), mild neurocognitive disorder (MND), or HIV-associated dementia (HAD). Individuals with ANI demonstrate symptoms of cognitive impairment but show no impairment in activities of daily living while those with MND show

some impairments and those with HAD show the most severe impairment in activates of daily living (19).

The introduction of cART has reduced the prevalence of HAD, but not the milder forms of HAND (23-26). A 2016 study using data from 364 HIV-positive men from the MACS, reported a prevalence of HAND of 33% overall. Specifically, the prevalence was 14% for ANI, 14% for MND, and 5% for HAD. The mean (SD) age of men in this study was 47.4 (8.9) years. Men with medical conditions that may confound a diagnosis of HAND (e.g., brain opportunistic infections, non-HIV-associated neurologic disease, history of major psychiatric disorder, current alcohol or substance dependence, collagen vascular disease, thyroid disease, chronic obstructive pulmonary disease, congestive heart failure, angina pectoris, myocardial infarction within the prior 6 months, hepatic failure, renal failure, daily use of systemic steroids, narcotic/opioid analgesics, or immunostimulant/immunosuppressive medications) were excluded from the study. Finally, a diagnosis of hypercholesterolemia was associated with an increased risk for worsening HAND stage. However, there was no association of age, education (8th grade or less vs above 8th grade), duration of HIV infection, CD4 cell count, nadir CD4, quantitated plasma HIV RNA, detectability of plasma HIV RNA, type of cART (protease inhibitor vs non-nucleoside reverse transcriptase inhibitor–based cART), site of evaluation, hepatitis C coinfection, or diagnosis of hypertension or diabetes and risk of HAND stage progression (27).

Similar prevalence rates were found in a 2010 using data from the CNS HIV Anti-Retroviral Therapy Effects Research (CHARTER). In this cohort, the prevalence of HAND among HIV-positive individuals was 47% overall. Specifically, the prevalence was 33% for ANI, 12% for MND, and 2% for HAD This sample included 1,555 individuals recruited from 6 study sites across the US, of which 23% were women, 58% were MSM, and 61% were non-Hispanic white. The

mean (SD) age of participants was 43.2 (8.5) years. The prevalence of AIDS was 63%. This study classified participants into 3 comorbidity groups with respect to demographics, HIV disease and treatment characteristics, depressed mood, and everyday functioning: incidental, contributing, and confounding. The prevalence of HAND in the comorbidity groups was 40%, 59%, and 83%, respectively (28).

A 2013 study found an overall HAND prevalence among HIV-positive individuals of 59%, of which 21% was attributable to ANI, 31% to MND, and 7% to HAD. This study included 400 HIV-positive individuals from a hospital-based cohort in Southern France. The sample composition was 79% men with a median (IQR) age of 47 (42-53). The prevalence of AIDS was 24%. Risk factors independently associated with HAND included lower education, anxiety, depressive symptoms, and any history or brain damage or prior neurologic AIDS-defining disorders. In contrast, there was no association with HIV transmission route, current or nadir CD4 count, or hepatitis co-infections (29).

Finally, in a 2015 study of HIV-positive participants in the Veteran's Aging Cohort Study, 40.6% were classified as cognitively impaired; the higher prevalence among this cohort is understandable given that over 60% of participants had AIDS. This sample included 601 HIV-positive individuals age 18-76 (mean age of 41.6). The majority were male (88%) and non-Hispanic white (63%). This study created a VACS Index, which combines age, HIV biomarker data, and biomarkers of multi-organ system dysfunction, and demonstrated that higher VACS scores are associated with cognitive impairment (30).

Recently, a study using data from the Pitt Men's Study, a sub-cohort of the MACS, compared rates of HAND in HIV-positive individuals to rates in HIV-negative individuals and found a similar overall prevalence of 31.82% among HIV-positive individuals and 31.89% among HIV-

negative individuals. This study included a total of 408 men, of whom 154 were HIV-positive, and 255 were age 50 or older. There were no associations between age, race, education, hepatitis C co-infection, hypertension, diabetes, metabolic syndrome, hypercholesterolemia, methamphetamine use, binge drinking, or HIV status with HAND (9).

The similar prevalence estimates of HAND between HIV-positive and HIV-negative individuals raises several concerns. By definition, HAND cannot occur in HIV-negative individuals, indicating that the criteria used to diagnose HAND may be lacking specificity (the true negative rate). Alternatively, these data may also suggest that when viral suppression is achieved, HIV is not independently associated with cognitive impairment (31). In fact, several studies found that after controlling for clinical AIDS, HIV infection does not appear to affect neuropsychological performance (32-34). The only difference in neuropsychological test performance by HIV-status was found in motor skills (31). Nevertheless, the high prevalence of cognitive impairment among both HIV-positive and HIV-negative MSM in the MACS warrants further exploration. It is possible that risk factors that uniquely or disproportionately affect older MSM such as chronic stress or mental illness may place them at higher risk for cognitive impairments in midlife and older adulthood. The role of these risk factors has yet to be explored in research of cognitive function among MSM.

1.1.3 Cognitive Health Among Sexual Minorities

Less is known about cognitive health among sexual minorities who do not have HIV or the mechanisms underlying the development of cognitive impairment, AD, or other dementias in the sexual minority population. The prevalence of self-reported cognitive difficulties varies widely

between studies. The NIH-funded Aging With Pride: National Health, Aging, Sexuality and Gender Study (hereafter "Aging with Pride") is the first national study to investigate cognitive health specifically among sexual and gender minority adults. The sample included 2,450 adults who identify as lesbian, gay, bisexual, or transgender ages 50 to 100 years. The mean (SD) age was 66.41 (9.10 years). The majority of the sample was non-Hispanic white (86.5%) and male (63.3%). In this study, 10% of respondents reported severe or extreme cognitive difficulties in the past 30 days in at least one of six areas (concentration, memory, problem solving, learning, comprehension, and communication) measured by the World Health Organization Disability Assessment Schedule (WHO-DAS) II cognition domain. (35). In the same study, 38% and 77% reported moderate and mild cognitive difficulties in at least one area, respectively (35).

In another study that used data from the 2015 Behavioral Risk Factor Surveillance System (BRFSS), of the 1,253 adults age 45 or older who identified as a sexual and/or gender minority, over 14% reported subjective cognitive decline, defined as self-reported confusion or memory problems that have been getting worse over the past year. In contrast, 10% of the heterosexual cisgender participants reported subjective cognitive decline. Even after adjustment for income, age, and race, sexual and gender minority participants had 29% higher odds of subjective cognitive decline (36). On the other hand, another study of adults age 20-65 showed no effect of sexual orientation on cognitive performance (37).

Similarly, the prevalence of diagnosed dementia among sexual minorities in non-HIV-specific studies is inconsistent, likely due to the differences in sample size, composition, and sampling methodology. A longitudinal analysis of 4,337 sexual minority adults age 60 or older who were members of Kaiser Permanente Northern California medical system found a dementia prevalence of 7.4% over 9 years of follow-up using ICD-9 dementia codes (36). In Aging with Pride,

under 1% of sexual minority adults age 80 or older reported a diagnosis of Alzheimer's disease or another dementia (35). However, the low prevalence of self-reported dementia diagnosis may be explained by a survivor bias. Finally, one recent examination of MCI and all-cause dementia diagnoses found no differences between adults age 55 or older in same-sex versus opposite-sex relationships (38).

Overall, the evidence regarding whether sexual minorities have a higher risk of cognitive difficulties is unclear. In HIV-specific cohorts comprised of mostly gay and bisexual men (e.g., the MACS), over one-third of HIV-positive and HIV-negative participants meet criteria for HAND. Similarly, non-HIV-specific studies that used subjective measurements of cognitive function suggest that sexual minorities may have a higher risk of cognitive impairment. However, non-HIV-specific studies using diagnosed dementia as the outcome suggest either lower risk or no difference in risk of dementia among sexual minorities compared to heterosexual older adults. Beyond differences in the outcomes, several other factors may explain the differences in prevalence rates in these studies. First, electronic health record data may under-represent the proportion of older adults who identify as sexual minorities, as sexual minorities may delay or avoid treatment of dementia-related symptoms or may choose not to disclose their sexual identity to their healthcare provider (39). Second, the BRFSS, Kaiser Permanente database, and Aging with Pride study samples are disproportionately comprised of white, highly-educated, high SES individuals and may exclude sexual minority older adults living in poverty, and those without health insurance. Finally, the HIV-specific cohorts are composed almost exclusively of cisgender men, whereas other studies of cognitive function among sexual minorities include a wider variety of genders but do not stratify the results by sex or gender, despite known sex differences in cognitive impairment among older adults (40).

1.2 Risk and Protective Factors for Cognitive Impairment

1.2.1 Risk Factors for Cognitive Impairment

From studies in the general population, there are several well-established risk factors for developing cognitive impairment and dementia including older age, specific genetic mutations, and carrying an APOE-e4 allele. Modifiable risk factors include mental illness (depression, anxiety, bipolar disorder), CVD, diabetes, smoking, heavy alcohol use, recreational (e.g., methamphetamine) and prescription (e.g., benzodiazepines) drug use, obesity, lower education quality, and limited social or cognitive engagement (41, 42). Many of these risk factors are known to be more prevalent in sexual minority older adults, indicating that sexual minorities may be at higher risk of cognitive impairment and dementia through these mechanisms, and not HIV infection alone.

1.2.2 Minority Stress Theory

Due to the social marginalization associated with sexual minority identities, attractions, or behaviors, MSM may also have unique risk factors that predispose them to poor cognitive function associated with neurodegenerative disease (i.e., non-injury-related cognitive impairment) in older adulthood. While any such risk factors have yet to be studied in the context of cognitive impairment among MSM, studies from racial and ethnic minority populations may provide insight into potential added risks beyond those present in the general population. In the US, Black and Hispanic/Latinx individuals, have disproportionately high rates of cognitive impairment and dementia compared to white individuals. Asian-Americans have been inadequately studied in dementia research, but appear to be the racial/ethnic group with the lowest incidence of dementia (16, 43). In

the US, racial and ethnic minority populations are disproportionately impacted by a myriad of sociocultural factors, each of which may account for the increased rates of cognitive impairment and dementia. Such factors include lower access to quality education, poverty, discrimination, and limited access to and/or use of health care services (44-46). For example, one study found that white individuals with low SES and Black individuals with high SES had twice the risk of dementia compared to white individuals with high SES. On the other hand, Black participants with low SES had five times the risk of dementia (47). Other authors have noted that place of birth may be a primary driver of racial inequalities in rates of dementia due to exposures to environmental toxins that affect brain development (e.g., mercury) or lack of institutional resources (e.g., libraries, community centers) (48-51).

MSM share many of the same social, economic, and environmental risks for cognitive impairment and dementia as other socially disadvantaged groups. The minority stress model refers to the expanded theory developed to explain how sexual minority individuals experience stressors that mediate the relationship between their sexual identities, behaviors, or attractions, and mental or physical health problems (52, 53). According to the theory, minority stress is additive to general stress experienced by all people, is chronic, and is socially based. That is, the stress is a result of social structures and norms that stigmatize their sexual identities. The theory also posits that sexual minorities experience both distal and proximal stressors within their environments. Distal stressors are external processes and include experiences with prejudice, discrimination, and violence. These distal processes are also often referred to as *enacted sexual minority stigma* (54). Proximal stressors occur as a product of exposure to distal stressors, and include internal processes such as expectations or being stereotyped or rejected, concealing one's sexual minority identity for fear of harm,

or internalizing negative social attitudes about sexual minorities and applying them to oneself (52, 53).

The combination of distal and proximal stressors produces high levels of stress. While adaptive in the short-term, protracted stress activation can lead to inflammation, cardiovascular strain, increased circulation of cortisol, hypothalamic-pituitary-adrenal (HPA) axis dysregulation, and other structural and functional damage to the body that underlie the development of chronic disease and cognitive impairment for sexual minorities (55). There are other ways that minority stress contributes to cognitive impairment for sexual minorities. For example, enacted sexual minority stigma creates barriers to health care for sexual minorities. Many sexual minority older adults report being denied health care or provided with inferior care due to their sexual identity (3). Furthermore, those who fear disclosing their sexual minority identity to healthcare providers are more likely to delay or avoid routine care and examinations (56). As a result, cognitive impairment may go unnoticed or untreated (5). Enacted sexual minority stigma also increases social isolation, loneliness, and substance use, all of which have been associated with increased risk of poor cognitive function in the general population (57).

1.2.3 Life-course Theory

A life-course perspective that considers the effects of early adversity can be used to more fully understand the aging process of sexual minorities (58). A life-course perspective provides a means for taking into consideration how an individuals' life is shaped by structural, social, and historical contexts (59). This perspective can be used to understand how the health of midlife and older sexual minority men is shaped by their life experiences, including coming of age in a time of patholigization and criminalization of sexual minority identities, surviving the height of the

AIDS epidemic, and witnessing a shift in public attitude towards broader acceptance of sexual minorities (60-62). Having lived through these periods of intense stigmatization and invisibility, sexual minority men continue to contend with stress associated with a lifetime of victimization and discrimination (63-66).

Within a life-course approach, there are concepts that relate the timing of exposures to subsequent disease outcomes, including critical periods and sensitive periods. A critical period is a limited time window in which an exposure can have adverse and lasting effects on the structure and function of an organism which cannot be later modified. A sensitive period is a time window when an exposure has a stronger effect on disease risk than it would at other times. However, outside this time window it is still possible to modify or reverse the disease outcomes (67). Developmental phases such as childhood or adolescence may represent critical or sensitive windows for cognitive function in later life. A growing body of literature provides empirical evidence that cognitive impairment in later life is rooted at least in part in childhood (68). While the mechanisms are unknown, it is hypothesized that early-life adversity affects cognition directly through impairments in brain development, indirectly through educational attainment, occupation, income, health behaviors, and chronic diseases, or a combination of both (69).

There is little data regarding the existence of critical or sensitive periods for how early adversity affects cognitive function among sexual minority men. A preliminary study using data from the MACS found a dose-response relationship for childhood dissatisfaction, victimization, and parental substance abuse during childhood and lower scores in global cognitive functioning in mid- to late-adulthood (70). Given the many developmental changes that occur throughout adolescence, including major landmarks in the development of sexuality, this may be a time of heightened vulnerability to various minority stressors for sexual minorities (71).

1.2.4 Resilience Theory

Although it is important to elucidate the socio-behavioral mechanisms that place sexual minorities at higher risk for poor health, it is also necessary to acknowledge that not all sexual minority individuals who have experienced adversity develop adverse health outcomes. Similarly, despite the likelihood of higher risk, not all sexual minorities develop cognitive impairment in midlife or older adulthood, suggesting the presence of considerable resilience in this population.

Resilience has been typically characterized as a trait, process, resource, or outcome that reflects positive adaptation in the context of past or present adversity or risk (72, 73). The concept of resilience encompasses individual, interpersonal, and environmental factors that assist with adaptation to adversity or risk (73). Certainly, the minority stress experienced by sexual minority individuals constitutes adversity, as sexual minorities must learn to integrate their sexual identity into their daily life in the presence of a homophobic culture.

Evidence for resilience among sexual minority men is abundant (74). In the literature, resilience is evidenced in the areas of smoking cessation and recovery (75), avoiding problematic drug use (76, 77), avoidance of high-risk sexual behaviors (76), the use of adaptive coping skills (78), and the fostering of strong community and social supports (79). Furthermore, in the US culture, sexual minorities have displayed resilience through activism in the early gay rights movement, fighting for attention to and treatment for HIV/AIDS, and the continued fight for social justice (74, 80).

Many authors have noted the limitations of addressing health disparities for sexual minorities based in models such as minority stress, that emphasize deficits and may overlook resources and strengths in sexual minority communities (74). Thus, it is necessary to examine both risk as

well as protective factors when examining the cognitive health of sexual minority men. One potentially potent protective factor is social support.

1.2.5 Social Support and Cognitive Health

In the general population, evidence suggests that social relationships have a robust effect on cognitive health (81-84). Although widely studied, the effect of social relationships on health is muddled by inconsistent and unclear definitions of various social factors (85). To address this issue, several authors have attempted to define and distinguish these terms. Berkman and colleagues developed a framework wherein they describe how social integration influences health status. In this framework, social, community, and family resources promote access to social networks, defined as the web of social relationships that surrounds an individual. Characteristics of social networks include the network size, the relationship between members, and frequency of contact between members. Networks, in turn, promote access to social activities (also known as social participation or engagement) and social support. Social activity includes participating in group recreational activities, meeting friends, or attending events. Social support refers to a person's perception of the availability of help or support from other people in their network, and is divided into emotional, instrumental, and informational support (86). To further refine the terminology, Kuiper and colleagues refer to social networks and activity as structural aspects of social relationships, while they consider social support to represent a functional aspect of social relationships (87).

The existing research has demonstrated mixed effects of social support on cognitive functioning. Evidence suggests that quality rather than quantity is protective of cognitive decline, and that

emotional support seems to have more beneficial effects than instrumental or informational support (88-91). In a systematic review, Kelly et al. found that social support may exert positive effects on global cognition and episodic memory but not attention or processing speed (84). Furthermore, the impact of social support may vary by the source of support, although there is little consensus among studies. Some studies have reported that family support was protective against cognitive decline, but support from friends or relatives was not (92-94). On the other hand, other studies found that support from friends had a protective effect (94, 95). It is also important to distinguish between different aspects of social relationships, because they may influence cognitive decline through different mechanisms (87). For example, structural aspects of social support such as having a small social network may influence health behaviors (96). On the other hand, social support may benefit cognitive function by providing psychological and material resources needed to cope with stress (96). Stress and stress hormones including cortisol have been shown to negatively affect cognitive functioning and are associated with cognitive decline and the development of AD due to structural changes in the hippocampus (82, 97).

In another review and meta-analysis, Kuiper et al. pooled estimates from four longitudinal cohort studies and found no relationship between low social support and cognitive decline, but in pooled estimates from three other studies found that being lonely was positively associated with cognitive decline (85). Indeed, efforts to elucidate the mechanisms between social support cognitive functioning have revealed that loneliness may account for the beneficial effect of social support on cognitive functioning (86). Loneliness is defined as "distressing feeling that accompanies the perception that one's social needs are not being met by the quantity or especially the quality of one's social relationships" (98). Loneliness results in disengagement from physical and social activities, increased stress, and heightened feelings of depression and anxiety which may explain the

association between being lonely and poor cognitive outcomes (99). Taken together, there is a continued need to elucidate whether social support protects against cognitive decline, and whether this relationship is best explained by a main-effects hypothesis, stress-buffering hypothesis, or if a third variable such as loneliness is a stronger predictor of cognitive function.

1.2.6 Social Support Among Sexual Minority Men

There is a need to investigate the effect of social support on the cognitive function of cis-gender sexual minority men. Importantly, given the known sex differences in risk of cognitive impairment among people assigned male and female at birth, and differences in biological and social processes that contribute to this risk, sexual minority men should be studied independently of other sexual minority subgroups.

Another important component of the minority stress model is the inclusion of various coping mechanisms that ameliorate minority stress (52, 53). For example, receiving social support from a group of peers provides an environment where negative self-evaluations can be overcome and group-based coping skills can be developed to mitigate the adverse effects of minority stress (52, 53). Indeed, social support appears to have robust health-promoting effects for sexual minority men, including greater viral load suppression (100), greater physical and mental health-related quality of life (HRQoL) (101), lower psychological distress (102), lower internalized homonegativity and sexual identity concealment (103), greater perceived health (104), and may buffer stigmatization (105). It is possible that the positive effects may extend to cognitive function as well. There are several reasons why it is important to investigate the role of social support among sexual minority men separately from heterosexual men.

First, the sources of social support may be different for sexual minority men. Generally,

older adults first seek social support from family members including spouses and children, followed by other relatives, friends, and neighbors. However, compared to their heterosexual peers, sexual minority older men are less likely to be married, less likely to have children or grandchildren, and are more likely to live alone (3, 106, 107). Furthermore, because of rejection from their families of origin, some sexual minority men form "chosen families" – fictive kinship networks with other members of sexual minority communities (108). For these reasons, sexual minority men may rely on friends as the primary source of social support (109, 110).

Second, although social support often decreases in later life, the consequences of decreased social support may be different, and more severe, for sexual minority men relative to other older adults. In the absence of support from family or friends, older adults often rely on formal community-based support systems (111). However, few service organizations provide specific services for sexual minority older adults, and sexual minority older adults may avoid seeking formal services due to stigma associated with being gay or bisexual (112, 113).

Nevertheless, ensuring adequate social supports for sexual minority men in older adulthood is critical. Social support appears to have significant health effects for other outcomes in this population including resilience (114), psychological distress and well-being (115), and health-related quality of life (101). It is also likely that social support may have a beneficial effect on cognition due to its buffering effect on stress (116). Thus, social support may be a salient resource in for sexual minority men to mitigate the effects of chronic exposure to sexual minority stress.

2.0 Current Dissertation Research

This dissertation addresses current gaps in the literature regarding cognitive function among MSM. Overall, this literature is sparse, especially regarding MSM who are HIV-negative. Furthermore, there is limited data on cognitive function among sexual minority older adults overall, and results from the extant literature are inconsistent. This dissertation seeks to add to the body of literature by including both MSM living with HIV and those who are HIV-negative. Additionally, these analyses are among the first to explore risk and protective factors for poor cognitive function among MSM. Exploring such factors is a necessary first step towards developing and testing interventions at the individual, community, and societal level to improve health and well-being for this population. The conceptual model (Figure 1) outlines how this dissertation includes a life-course perspective in an adaptation of the minority stress model to address cognitive function among midlife and older MSM.

To achieve these goals, the first analysis explores the effect of perceived social support on cognitive function of MSM both at baseline and across a 2-year period. This study is the first to explore the effect of social support on cognitive function among MSM specifically. The second analysis draws upon the Minority Stress Theory to explore whether enacted sexual minority stigma may contribute to the risk of poor cognitive function among MSM. In prior work with the MACS, biological and sociodemographic variables did not fully explain why some MSM developed poor cognitive function in midlife and older adulthood, whereas some did not. Psychosocial factors such as enacted sexual minority stigma may be a variable unique to MSM that confer additional risk for poor cognitive function in this population. In the third analysis, the analysis of enacted sexual

minority stigma is expanded to include enacted sexual minority stigma both experienced and witnessed during adolescence. Finally, the third paper also explores social support as an effect modifier of the association between all forms of enacted sexual minority stigma and cognitive function.

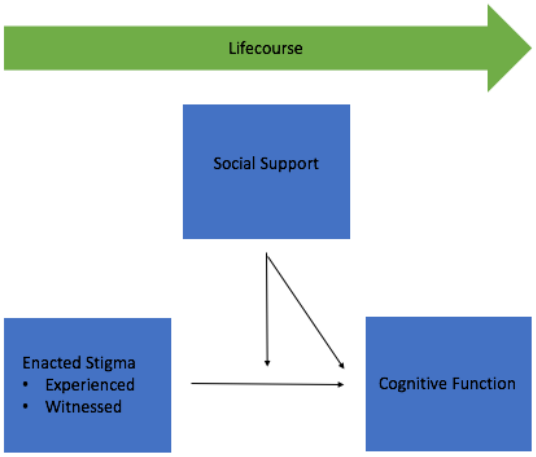

Figure 1. Dissertation Conceptual Model

2.1 Analysis 1: Aims and Hypotheses

Aim 1: Determine whether perceived social support is associated with cognitive function among midlife and older adult MSM.

Hypothesis 1.1: Men with lower social support will have poorer cognitive function compared to those with higher social support.

2.2 Analysis 2: Aims and Hypotheses

Aim 1: Determine whether enacted sexual minority stigma experienced during adulthood is associated with cognitive function among midlife and older adult MSM.

Hypothesis 1.1: MSM who experienced more enacted sexual minority stigma during adulthood will have poorer cognitive function compared to those who report fewer instances of enacted sexual minority stigma

2.3 Analysis 3: Aims and Hypotheses

Aim 1: Determine whether enacted sexual minority stigma in adolescence or adulthood is associated with cognitive function among midlife and older adult MSM.

Hypothesis 1.1: MSM who experienced more enacted sexual minority stigma during adolescence will have poorer cognitive function during midlife or older adulthood compared to those who reported fewer instances of enacted sexual minority stigma, after accounting for enacted sexual minority stigma experienced during adulthood and enacted sexual minority stigma witnessed during adolescence.

Hypothesis 1.2: MSM who witnessed more enacted sexual minority stigma during adolescence will have poorer cognitive function during midlife or older adulthood compared to those who reported fewer instances of witnessing enacted sexual minority stigma, after accounting for enacted sexual minority stigma experienced during adolescence and adulthood.

Hypothesis 1.3: MSM who experienced more enacted sexual minority stigma during adulthood will have poorer cognitive function compared to those who report fewer instances of enacted

sexual minority stigma, after accounting for enacted sexual minority stigma experienced and witnessed during adolescence.

Aim 2: To determine whether social support modifies the association between enacted sexual minority stigma and cognitive function among midlife and older adult MSM.

Hypothesis 2.1: The effect of enacted sexual minority stigma experienced during adolescence on cognitive function will be greater in magnitude for MSM with lower social support.

Hypothesis 2.1: The effect of enacted sexual minority stigma witnessed during adolescence on cognitive function will be greater in magnitude for MSM with lower social support.

Hypothesis 2.1: The effect of enacted sexual minority stigma experienced during adulthood on cognitive function will be greater in magnitude for MSM with lower social support.

3.0 Social Support and Cognitive Function Among Midlife and Older Men Who Have Sex with Men from the Multicenter AIDS Cohort Study

3.1 Introduction

Understanding cognitive function is critical in the study of healthy aging of gay, bisexual, and other men who have sex with men (MSM). Maintaining healthy cognitive function is necessary to carry out the mental processes of memory, language, attention, executive function, judgement, as well as skills such as driving and the ability to lead a purposeful life (15). Impairments in cognitive function can lead to problems remembering, learning new things, concentrating, or making decisions, and can interfere with a person's ability to complete activities of daily, leading to decreased independence and well-being (15). Most of what is known regarding cognitive function among MSM has been studied in the context of HIV. Despite the increasing efficacy of combination antiretroviral therapy (cART), people living with HIV still experience a high prevalence of cognitive impairment, particularly the milder forms, with prevalence estimates ranging from approximately 30-60% (9). Additionally, a recent analysis also showed that over 30% of HIV-negative MSM also experienced any severity of cognitive impairment (9). These estimates suggest an urgent need to identify factors that promote cognitive health among MSM.

One factor that may promote cognitive health among MSM is social support. Social support refers to a person's perception of the availability of help or support from other people in their network, and is divided into emotional, instrumental, and informational support (86). In the general population, evidence suggests that social support has a positive effect on cognitive function (81-84). One proposed mechanism for these effects is that social support provides psychological and

material resources needed to cope with stress (96). Additionally, social support may be important for cognitive health due to its efficacy in reducing loneliness (88). Among MSM, there is substantial research showing that social support has positive effects for several health outcomes including HIV viral load suppression (100), physical and mental health-related quality of life (HRQoL) (101), psychological distress (102), and depression (117). It is possible that the positive effects may extend to cognitive function as well.

There are several reasons why it is important to investigate how social support affects cognitive function for MSM separately from their heterosexual counterparts. First, the sources of social support may be different for sexual minority men. Generally, older adults first seek social support from family members including spouses and children, followed by other relatives, friends, and neighbors. However, compared to their heterosexual peers, MSM are less likely to be married, less likely to have children or grandchildren, and are more likely to live alone (3, 106, 107). Furthermore, because of rejection from their families of origin, some MSM form "chosen families" – fictive kinship networks with other members of sexual minority communities (108). For these reasons, sexual minority men may rely on friends as the primary source of social support (109, 110). Second, although social support often decreases in later life, the consequences of decreased social support may be different, and more severe, for MSM relative to other older adults. In the absence of support from family or friends, older adults often rely on formal community-based support systems (111). However, few service organizations provide specific services for MSM, and MSM may avoid seeking formal services due to stigma associated with their sexual identity or behavior (112, 113).

Currently there are no studies that investigate the effect of social support on the cognitive function of MSM. Therefore, the purpose of this study was to evaluate the effects of social support

on cognitive function in a cohort of midlife and older MSM, including both HIV-negative MSM and MSM living with HIV. First, we examined the cross-sectional association of social support on cognitive function at baseline. We hypothesized that participants with lower social support at baseline would have poorer cognitive function at baseline. Next, we examined the prospective association of social support and cognitive function over a 2-year period. We hypothesized that lower social support would relate to poorer cognitive function.

3.2 Methods

3.2.1 Study Design

To address these research questions, we conducted a secondary analysis of data collected by the Multicenter AIDS Cohort Study (MACS). The MACS, now part of the MACS-WIHS Combined Cohort Study (MWCCS) is an ongoing study of the natural and treated history of HIV infection among gay, bisexual, and other MSM. The MACS includes men living with HIV as well as HIV-negative men (118). The study design of the MACS has been described in several prior studies (119, 120). Briefly, participants were enrolled in one of four sites (Los Angeles, Pittsburgh, Chicago, and Baltimore/Washington). Enrollment occurred in three cohorts: in 1984–1985, 1987–1991, and 2001–2003. Each center recruited men through combinations of notices placed in gay bars, newspapers, and community centers, promotional offerings (e.g., medical screening), and connections to medical centers that served largely gay and bisexual men. Enrollees were also encouraged to tell friends about the study. Participants return to MACS sites every six months for a battery of medical and behavioral surveys, physical and neuropsychological examinations, and

specimen collection. All study procedures were approved by the Institutional Review Boards at each of the local study sites. Informed consent was obtained from all participants at the beginning of each study visit.

The details of the neuropsychological testing have been described previously (31). The MACS administers a full battery of neuropsychological tests at baseline and every 2 years for all participants as well as a brief battery during each semi-annual visit. The MACS neuropsychological evaluation includes tests from multiple cognitive domains including executive function, speed of information processing, attention and working memory, learning, memory, and motor speed/coordination. The brief battery consists of the Standard Trail Making Test (TMT) Parts A and B and the Symbol Digit Modalities Tasks (SDMT) corresponding to attention and processing speed, executive function, and information processing, respectively.

The present analysis was restricted to participants enrolled in the *Healthy Aging Study*, a sub-study of the MACS (10). To be eligible for the study, participants had to have been present at two consecutive MACS visits, report an age at or above 40 years, and report having had sex with another man at least once since enrolling into the MACS. This analysis utilized data from 1,318 participants (~20% of the entire MACS cohort) at visits 66–70 from October 2016 to March 2019 who had at least one score from the brief neuropsychological battery administered during these visits.

3.2.2 Measures

Demographic characteristics. Self-reported demographic characteristics included age at the time of the study visit (40-64 years, 65 years or older), sexual identity (gay, bisexual, other [i.e., queer, pansexual, heterosexual/straight]), race/ethnicity (non-Hispanic white, non-Hispanic

Black, Hispanic/Latino, non-Hispanic other race [i.e., American Indian/Alaska native, Asian, multiple races]), HIV status (HIV-positive, HIV-negative), employment (employed full-time or part-time, unemployed [i.e., unemployed, a student, or unable to work due to disability] or retired), educational attainment (high school or less, some college or more), and relationship status (partnered or married, single). Other variables included in this analysis were study site (Baltimore/Washington, Chicago, Pittsburgh, Los Angeles) and wave of enrollment (pre-1987, post-2001).

Social support. Social support was measured by the Social Provisions Scale (SPS) (121). The instrument contains 24 items, four for each of the following constructs: attachment; social integration; reassurance of worth; reliable alliance; guidance; and opportunity for nurturance. The respondents indicated on a 4-point Likert scale the extent to which each statement describes their current relationships with all people in their lives (friends, family members, coworkers, community members, and so on). Responses range from 1 (strongly disagree) to 4 (strongly agree). After reversal of negatively worded items, a total score was computed by averaging all items for each subscale individually, and then averaging the subscale scores to generate an overall score. Scores range from 1 to 4, with higher scores indicating more social support. To retain as many participants as possible, we calculated sub-scale averages using all available responses. For example, if a participant answered 3 out of the 4 items in a sub-scale, the score for that sub-scale was the average of the 3 answered items.

Standard Trail Making Test (TMT) Parts A and B. The instructions for TMT A and TMT B require that the tests must be performed as quickly and accurately as possible. In TMT A, participants are asked to draw lines sequentially connecting in ascending order 25 encircled numbers randomly distributed on a piece of paper. In TMT B, participants are asked to connect numbers (1-

13) and letters (A-L) while alternating between them (i.e., 1-A-2-B, etc.). The test proctor immediately stops the participant when a mistake occurs and prompts correction. The time to complete TMT A and TMT B are recorded as the main outcome. We used the TMT A score as a measure of psychomotor ability. We also used the ratio of the TMT B to TMT A scores as a measure of executive function, while accounting for the effects of psychomotor speed and visual searching ability. Higher ratio scores indicate poorer set-shifting ability (an aspect of executive function). We log transformed tests scores from the TMT A and TMT B to approximate a normal distribution.

Symbol Digit Modalities Tasks (SDMT). The SDMT asks participants to use a coded key to match nine abstract symbols paired with numerical digits. After completing the first 10 items with guidance, the subject is timed to determine how many responses can be made in 90 seconds. We used the SDMT as a measure of information processing ability. Lower scores indicate poorer information processing.

3.2.3 Missing Data Analysis

Of the 1,318 eligible participants, 94 (7.13%) were missing demographic data (sexual identity, employment status, educational attainment, or relationship status) and were removed from the analysis. Of the remaining 1,224 participants, 142 were missing all TMT A, TMT B and SDMT scores in visits 66–70. Participants with missing data were more likely to be older ($p < 0.001$), Non-Hispanic White ($p < 0.001$), retired ($p = 0.001$), HIV-negative ($p = 0.048$), enrolled pre-1987 ($p = 0.001$), and from the Los Angeles study site ($p < 0.001$). No statistically significant differences were observed by sexual identity, educational attainment, or relationship status. These participants with missing data were removed from the analysis. Of the remaining participants, 1 participant was missing scores for the SPS-24 at all study visits and was also removed from the analysis,

creating a final analytic sample of $N = 1{,}081$ midlife and older MSM.

3.2.4 Statistical Analyses

First, we calculated the internal consistency of the SPS-24 using Cronbach's alpha. Next, descriptive statistics were generated for sociodemographic, social support, and cognitive function variables at baseline. We then conducted bivariate tests of association (e.g., *t-tests, one-way ANOVA)* to identify demographic differences in social support and cognitive function variables at baseline. Next, we conducted a cross-sectional analysis using a series of multivariable linear regression models to estimate the association between social support and cognitive function at baseline. Each series of analyses was conducted separately for the TMT A, TMT B to A ratio, and SDMT. All analyses adjusted for age, education, race/ethnicity, sexual identity, employment status, relationship status, HIV status, enrollment wave, and study site.

Next, descriptive statistics were generated for the social support and cognitive function variables across all study visits. We then conducted a longitudinal analysis using linear mixed models with repeated measures to assess the association between social support and cognitive function across a 2-year period (visits 66-70) using the same series of models as the cross-sectional analysis. Full-information maximum likelihood parameter estimation was used to account for missing data. For the model using the TMT A score as the dependent variable, a likelihood ratio test determined that a random slopes model fit the data best. Time-fixed predictors included sexual identity, employment status, relationship status, HIV status, enrollment wave, and study site. Random effects were modeled for time (coded as 0, 6, 12, 18, and 24 months). Random effects allow for the slopes between time and the dependent variable to differ across participants. For the model using TMT B to A ratio as the dependent variable, a likelihood ratio test determined that a random

intercept model fit the data best, and the cognitive function scores at baseline were allowed to differ across participants. Time-fixed predictors included age, education, race/ethnicity, sexual identity, employment status, relationship status, HIV status, enrollment wave, and study site. Finally, for the model using the SDMT score as the dependent variable, a likelihood ratio test determined that a random slopes model fit the data best. Time-fixed predictors included sexual identity, employment status, relationship status, HIV status, enrollment wave, and study site. Random effects were modeled for time. Random effects allow for the slopes between time and the dependent variable to differ across participants. All analyses were conducted using Stata version 16.0 (StataCorp, College Station, TX, USA).

3.3 Results

Table 1 provides a description of the sociodemographic characteristics of our sample at baseline. Of the men included in this sample, 30.3% of the men were age 65 or older. The sample was predominantly gay (90.0%), white (68.6%), employed (55.5%), and had attended some college or more (88.8%). Approximately half (49.9%) of participants were married or partnered, and approximately have were living with HIV (50.3%). Finally, the highest proportion of the sample was recruited prior to 1987 (63.0%) and attended the Baltimore/Washington study site (32.3%).

Reliability of the Social Support Measure

There was attrition in SPS-24 completion over time. Of the 1,081 men in the sample, 951 completed the SPS-24 at visit 66, 965 completed the SPS-24 at visit 67, 862 completed the SPS-24 at visit 68, 901 completed the SPS-24 at visit 69, and 864 completed the SPS-24 at visit 70. At visit 66, participants with missing SPS-24 data were more likely to be Hispanic/Latino ($p = 0.043$)

and from the Los Angeles study site ($p < 0.001$). At visit 67, participants with missing SPS-24 data were more likely to be HIV-positive ($p = 0.037$) and from the Los Angeles study site ($p = 0.003$). At visit 68, participants with missing SPS-24 data were more likely to be from the Los Angeles study site ($p = 0.001$). There were no significant differences in missingness at visit 69. At visit 70, participants with missing SPS-24 data were more likely to be from the Los Angeles study site ($p = 0.001$). The SPS-24 showed high internal consistency overall across all visits of data collection (Cronbach's alpha ranged from 0.90-0.92).

Baseline Analysis

Table 2 provides a description of the SPS-24. The mean (SD) scores on the SPS-24 from visits 66-70 ranged from 3.2 (0.45) – 3.23 (0.46). Figure 2 also displays the mean scores on the SPS-24 across all study visits. At baseline, higher mean social support scores were found among gay ($p < 0.001$), non-Hispanic white ($p < 0.001$), employed ($p < 0.001$), married or partnered ($p < 0.001$), and HIV-negative men ($p < 0.001$), those with higher education attainment ($p < 0.001$), and those enrolled prior to 1987 ($p < 0.001$). No statistically significant differences were observed by age or study site (data not shown).

Table 3 presents the unadjusted mean (SD) scores for the cognitive function outcomes. The unadjusted mean (SD) TMT A score at visit 66 was 21.49 (8.56) seconds. The highest mean TMT A scores (indicating poorer psychomotor speed) were found among MSM who were older ($p < 0.001$), bisexual ($p < 0.001$), non-Hispanic Black ($p < 0.001$), unemployed ($p < 0.001$), had lower educational attainment ($p < 0.001$), single ($p < 0.001$), HIV-positive ($p = 0.02$), enrolled after 2001 ($p < 0.001$), and from the Chicago study site ($p < 0.001$) (data not shown). Figure 3 displays the mean TMT A scores across all study visits. The unadjusted mean (SD) for the TMT B to A ratio at visit 66 was 2.32 (0.92). The highest mean TMT B to A ratio scores (indicative of worse set-

shifting performance) were found among men identifying as other sexual identity ($p < 0.001$), Hispanic/Latino ($p < 0.001$), unemployed ($p = 0.003$), had lower educational attainment ($p < 0.001$), HIV-positive ($p = 0.003$), enrolled after 2001 ($p < 0.001$), and from the Baltimore/Washington study site ($p < 0.001$) (data not shown). Figure 4 displays the mean TMT B to A ratios across all study visits. Finally, the unadjusted mean (SD) SDMT score at visit 66 was 54.95 (14.02) correct answers. Lower SDMT scores (indicating poorer information processing) were found among MSM who were older ($p < 0.001$), bisexual ($p < 0.001$), non-Hispanic Black ($p < 0.001$), unemployed ($p < 0.001$), had lower educational attainment ($p < 0.001$), single ($p < 0.001$), HIV-positive ($p = 0.005$), and enrolled after 2001 ($p < 0.001$) (data not shown). Figure 5 displays the mean SDMT scores across all study visits.

Table 4 presents the adjusted associations at baseline between social support and the TMT A score. After adjusting for covariates, individuals who reported higher social support had lower TMT A scores, indicating better psychomotor ability ($b = -2.01$, 95% CI = -3.24, -0.77). Compared to participants age 40-64, those ages 65 or older had higher TMT A scores, indicating that they took longer to complete the task ($b = 4.69$, 95% CI = 3.26, 6.11). Compared to non-Hispanic white participants, we found higher TMT A scores among non-Hispanic Black ($b = 3.65$, 95% CI = 2.08, 5.23) and Hispanic/Latino ($b = 2.46$, 95% CI = 0.44, 4.48) participants. Relative to those who were employed, we found higher TMT A scores among unemployed ($b = 3.29$, 95% CI = 1.66, 4.91) and retired ($b = 2.32$, 95% CI = 0.89, 3.74) participants. Finally, we found higher TMT A scores among participants recruited after 2001 compared to before 1987 ($b = 1.53$, 95% CI = 0.23, 2.82) and from the Chicago compared to the Baltimore/Washington study site ($b = 2.51$, 95% CI = 0.94, 4.08). We found lower TMT A scores among participants who attended some college or more compared to high school or less ($b = -2.14$, 95% CI = -3.93, -0.35) and those from the Los Angeles

compared to the Baltimore/Washington study site (*b* = -1.56, 95% CI = -3.02, -0.10). There were no differences by sexual identity, relationship status, or HIV status.

Table 4 also presents the adjusted associations at baseline between social support and the TMT B to A ratio. After adjusting for covariates, we observed no association between social support and TMT B to A ratio (*b* = -0.08, 95% CI = -0.22, 0.06). Compared to non-Hispanic white participants, we found higher TMT B to A ratios among non-Hispanic Black (*b* = 0.30 (0.11, 0.48) and Hispanic/Latino (*b* = 0.30 (0.11, 0.48) participants, indicating that they took longer to complete the task. We found lower TMT B to A ratios among participants who attended some college or more compared to high school or less (*b* = -0.38, 95% CI = -0.59, -0.17) and those from the Pittsburgh compared to the Baltimore/Washington study site (*b* = -0.24, 95% CI = -0.40, -0.08). There were no differences by age cohort, sexual identity, employment, relationship status, HIV status, or enrollment wave.

Finally, Table 4 presents the adjusted associations at baseline between social support and the SDMT score. After adjusting for covariates, individuals who reported higher social support had higher SDMT scores, indicating better information processing ability (*b* = 2.28, 95% CI = 0.22, 4.34). Compared to participants age 40-64, those ages 65 or older had lower SDMT scores, indicating that they had fewer correct answers (*b* = -7.31, 95% CI = -9.68, -4.93). We also found lower SDMT scores among non-Hispanic Black compared to non-Hispanic white participants (*b* = 3.65, 95% CI = 2.08, 5.23), those who were unemployed compared to employed (*b* = -4.49, 95% CI = -7.21, -1.77), and from the Pittsburgh compared to Baltimore/Washington study site (*b* = -2.49, 95% CI = -4.81, -0.17). Compared to participants who attended high school or less, those who attended some college or more had higher SDMT scores (*b* = 6.78, 95% CI = 3.81, 9.75). There were no differences by sexual identity, relationship status, HIV status, or enrollment wave.

Longitudinal Analysis

Table 5 presents the adjusted associations between social support and TMT A score, TMT B to A ratio, and SDMT score across visits 66-70. After adjusting for covariates, individuals who reported higher social support had lower TMT A scores, indicating better psychomotor ability (*b* = -1.76, 95% CI = -2.42, -1.10). Compared to participants age 40-64, those ages 65 or older had higher TMT A scores (*b* = 4.84, 95% CI = 3.66, 6.01). Bisexual participants had higher TMT A scores relative to those who identified as gay (*b* = 2.66, 95% CI = 0.67, 4.64). Compared to non-Hispanic white participants, we found higher TMT A scores among non-Hispanic Black (*b* = 3.59, 95% CI = 2.33, 4.85) and Hispanic/Latino (*b* = 3.49, 95% CI = 1.84, 5.15) participants. Relative to those who were employed, we found higher TMT A scores among unemployed (*b* = 3.81, 95% CI = 2.51, 5.11) and retired (*b* = 2.33, 95% CI = 1.17, 3.49) participants. Finally, we found higher TMT A scores among participants recruited after 2001 compared to before 1987 (*b* = 1.32, 95% CI = 0.27, 2.38) and from the Chicago compared to the Baltimore/Washington study site (*b* = 1.69, 95% CI = 0.46, 2.92). We found lower TMT A scores among participants who attended some college or more compared to high school or less (*b* = -2.49, 95% CI = -3.93, -1.06) and those from the Los Angeles compared to the Baltimore/Washington study site (*b* = -1.99, 95% CI = -3.32, 2.62). There were no differences by relationship status or HIV status.

After adjusting for covariates, we observed no association between social support and TMT B to A ratio (*b* = 0.01, 95% CI = -0.09, 0.21). Compared to participants age 40-64, those ages 65 or older had higher TMT B to A ratios, indicating they took longer to complete the task (*b* = 0.14, 95% CI = 0.02, 0.25). Compared to non-Hispanic white participants, we found higher TMT B to A ratios among non-Hispanic Black (*b* = 0.23, 95% CI = 0.10, 0.35), Hispanic/Latino (*b* = 0.33, 95% CI = 0.17, 0.49), and participants who identified as other race (*b* = 0.54, 95% CI = 0.26, 0.82).

Relative to those who were employed, we found higher TMT B to A ratios among unemployed (*b* = 0.16, 95% CI = 0.03, 0.29) participants. Finally, we found higher TMT B to A ratios among participants recruited after 2001 compared to before 1987 (*b* = 0.12, 95% CI = 0.02, 0.22). We found lower TMT B to A ratios among participants who attended some college or more compared to high school or less (*b* = -0.28, 95% CI = -0.43, -0.14) and those from the Chicago compared to the Baltimore/Washington study site (*b* = -0.12, 95% CI = -0.24, -0.01). There were no differences by sexual identity, relationship status, or HIV status.

After adjusting for covariates, individuals who reported higher social support had higher SDMT scores, indicating better information processing ability (*b* = 1.05, 95% CI = 0.20, 1.90). Compared to participants age 40-64, those ages 65 or older had lower SDMT scores, indicating that they had fewer correct answers (*b* = -7.65, 95% CI = -9.76, -5.54). Bisexual participants had lower SDMT scores relative to those who identified as gay (*b* = -3.84, 95% CI = -7.44, -0.25). We also found lower SDMT scores among non-Hispanic Black (*b* = -7.63, 95% CI = -9.90, -5.36) and Hispanic/Latino -5.14, 95% CI = -8.11, -2.17) compared to non-Hispanic white participants, and those who were unemployed compared to employed (*b* = -7.47, 95% CI = -9.76, -5.17). Compared to participants who attended high school or less, those who attended some college or more had higher SDMT scores (*b* = 6.34, 95% CI = 3.75, 8.93). There were no differences by relationship status, HIV status, enrollment wave, or study site.

Table 1. Sociodemographic Characteristics of Midlife and Older MSM in the MACS at Baseline (10/2016 – 3/2017), n = 1,081

Sociodemographic Variables	n (%)
Age Cohort	
Midlife (40-64 years)	753 (69.7)
Older (65+ years)	328 (30.3)
Sexual Identity	
Gay	973 (90.0)
Bisexual	55 (5.1)
Other[a]	53 (4.9)
Race/Ethnicity	
Non-Hispanic white	741 (68.6)
Non-Hispanic Black	217 (20.1)
Hispanic/Latino	101 (9.3)
Non-Hispanic other races	22 (2.0)
Employment	
Employed	600 (55.5)
Unemployed[b]	179 (16.6)
Retired	302 (27.9)
Education	
High school or less	121 (11.2)
Some college or more	960 (88.8)
Relationship Status	
Married or partnered	539 (49.9)
Single	542 (50.1)
HIV Status	
Negative	537 (49.7)
Positive	544 (50.3)
Enrollment Wave	
Pre-1987	681 (63.0)
Post-2001	400 (37.0)
Study Site	
Baltimore/Washington	349 (32.3)
Chicago	205 (18.9)
Pittsburgh	271 (25.1)
Los Angeles	256 (23.7)

[a] Includes Queer, pansexual, heterosexual
[b] Includes people who were unemployed, students, or unable to work due to disability

Table 2. Characteristics of the 24-Question Social Provisions Scale

Study Visit	n	Mean (SD)	Reliability[a]
66 (Baseline)	951	3.20 (0.46)	0.92
67 (6 Months)	965	3.20 (0.46)	0.91
68 (12 Months)	862	3.23 (0.46)	0.90
69 (18 Months)	901	3.20 (0.45)	0.90
70 (24 Months)	864	3.21 (0.48)	0.91

[a] Reliability was assessed with Cronbach's alpha

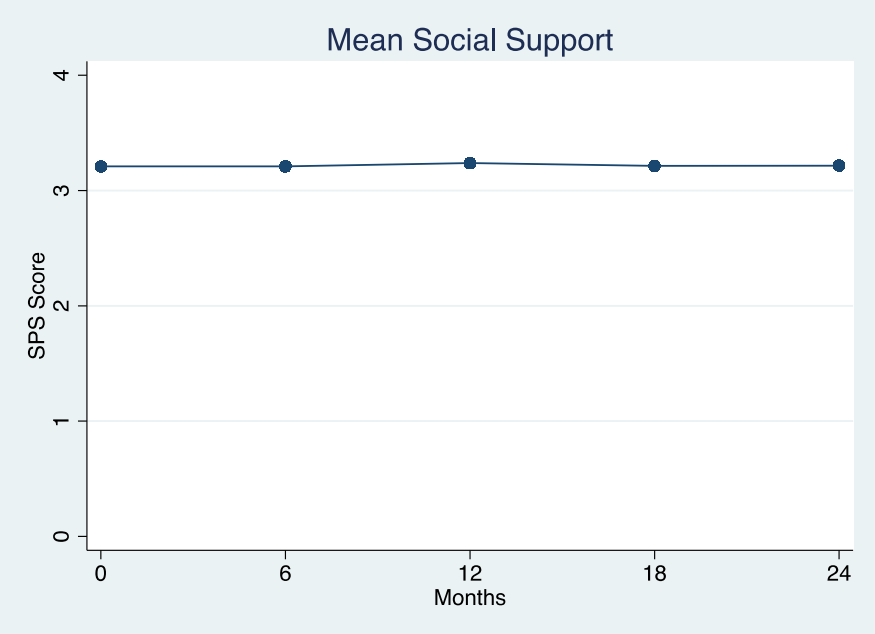

Figure 2. Mean Scores from the 24-item Social Provisions Scale from Visits 66-70 (10/2016 – 3/2019)

Table 3. Cognitive Function Scores of MSM in the MACS from Visits 66-70 (10/2016 – 3/2019)

	TMT A	TMT B	TMT B/A	SDMT
Study Visit	Mean[a] (SD)	Mean[a] (SD)	Mean (SD)	Mean[b] (SD)
66 (Baseline)	21.49 (8.56)	49.06 (26.55)	2.32 (0.92)	54.61 (13.98)
67 (6 Months)	21.86 (8.79)	50.25 (26.67)	2.34 (0.92)	53.95 (14.39)
68 (12 Months)	22.42 (9.21)	49.50 (27.43)	2.26 (0.93)	53.73 (14.32)
69 (18 Months)	22.03 (9.19)	50.99 (30.35)	2.34 (0.91)	53.23 (14.94)
70 (24 Months)	22.72 (9.86)	50.82 (27.87)	2.28 (0.93)	53.63 (14.28)

[a] Seconds
[b] Number of correct responses
Note. TMT = Trail Making Test; SDMT = Symbol Digit Modalities Tasks

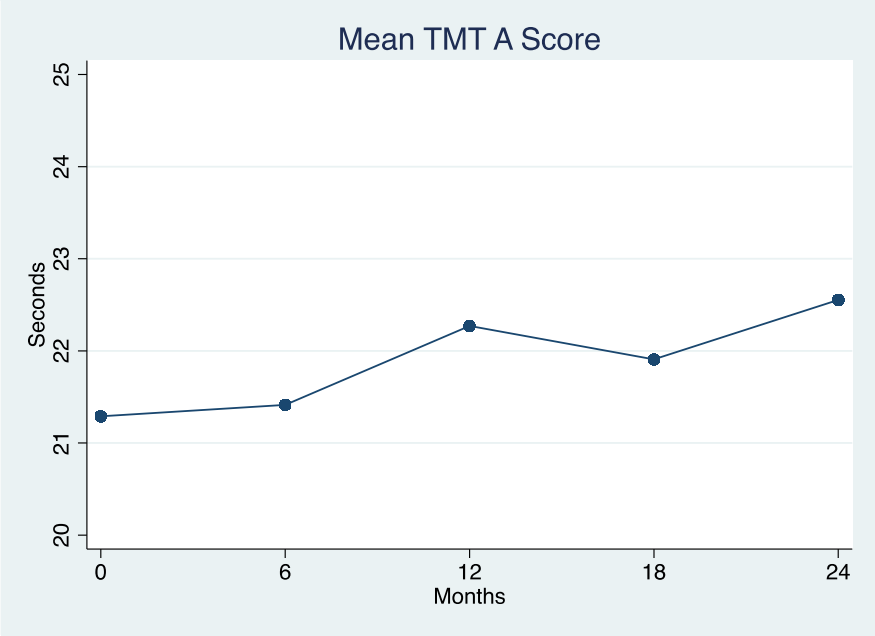

Figure 3. Mean Scores from the Trail Making Test Part A from Visits 66-70 (10/2016 – 3/2019)

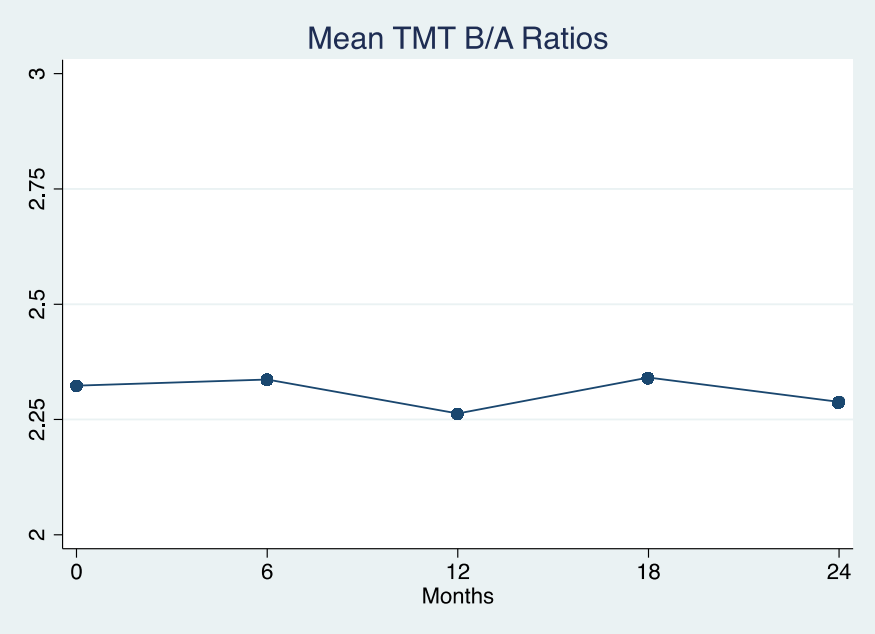

Figure 4. Mean Ratios of the Trail Making Test Part B to A from Visits 66-70 (10/2016 – 3/2019)

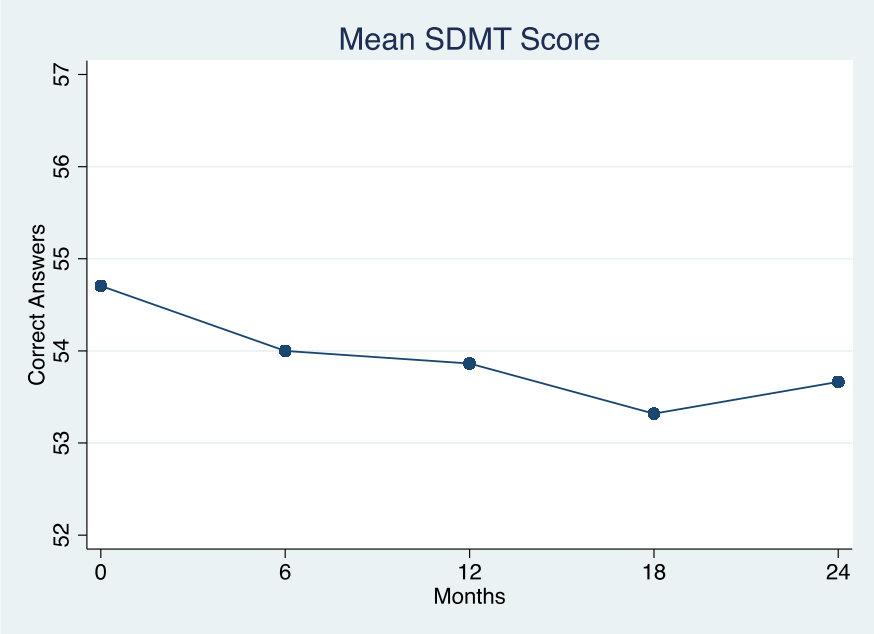

Figure 5. Mean Scores from the Symbol Digit Modalities Tasks from Visits 66-70 (10/2016 – 3/2019)

Table 4. Adjusted Associations of Sociodemograpic Variables and Social Support on Cognitive Function among MSM in the MACS at Baseline (10/2016 – 3/2019)

	TMT A n=834	TMT B/A n=833	SDMT n=832
	***b* (95% CI)**	***b* (95% CI)**	***b* (95% CI)**
Social Support	-2.01 (-3.24, -0.77)**	-0.08 (-0.22, 0.06)	2.28 (0.22, 4.34)*
Age Cohort			
Midlife (40-64 years)	Ref	Ref	Ref
Older (65+ years)	4.69 (3.26, 6.11)**	0.09 (-0.07, 0.26)	-7.31 (-9.68, -4.93)**
Sexual Identity			
Gay	Ref	Ref	Ref
Bisexual	2.30 (-0.10, 4.70)	0.08 (-0.20, 0.36)	-3.65 (-7.66, 0.36)
Other[a]	1.36 (-1.29, 4.01)	-0.005 (-0.31, 0.31)	-1.99 (-6.42, 2.44)
Race/Ethnicity			
Non-Hispanic white	Ref	Ref	Ref
Non-Hispanic Black	3.65 (2.08, 5.23)**	0.30 (0.11, 0.48)**	-7.42 (-10.06, -4.79)**
Hispanic/Latino	2.46 (0.44, 4.48)*	0.30 (0.11, 0.48)**	-2.24 (-5.64, 1.16)
Non-Hispanic other	0.79 (-2.65, 4.22)	0.28 (-0.12, 0.68)	-2.03 (-7.77, 3.71)
Employment			
Employed	Ref	Ref	Ref
Unemployed[b]	3.29 (1.66, 4.91)**	0.02 (-0.16, 0.21)	-4.49 (-7.21, -1.77)**
Retired	2.32 (0.89, 3.74)*	-0.16 (-0.18, 0.15)	-1.08 (-3.46, 1.29)
Education			
High school or less	Ref	Ref	Ref
Some college or more	-2.14 (-3.93, -0.35)*	-0.38 (-0.59, -0.17)**	6.78 (3.81, 9.75)**
Relationship Status			
Married or partnered	Ref	Ref	Ref
Single	0.39 (-0.72, 1.51)	-0.06 (-0.19, 0.06)	-0.13 (-1.99, 1.73)
HIV Status			
Negative	Ref	Ref	Ref
Positive	0.22 (-0.91, 1.35)	0.01 (-0.12, 0.14)	-1.02 (-2.90, 0.87)
Enrollment Wave			
Pre-1987	Ref	Ref	Ref
Post-2001	1.53 (0.23, 2.82)*	0.12 (-0.03, 0.27)	-1.66 (-3.84, 0.51)
Study Site			
Baltimore/Washington	Ref	Ref	Ref
Chicago	2.51 (0.94, 4.08)*	-0.18 (-0.36, 0.004)	1.12 (-1.52, 3.75)
Pittsburgh	1.37 (-0.02, 2.76)	-0.24 (-0.40, -0.08)*	-2.49 (-4.81, -0.17)*
Los Angeles	-1.56 (-3.02, -0.10)*	-0.01 (-0.18, 0.15)	0.01 (-2.42, 2.45)

[a] Includes Queer, pansexual, heterosexual

[b] Includes people who were unemployed, students, or unable to work due to disability

* $p < 0.01$ ** $p < 0.001$

Note. TMT = Trail Making Test; SDMT = Symbol Digit Modalities Tasks; All models adjusted for age, sexual identity, race/ethnicity, educational attainment, employment status, relationship status, HIV status, enrollment wave, study site

Table 5. Adjusted Associations of Sociodemograpic Variables and Social Support on Cognitive Cognitive Function among MSM in the MACS from Visits 66-70 (10/2016 – 3/2019)

	TMT A n=1,064	TMT B/A n=1,062	SDMT n=1,060
	b (95% CI)	*b* (95% CI)	*b* (95% CI)
Social Support	-1.76 (-2.42, -1.10)**	0.01 (-0.09, 0.21)	1.05 (0.20, 1.90)*
Age Cohort			
Midlife (40-64 years)	Ref	Ref	Ref
Older (65+ years)	4.84 (3.66, 6.01)**	0.14 (0.02, 0.25)*	-7.65 (-9.76, -5.54)**
Sexual Identity			
Gay	Ref	Ref	Ref
Bisexual	2.66 (0.67, 4.64)*	0.07 (-0.12, 0.27)	-3.84 (-7.44, -0.25)*
Other[a]	1.20 (-0.84, 3.24)	0.09 (-0.12, 0.31)	-2.02 (-5.93, 1.89)
Race/Ethnicity			
Non-Hispanic white	Ref	Ref	Ref
Non-Hispanic Black	3.59 (2.33, 4.85)**	0.23 (0.10, 0.35)**	-7.63 (-9.90, -5.36)**
Hispanic/Latino	3.49 (1.84, 5.15)**	0.33 (0.17, 0.49)**	-5.14 (-8.11, -2.17)*
Non-Hispanic other	-0.35 (-3.32, 2.62)	0.54 (0.26, 0.82)**	-2.83 (-8.12, 2.46)
Employment			
Employed	Ref	Ref	Ref
Unemployed[b]	3.81 (2.51, 5.11)**	0.16 (0.03, 0.29)*	-7.47 (-9.76, -5.17)**
Retired	2.33 (1.17, 3.49)**	-0.02 (-0.14, 0.09)	-1.73 (-3.82, 0.37)
Education			
High school or less	Ref	Ref	Ref
Some college or more	-2.49 (-3.93, -1.06)*	-0.28 (-0.43, -0.14)**	6.34 (3.75, 8.93)**
Relationship Status			
Married or partnered	Ref	Ref	Ref
Single	0.31 (-0.57, 1.20)	-0.01 (-0.09, 0.08)	-1.20 (-2.75, 0.55)
HIV Status			
Negative	Ref	Ref	Ref
Positive	0.36 (-0.55, 1.27)	0.04 (-0.05, 0.13)	-1.15 (-2.78, 0.47)
Enrollment Wave			
Pre-1987	Ref	Ref	Ref
Post-2001	1.32 (0.27, 2.38)*	0.12 (0.02, 0.22)*	-1.45 (-3.32, 0.42)
Study Site			
Baltimore/Washington	Ref	Ref	Ref
Chicago	1.69 (0.46, 2.92)*	-0.12 (-0.24, -0.01)*	2.09 (-0.10, 4.27)
Pittsburgh	0.45 (-0.69, 1.60)	-0.09 (-0.20, -0.02)	-1.80 (-3.84, 0.24)
Los Angeles	-1.99 (-3.32, 2.62)*	-0.06 (-0.06, 0.17)	0.57 (-1.59, 2.74)
Time[c]	0.02 (0.0001, 0.04)*	-0.002 (-0.004, 0.001)	-0.04 (-0.06, -0.02)*

[a] Includes Queer, pansexual, heterosexual
[b] Includes people who were unemployed, students, or unable to work due to disability
[c] 0, 6, 12, 18, 24 months
* $p < 0.01$ ** $p < 0.001$
Note. TMT = Trail Making Test; SDMT = Symbol Digit Modalities Tasks; All models adjusted for age, sexual identity, race/ethnicity, educational attainment, employment status, relationship status, HIV status, enrollment wave, study site

3.4 Discussion

In this study of midlife and older MSM, we found that, on average, participants reported strong perceived social support which remained stable across all five study visits. We also found that at baseline and across a 2-year period, higher social support was associated with better psychomotor ability and better information processing ability. We found no association at baseline or across a 2-year period between social support and executive function. These results demonstrate that social support may be a critical resource for promoting cognitive function across certain cognitive domains, in addition to the benefits of social support for other outcomes among older MSM including mental HRQoL, resilience and mastery, and depression (101, 114, 117). Social support may confer benefits for cognitive function by providing psychological and material resources needed to cope with stress, by influencing health behaviors, promoting access to social activities, or increasing access to healthcare (87, 96).

The finding that perceived social support remained high across all study visits contrasts prevailing stereotypes and empirical research which suggest that older MSM lack adequate social support. Older MSM have less social support and smaller social networks compared to sexual minority women and heterosexual men (122). Compared to their heterosexual peers older MSM are less likely to have support from biological families, be married, have children or grandchildren, and are more likely to live alone (3, 106, 107). On the other hand, our results are consistent with a study of a cohort of older gay and bisexual men which found that participants reported moderate to high social support (114).

We found significant within-group differences in perceived social support that are consistent with prior research. First, we found that HIV-negative MSM reported higher social support than MSM living with HIV. A recent study found that older HIV-positive MSM reported lower

social support than HIV-negative MSM which partially accounted for mental and physical health disparities (123). Several studies suggest that social isolation accounts for the low social support found among HIV-positive MSM (124, 125) Indeed, HIV-positive older adults report being isolated from social supports due to both HIV stigma and ageism (124). Second, white MSM reported higher social support than Black MSM. Our earlier work with this cohort found that Black MSM had more robust social networks than white MSM. These slightly contrasting findings again support the idea that objective aspects of social relationships (e.g., network size) do not necessary align with more subjective measures (e.g., support) (117). Because subjective evaluations of social relationships are more closely associated with well-being, increased efforts should be made ensure adequate social support for older Black MSM (126).

As studies continue to address healthy aging of MSM as a public health priority, future research may benefit from addressing the limitations of our study design and analysis. First, while the MACS administers a full battery of neuropsychological tests every 2 years, the present analysis used only the brief battery administered every 6 months to have more observations within the 2-year period of data collection for the *Healthy Aging Study*. As such, we included only the TMT Part A and B and the SDMT as tests of cognitive function. Future research may wish to investigate the prospective association of social support and other measures of cognitive function including attention and working memory, learning, and motor skills. Additionally, a longer follow-up period would allow for an investigation of the stability of social support over time, and a more thorough understanding of the dynamics of social support in relation to cognitive function.

Second, there are also limitations to our measure of social support. The SPS-24 was originally intended to be scored by adding the sum of all responses for a total score ranging 24-96 (121). However, we took the average of all available items for each sub-scale, and then took the average

of all sub-scale scores for a total score ranging from 1-4. Due to the large proportion of missing SPS-24 data across all study visits, we choose this scoring method to retain as many participants as possible in the analyses. Neither the original scoring of the SPS-24 nor the method used in this analysis have been validated among MSM; however, the scoring method used in this analysis may have reduced variability in SPS-24 scores and may have biased the results towards the null.

Finally, this analysis may have reduced external validity because the sampling design included a convenience sample of MSM from the MACS and may not be generalizable to all midlife and older MSM in the US and globally. Additionally, the sample was predominantly white, gay, and had high educational attainment. Our findings may be limited by small sample sizes within racial/ethnic minority subgroups and non-gay identified MSM, particularly because these groups were found to have lower social support and cognitive function scores. Further research is needed to identify additional risk and resilience factors associated with healthy aging among these groups.

Conclusion

Despite our limitations, to our knowledge this study is the first to focus on social support among midlife and older MSM as a predictor of cognitive function within the context of healthy aging. Our results suggest that among midlife and older MSM, social support remains relatively high and stable across time and may be associated with cognitive function, particularly for psychomotor ability and information processing ability.

4.0 Enacted Sexual Minority Stigma and Cognitive Function Among Midlife and Older Men Who Have Sex with Men from the Multicenter AIDS Cohort Study

4.1 Introduction

Gay, bisexual, and other men who have sex with men (MSM) experience numerous physical and mental health challenges related to aging, including high rates of HIV/AIDS, disability, cardiovascular disease, some cancers, anxiety, and depression (1, 3, 4, 13). MSM living with HIV also experience notable impairments in cognitive function. Current estimates indicate that over 30% of MSM living with HIV experience any form of cognitive impairment (27). Most of what is known regarding cognitive function among MSM has been studied in the context of HIV given the well-established neurocognitive complications of the disease (19, 20). However, recent research suggests an urgent need to address cognitive function among HIV-negative MSM as well. In previous work from the Multicenter AIDS Cohort Study, 31.89% of HIV-negative MSM were found to have any severity of cognitive impairment (9).

Previous research has identified sociodemographic and disease-based risk factors that affect cognitive function in MSM living with HIV such as depression, hepatitis C virus, older age, and less education (127). Neighborhood-level factors such as exposure to environmental pollutants may also increase risk of poor cognitive function (48-51). However, these variables do not fully explain why some MSM develop impairments in cognitive function while others do not. The development of poor cognitive function among MSM may be due, in part, to the stigma associated with their sexual identities, attractions, or behaviors. Stigma is defined as “the co-occurrence of labeling, stereotyping, separation, status loss, and discrimination in a context in which power is

exercised" (128). When this stigma is manifested as overt violence, rejection, and discrimination, it is considered to be *enacted sexual minority stigma* (54).

Enacted sexual minority stigma has been shown to contribute to several adverse health outcomes for MSM, including depression (129). Among older MSM, enacted sexual minority stigma encountered in healthcare settings was associated with increase sexual risk taking behaviors (130). Enacted sexual minority stigma may also contribute to poor cognitive function among mid-life and older MSM, but this association has yet to be studied. Enacted sexual minority stigma is associated with increase psychological distress (53). In addition, experiences of enacted sexual minority stigma may lead to physiological stress, the consequences of which include inflammation, cardiovascular strain, increased circulation of cortisol, hypothalamic-pituitary-adrenal (HPA) axis dysregulation, and structural changes in the hippocampus that are associated with poor cognitive function (82, 97). Enacted sexual minority stigma also creates barriers to health care for MSM (3). As such, these physiological changes may remain unnoticed or unaddressed (3). Finally, enacted sexual minority stigma also increases social isolation, loneliness, and substance use, all of which have been associated with increased risk of poor cognitive function in the general population (57).

To promote the healthy aging of MSM, it is first necessary to understand the risk factors that contribute to poor cognitive function among MSM in midlife and older adulthood. Examining the role of enacted sexual minority stigma on cognitive function in a population characterized by societal inequalities would represent an important step in delineating whether psychosocial stress is a modifiable risk factor for poor cognitive function. Therefore, the purpose of this study was to examine the effects of enacted sexual minority stigma on cognitive function among midlife and older MSM. We hypothesized that experiencing more enacted sexual minority stigma would be associated with poorer cognitive test performance.

4.2 Methods

4.2.1 Study Design

To address these research questions, we conducted a secondary analysis of data collected by the Multicenter AIDS Cohort Study (MACS). The MACS, now part of the MACS-WIHS Combined Cohort Study (MWCCS) is an ongoing study of the natural and treated history of HIV infection among gay, bisexual, and other MSM. The MACS includes men living with HIV as well as HIV-negative men (118). The study design of the MACS has been described in several prior studies (119, 120). Briefly, participants were enrolled in one of four sites (Los Angeles, Pittsburgh, Chicago, and Baltimore/Washington). Enrollment occurred in three cohorts: in 1984–1985, 1987–1991, and 2001–2003. Each center recruited men through combinations of notices placed in gay bars, newspapers, and community centers, promotional offerings (e.g., medical screening), and connections to medical centers that served largely gay and bisexual men. Enrollees were also encouraged to tell friends about the study. Participants return to MACS sites every six months for a battery of medical and behavioral surveys, physical and neuropsychological examinations, and specimen collection. All study procedures were approved by the Institutional Review Boards at each of the local study sites. Informed consent was obtained from all participants at the beginning of each study visit.

The details of the neuropsychological testing have been described previously (31). The MACS administers a full battery of neuropsychological tests at baseline and every 2 years for all participants as well as a brief battery during each semi-annual visit. The MACS neuropsychological evaluation includes tests from multiple cognitive domains including executive function, speed

of information processing, attention and working memory, learning, memory, and motor speed/co-ordination. The brief battery consists of the Standard Trail Making Test (TMT) Parts A and B and the Symbol Digit Modalities Tasks (SDMT) corresponding to attention and processing speed, executive function, and information processing, respectively.

The present analysis was restricted to participants enrolled in the *Healthy Aging Study*, a sub-study of the MACS (10). To be eligible for the study, participants had to have been present at two consecutive MACS visits, report an age at or above 40 years, and report having had sex with another man at least once since enrolling into the MACS. This analysis utilized data from 1,318 participants (~20% of the entire MACS cohort) at visits 66–70 from October 2016 to March 2019 who had at least one score from the brief neuropsychological battery administered during these visits.

4.2.2 Measures

Demographic characteristics. Self-reported demographic characteristics included age at the time of the study visit (40-64 years, 65 years or older), sexual identity (gay, bisexual, other [i.e., queer, pansexual, heterosexual/straight]), race/ethnicity (non-Hispanic white, non-Hispanic Black, Hispanic/Latino, non-Hispanic other race [i.e., American Indian/Alaska native, Asian, multiple races]), HIV status (HIV-positive, HIV-negative), employment (employed full-time or part-time, unemployed [i.e., unemployed, a student, or unable to work due to disability] or retired), educational attainment (high school or less, some college or more), and relationship status (partnered or married, single). Other variables included in this analysis were study site (Baltimore/Washington, Chicago, Pittsburgh, Los Angeles) and wave of enrollment (pre-1987, post-2001).

Enacted Sexual Minority Stigma. An index was created to measure enacted sexual minority stigma in adulthood. This variable was measured during *Healthy Aging Study* visits 66 (baseline) and visits 67-70. Participants were asked if any of the following happened to them within the past 12 months because they were or were thought to be gay or bisexual: (1) verbally insulted; (2) threatened with physical violence; (3) had an object thrown at them; (4) punched, kicked, or beaten; or (5) threatened with a knife, gun, or another weapon. The response options were yes or no. Responses of "I don't know" or "prefer not to say" were coded as "no". The number of "yes" responses was totaled, reflecting the number of different domains of enacted sexual minority stigma reported. Recent research has shown that experiencing multiple forms of victimization (i.e., polyvictimization) results in mental and physical health consequences above and beyond single-type victimization (131, 132). Therefore, we chose to score the responses from 0 (none of the events reported) to 5 (all domains reported). This variable was treated as continuous in the analyses to allow for more variability in participant responses.

Standard Trail Making Test (TMT) Parts A and B. The instructions for TMT A and TMT B require that the tests must be performed as quickly and accurately as possible. In TMT A, participants are asked to draw lines sequentially connecting in ascending order 25 encircled numbers randomly distributed on a piece of paper. In TMT B, participants are asked to connect numbers (1-13) and letters (A-L) while alternating between them (i.e., 1-A-2-B, etc.). The test proctor immediately stops the participant when a mistake occurs and prompts correction. The time to complete TMT A and TMT B are recorded as the main outcome. We used the TMT A score as a measure of processing speed ability. We also used the ratio of the TMT B to TMT A scores as a measure of executive function, while accounting for the effects of psychomotor speed and visual searching

ability. Higher ratio scores indicate poorer set-shifting ability (an aspect of executive function). We log transformed tests scores from the TMT A and TMT B to approximate a normal distribution.

Symbol Digit Modalities Tasks (SDMT). The SDMT asks participants to use a coded key to match nine abstract symbols paired with numerical digits. After completing the first 10 items with guidance, the subject is timed to determine how many responses can be made in 90 seconds. We used the SDMT as a measure of information processing ability. Lower scores indicate poorer information processing.

4.2.3 Missing Data Analysis

Of the 1,318 eligible participants, 94 (7.13%) were missing demographic data (sexual identity, employment status, educational attainment, or relationship status) and were removed from the analysis. Of the remaining 1,224 participants, 155 (12.7%) were missing all TMT A, TMT B and SDMT scores in visits 66–70. Participants with missing data were more likely to be older ($p < 0.001$), Non-Hispanic white ($p < 0.001$), retired ($p = 0.001$), HIV-negative ($p = 0.048$), enrolled pre-1987 ($p = 0.001$), and from the Los Angeles study site ($p < 0.001$). No statistically significant differences were observed by sexual identity, educational attainment, or relationship status. These participants with missing data were removed from the analysis. Of the remaining participants, 13 (1.2%) were missing responses for enacted sexual minority stigma at all study visits and were removed from the analysis, creating a final analytic sample of $N = 1{,}056$ midlife and older MSM.

4.2.4 Statistical Analyses

First, descriptive statistics were generated for sociodemographic, enacted sexual minority stigma, and cognitive function variables at visit 66 (baseline). We then conducted bivariate tests of association (e.g., *t-tests, one-way ANOVA)* to identify demographic differences in enacted sexual minority stigma and cognitive function variables at baseline. Next, we conducted a cross-sectional analysis using a series of multivariable linear regression models to estimate the association between enacted sexual minority stigma and cognitive function at baseline. Each series of analyses was conducted separately for the TMT A, TMT B to A ratio, and SDMT. All analyses adjusted for age, education, race/ethnicity, sexual identity, employment status, relationship status, HIV status, enrollment wave, and study site.

Next, descriptive statistics were generated for adulthood enacted sexual minority stigma and cognitive function across all study visits. We then conducted a longitudinal analyses using linear mixed models with repeated measures to assess the association between enacted sexual minority stigma and cognitive function across a 2-year period (visits 66-70) using the same series of models as the cross-sectional analysis. Full-information maximum likelihood parameter estimation was used to account for missing data. For the model using the TMT A score as the dependent variable, a likelihood ratio test determined that a random slopes model fit the data best. Time-fixed predictors included sexual identity, employment status, relationship status, HIV status, enrollment wave, and study site. Random effects were modeled for time (coded as 0, 6, 12, 18, and 24 months). Random effects allow for the slopes between time and the dependent variable to differ across participants. For the model using the TMT B to A ratio as the dependent variable, a likelihood ratio test determined that a random intercept model fit the data best, and the cognitive function scores

at baseline were allowed to differ across participants. Time-fixed predictors included age, education, race/ethnicity, sexual identity, employment status, relationship status, HIV status, enrollment wave, and study site. Finally, for the model using the SDMT score as the dependent variable, a likelihood ratio test determined that a random slopes model fit the data best. Time-fixed predictors included sexual identity, employment status, relationship status, HIV status, enrollment wave, and study site. Random effects were modeled for time. Random effects allow for the slopes between time and the dependent variable to differ across participants. All analyses were conducted using Stata version 16.0 (StataCorp, College Station, TX, USA).

4.3 Results

Table 6 provides a description of the sociodemographic characteristics of our sample at baseline. In this sample, 30.6% of the men were age 65 or older. The sample was predominantly gay (90.4%), white (68.9%), employed (55.5%), and had attended some college or more (88.9%). Approximately half (49.8%) of participants were married or partnered and living with HIV (50.3%). Finally, the highest proportion of the sample was recruited prior to 1987 (63.2%) and attended the Baltimore/Washington study site (32.5%).

Enacted Sexual Minority Stigma

Table 7 provides a description of the enacted sexual minority stigma scores. Of the 1,056 men in the sample, 880 answered the enacted sexual minority stigma questions at visit 66, 879 answered them at visit 67, 791 at visit 68, 822 at visit 69, and 815 at visit 70. At visit 66, participants with missing enacted sexual minority stigma data were more likely to identify as other sexual identity ($p = 0.005$), be Hispanic ($p < 0.001$), and have lower education attainment ($p < 0.001$). At

visit 67, participants with missing enacted sexual minority stigma data were more likely to identify as other sexual identity ($p < 0.001$), be non-Hispanic Black ($p < 0.001$), unemployed ($p < 0.001$), have lower education attainment ($p < 0.001$), and enrolled after 2001 ($p < 0.001$). At visit 68, those missing were more likely to identify as bisexual ($p = 0.015$), be non-Hispanic Black ($p = 0.002$), have lower education attainment ($p = 0.029$), enrolled after 2001 ($p = 0.049$), and from the Baltimore/Washington study site ($p = 0.001$). At visit 69, those missing were more likely to identify as other sexual identity ($p = 0.028$), be non-Hispanic Black ($p = 0.005$), unemployed ($p = 0.046$), have lower educational attainment ($p = 0.004$), single ($p = 0.009$), and enrolled after 2001 ($p = 0.006$). Finally, at visit 70 those missing were more likely to identify as other sexual identity ($p = 0.038$), have lower educational attainment ($p = 0.030$), and be from the Pittsburgh study site ($p = 0.003$).

The mean (SD) number of domains of enacted sexual minority stigma experienced during adulthood from visit 66-70 were 0.26 (0.79), 1.05 (1.46), 0.28 (0.82), 0.28 (0.85), and 0.36 (0.84), respectively (Table 7). Figure 6 also displays the mean number of enacted sexual minority stigma domains across all study visits. At baseline, more domains of enacted sexual minority stigma were reported by midlife ($p = 0.002$), bisexual ($p < 0.001$), Hispanic ($p < 0.001$), unemployed ($p < 0.001$), HIV-positive ($p = 0.003$), those with lower education attainment ($p < 0.001$), and those enrolled after to 2001 ($p < 0.001$). No statistically significant differences were observed by relationship status or study site.

Baseline Analysis

The unadjusted mean (SD) TMT A score at visit 66 was 21.28 (8.47) seconds. The highest mean TMT A scores (indicating poorer psychomotor speed) were found among MSM who were older ($p < 0.001$), bisexual ($p < 0.001$), non-Hispanic Black ($p < 0.001$), unemployed ($p < 0.001$),

had lower educational attainment ($p < 0.001$), single ($p < 0.001$), HIV-positive ($p < 0.01$), enrolled after 2001 ($p < 0.002$), and from the Chicago study site ($p < 0.001$). The unadjusted mean (SD) for the TMT B to A ratio at visit 66 was 2.30 (0.89). The highest mean TMT B to A ratio scores (indicative of worse set-shifting performance) were found among men found among men who were Hispanic ($p < 0.001$), unemployed ($p = 0.002$), had lower educational attainment ($p < 0.001$), HIV-positive ($p = 0.019$), enrolled after 2001 ($p < 0.001$), and from the Baltimore/Washington study site ($p < 0.001$). Finally, the unadjusted mean (SD) SDMT score at visit 66 was 57.21 (14.03) correct answers. Lower SDMT scores (indicating poorer information processing) were found among MSM who were older ($p < 0.001$), bisexual ($p < 0.001$), non-Hispanic Black ($p < 0.001$), unemployed ($p < 0.001$), had lower educational attainment ($p < 0.001$), single ($p < 0.001$), HIV-positive ($p = 0.004$), and enrolled after 2001 ($p < 0.001$) (data not shown).

Table 8 presents the adjusted associations between demographic variables, enacted sexual minority stigma, and the TMT A score at baseline. We observed no statistically significant differences in TMT A score by number of domains experienced of enacted sexual minority stigma. Compared to participants age 40-64, those 65 or older had higher TMT A scores, indicating they took longer to complete the task ($b = 4.81$, 95% CI = 3.34, 6.27). Bisexual participants had higher TMT A scores compared to gay participants ($b = 0.28$, 95% CI = 0.09, 0.47). Compared to non-Hispanic white participants, non-Hispanic Black participants ($b = 3.52$, 95% CI = 1.83, 5.21) and Hispanic/Latino participants ($b = 2.83$, 95% CI = 0.70, 4.95) had higher TMT A scores. We found higher TMT A among unemployed ($b = 3.88$, 95% CI = 2.21, 5.56) and retired ($b = 2.56$, 95% CI = 1.11, 4.04) compared to employed men, participants enrolled after 2001 compared to before 1987 ($b = 1.49$, 95% CI = 0.15, 2.82), and participants from the Chicago study site ($b = 2.70$, 95%

CI = 1.08, 4.31) and Pittsburgh site (*b* = 1.70, 95% CI = 0.26, 3.14) compared to the Baltimore/Washington site. Relative to the Baltimore/Washington site, participants from the Los Angeles study site had lower TMT A scores (*b* = -1.65, 95% CI = -3.16, -0.14). There were no statistically significant differences by educational attainment, relationship status, or HIV status.

Table 8 also presents the adjusted associations between demographic variables, enacted sexual minority stigma, and the TMT B to A ratio at baseline. Individuals who experienced more domains of enacted sexual minority stigma had higher TMT B to A ratios (indicative of worse set-shifting performance) (*b* = 0.14, 95% CI = 0.06, 0.22). Compared to non-Hispanic white participants, we found higher TMT B to A ratios among non-Hispanic Black (*b* = 0.28, 95% CI = 0.09, 0.47) and Hispanic/Latino participants (*b* = 0.40, 95% CI = 0.16, 0.64). Participants who attended college or more had lower TMT B to A ratios than those who attended high school or less (*b* = -0.40, 95% CI = -0.62, -0.17). Finally, relative to the Baltimore/Washington site, participants from the Chicago site (*b* = -0.19, 95% CI = -0.38, -0.01) and Pittsburgh site (*b* = -0.26, 95% CI = -0.43, -0.10) had lower TMT B to A ratios. There were no statistically significant differences by age cohort, sexual identity, employment, relationship status, HIV status, or enrollment wave.

Finally, Table 8 presents the adjusted associations between demographic variables, enacted sexual minority stigma, and the SDMT at baseline. Individuals who experienced more domains of enacted sexual minority stigma had lower SDMT scores (*b* = -1.63, 95% CI = -2.81, -0.44). Compared to participants age 40-64, those 65 or older had lower SDMT scores, indicating they had fewer correct answers on the task (*b* = -7.81, 95% CI = -10.26, -5.36). Bisexual participants had lower SDMT scores compared to gay participants (*b* = -3.89, 95% CI = -8.25, -2.65). We found lower SDMT scores among non-Hispanic Black compared to non-Hispanic white (*b* = -7.14, 95% CI = -9.97, -4.30), men who were unemployed compared to employed (*b* = -5.47, 95% CI = -8.29,

-2.65), and participants from the Pittsburgh study site compared to Baltimore/Washington (b = -3.10, 95% CI = -5.51, -0.69). Participants who attended college or more had higher SDMT scores compared to those who attended high school or less (b = 5.73, 95% CI = 2.49, 8.97). There were no statistically significant differences by relationship status, HIV status, or enrollment wave.

Longitudinal Analysis

Table 9 presents the adjusted associations between demographic variables, enacted sexual minority stigma, and the three dependent variables across visits 66-70. After adjusting for covariates, we found that enacted sexual minority stigma was associated with the TMT B to A ratio such that individuals who experienced more domains of enacted sexual minority stigma had worse set-shifting performance (b = 0.04, 95% CI = 0.01, 0.07). However, we observed no statistically significant association with the TMT A score or SDMT score.

Compared to participants age 40-64, those 65 or older had poorer scores over time for the TMT B to A ratio (b = 0.14, 95% CI = 0.02, 0.25), TMT A (b = 4.75, 95% CI = 3.56, 5.94) and SDMT (b = -7.65, 95% CI = -9.76, -5.54). Compared to gay men, those who identified as bisexual had poorer scores on the TMT A (b = 2.51, 95% CI = 0.46, 4.55) and SDMT -3.84, 95% CI = -7.44, -0.25). Compared to non-Hispanic white participants, non-Hispanic Black participants had poorer scores for the TMT B to A ratio (b = 0.23, 95% CI = 0.10, 0.35), TMT A (b = 3.52, 95% CI = 2.22, 4.81), and SDMT (b = -7.63, 95% CI = -9.90, -5.36). Similarly, Hispanic/Latino participants had poorer scores for the TMT B to A ratio (b = 0.33, 95% CI = 0.17, 0.49), TMT A (b = 3.86, 95% CI = 2.16, 5.55), and SDMT (b = -5.14, 95% CI = -8.11, -2.17) compared to non-Hispanic white participants. Participants who identified as other race had poorer TMT B to A ratio scores compared to those who were non-Hispanic white (b = 0.54, 95% CI = 0.26, 0.82). Participants who were unemployed (b = 4.18, 95% CI = 2.85, 5.51) or retired (b = 2.47, 95% CI = 1.29,

3.65) had poorer TMT A scores compared to those who were employed. Compared to employed, unemployed participants also had poorer SDMT scores (b = 7.47, 95% CI = -9.76, -5.17) Participants who attended college or more had higher scores on the TMT B to A ratio (b = -0.28, 95% CI = -0.43, -0.14), TMT A (b = -2.52, 95% CI = -4.01, -1.03), and SDMT (b = 6.34, 95% CI = 3.75, 8.93) than those who attended high school or less. Participants enrolled after 2001 had poorer scores on the TMT B to A ratio (b = 0.12, 95% CI = 0.02, 0.22) and TMT A (b = 1.32, 95% CI = 0.26, 2.39) compared to those enrolled prior to 1987. Relative to the Baltimore/Washington site, participants from the Chicago site had higher scores on the TMT B to A ratio (b = -0.12, 95% CI = -0.24, -0.01) but poorer scores on the TMT A (b = 1.86, 95% CI = 0.61, 3.11). Finally, relative to the Baltimore/Washington site, participants from the Los Angeles site had higher scores on the TMT A (b = -1.80, 95% CI = -3.04, -0.56). There were no statistically significant differences by relationship status or HIV status for all three dependent variables.

Table 6. Sociodemographic Characteristics of Midlife and Older MSM in the MACS at Baseline (10/2016 – 3/2017), n = 1,056

Sociodemographic Variables	n (%)
Age Cohort	
Midlife (40-64 years)	733 (69.4)
Older (65+ years)	323 (30.6)
Sexual Identity	
Gay	955 (90.4)
Bisexual	53 (5.0)
Other[a]	48 (4.6)
Race/Ethnicity	
Non-Hispanic white	727 (68.9)
Non-Hispanic Black	210 (19.9)
Hispanic/Latino	97 (9.2)
Non-Hispanic other races	22 (2.1)
Employment	
Employed	586 (55.5)
Unemployed[b]	172 (16.3)
Retired	298 (28.2)
Education	
High school or less	117 (11.1)
Some college or more	939 (88.9)
Relationship Status	
Married or partnered	526 (49.8)
Single	530 (50.2)
HIV Status	
Negative	525 (49.7)
Positive	531 (50.3)
Enrollment Wave	
Pre-1987	667 (63.2)
Post-2001	389 (36.8)
Study Site	
Baltimore/Washington	343 (32.5)
Chicago	205 (19.4)
Pittsburgh	266 (25.2)
Los Angeles	242 (22.9)

[a] Includes Queer, pansexual, heterosexual
[b] Includes people who were unemployed, students, or unable to work due to disability

Table 7. Characteristics of Enacted Sexual Minority Stigma Scores from Visits 66-70 (10/2016 – 3/2019)

	Visit 66 (Baseline)		Visit 67 (6 Months)		Visit 68 (12 months)		Visit 69 (18 months)		Visit 70 (24 months)	
	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)
Domains Reported[a]	880	0.26 (0.79)	879	1.05 (1.46)	791	0.28 (0.82)	822	0.28 (0.85)	815	0.36 (0.84)

[a] Range 0-5

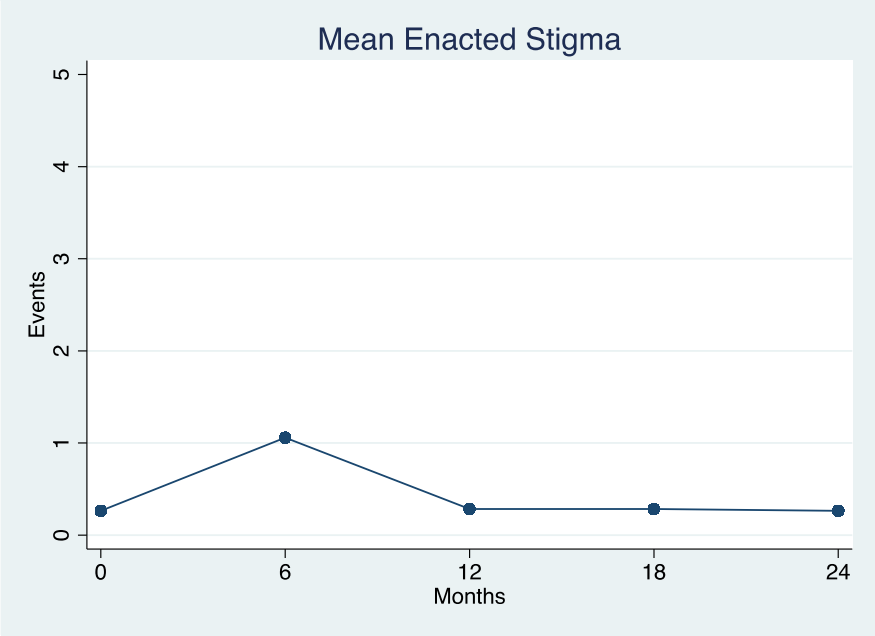

Figure 6. Mean Enacted Sexual Minority Stigma Events from Visits 66-70 (10/2016 – 3/2019)

Table 8. Adjusted Associations of Sociodemograpic Variables and Enacted sexual minority stigma on Cognitive Function among MSM in the MACS at Baseline (10/2016 – 3/2017)

	TMT A n=777	TMT B/A n=776	SDMT n=775
	b (95% CI)	*b* (95% CI)	*b* (95% CI)
Enacted Stigma	0.23 (-0.48, 0.94)	0.14 (0.06, 0.22)**	-1.63 (-2.81, -0.44)*
Age Cohort			
Midlife (40-64 years)	Ref	Ref	Ref
Older (65+ years)	4.81 (3.34, 6.27)**	0.05 (-0.11, 0.22)	-7.81 (-10.26, -5.36)**
Sexual Identity			
Gay	Ref	Ref	Ref
Bisexual	2.70 (0.10, 5.30)*	-0.09 (-0.39, 0.19)	-3.89 (-8.25, -2.65)*
Other[a]	1.58 (-1.33, 4.48)	0.06 (-0.27, 0.39)	-2.35 (-7.22, 2.52)
Race/Ethnicity			
Non-Hispanic white	Ref	Ref	Ref
Non-Hispanic Black	3.52 (1.83, 5.21)**	0.28 (0.09, 0.47)**	-7.14 (-9.97, -4.30)**
Hispanic/Latino	2.83 (0.70, 4.95)*	0.40 (0.16, 0.64)*	-1.67 (-5.26, 1.92)
Non-Hispanic other	1.18 (-2.33, 4.69)	0.31 (-0.08, 0.71)	-2.76 (-8.64, 3.12)
Employment			
Employed	Ref	Ref	Ref
Unemployed[b]	3.88 (2.21, 5.56)**	0.03 (-0.16, 0.22)	-5.47 (-8.29, -2.65)**
Retired	2.56 (1.11, 4.04)*	0.06 (-0.11, 0.22)	-1.57 (-4.02, 0.88)
Education			
High school or less	Ref	Ref	Ref
Some college or more	-1.61 (-3.56, 0.34)	-0.40 (-0.62, -0.17)**	5.73 (2.49, 8.97)*
Relationship Status			
Married or partnered	Ref	Ref	Ref
Single	0.89 (-0.22, 2.00)	-0.08 (-0.20, 0.05)	-0.27 (-2.14, 1.59)
HIV Status			
Negative	Ref	Ref	Ref
Positive	0.37 (-0.80, 1.54)	-0.009 (-0.14, 0.12)	-0.90 (-2.86, 1.06)
Enrollment Wave			
Pre-1987	Ref	Ref	Ref
Post-2001	1.49 (0.15, 2.82)*	0.10 (-0.05, 0.25)	-1.35 (-3.59, 0.90)
Study Site			
Baltimore/Washington	Ref	Ref	Ref
Chicago	2.70 (1.08, 4.31)*	-0.19 (-0.38, -0.01)*	0.54 (-2.18, 3.26)
Pittsburgh	1.70 (0.26, 3.14)*	-0.26 (-0.43, -0.10)*	-3.10 (-5.51, -0.69)*
Los Angeles	-1.65 (-3.16, -0.14)*	-0.05 (-0.22, 0.13)	-0.12 (-2.65, 2.42)

[a] Includes Queer, pansexual, heterosexual
[b] Includes people who were unemployed, students, or unable to work due to disability
* $p < 0.01$ ** $p < 0.001$

Table 9. Adjusted Associations of Sociodemograpic Variables and Enacted sexual minority stigma on Cognitive Cognitive Function among MSM in the MACS from Visits 66-70 (10/2016 – 3/2019)

	TMT A n=1,037	TMT B/A n=1,035	SDMT n=1,032
	b (95% CI)	*b* (95% CI)	*b* (95% CI)
Enacted Stigma	0.01 (-0.19, 0.21)	0.04 (0.01, 0.07)*	0.08 (-0.16, 0.32)
Age Cohort			
Midlife (40-64 years)	Ref	Ref	Ref
Older (65+ years)	4.75 (3.56, 5.94)**	0.14 (0.02, 0.25)*	-7.65 (-9.76, -5.54)**
Sexual Identity			
Gay	Ref	Ref	Ref
Bisexual	2.51 (0.46, 4.55)*	0.07 (-0.12, 0.27)	-3.84 (-7.44, -0.25)*
Other[a]	1.22 (-1.02, 3.45)	0.09 (-0.12, 0.31)	-2.02 (-5.93, 1.89)
Race/Ethnicity			
Non-Hispanic white	Ref	Ref	Ref
Non-Hispanic Black	3.52 (2.22, 4.81)**	0.23 (0.10, 0.35)**	-7.63 (-9.90, -5.36)**
Hispanic/Latino	3.86 (2.16, 5.55)**	0.33 (0.17, 0.49)**	-5.14 (-8.11, -2.17)*
Non-Hispanic other	-0.17 (-3.16, 2.81)	0.54 (0.26, 0.82)**	-2.83 (-8.12, 2.46)
Employment			
Employed	Ref	Ref	Ref
Unemployed[b]	4.18 (2.85, 5.51)**	0.16 (0.03, 0.29)	-7.47 (-9.76, -5.17)**
Retired	2.47 (1.29, 3.65)**	-0.02 (-0.14, 0.09)	-1.73 (-3.82, 0.37)
Education			
High school or less	Ref	Ref	Ref
Some college or more	-2.52 (-4.01, -1.03)*	-0.28 (-0.43, -0.14)**	6.34 (3.75, 8.93)**
Relationship Status			
Married or partnered	Ref	Ref	Ref
Single	0.80 (-0.09, 1.68)	-0.01 (-0.09, 0.08)	-1.20 (-2.75, 0.55)
HIV Status			
Negative	Ref	Ref	Ref
Positive	0.43 (-0.50, 1.36)	0.04 (-0.05, 0.13)	-1.15 (-2.78, 0.47)
Enrollment Wave			
Pre-1987	Ref	Ref	Ref
Post-2001	1.32 (0.26, 2.39)*	0.12 (0.02, 0.22)*	-1.45 (-3.32, 0.42)
Study Site			
Baltimore/Washington	Ref	Ref	Ref
Chicago	1.86 (0.61, 3.11)*	-0.12 (-0.24, -0.01)*	2.09 (-0.10, 4.27)
Pittsburgh	0.67 (-0.49, 1.83)	-0.09 (-0.20, -0.02)	-1.80 (-3.84, 0.24)
Los Angeles	-1.80 (-3.04, -0.56)*	-0.06 (-0.06, 0.17)	0.57 (-1.59, 2.74)
Time[c]	0.014 (-0.006, 0.03)	-0.0005 (-0.003, 0.003)	-0.04 (-0.06, -0.01)*

[a] Includes Queer, pansexual, heterosexual
[b] Includes people who were unemployed, students, or unable to work due to disability
[c] 0, 6, 12, 18, 24 months
* $p < 0.01$ ** $p < 0.001$

4.4 Discussion

In this study, we found that midlife and older MSM experienced an average of 0.45 out of a possible total of 5 events of enacted sexual minority stigma during a time frame of 12 months. At baseline, experiencing more events of enacted sexual minority stigma was associated with poorer executive function and poorer information processing, but was not associated with processing speed. Longitudinally, experiencing more events of enacted sexual minority stigma was associated with poorer executive function across 2 years, but not with psychomotor ability or information processing ability.

Within the context of the minority stress model, prior research has theorized that stressors such as stigma, discrimination, and violence victimization that MSM experience due to their sexual minority identities or behaviors may be risk factors for poor cognitive function in midlife and older adulthood (35). To our knowledge, this study is the first to empirically demonstrate such a link. Enacted sexual minority stigma has also been shown to contribute to other physical and mental health conditions for MSM, including depression (129). The relationship between depression and poor cognitive function has been well-established in both studies of the general population and those exclusively of MSM (127, 133, 134). Two longitudinal studies using data from the MACS evaluated the association between depression and cognitive function in MSM living with HIV as well as HIV negative MSM. Both studies used trajectory modeling approaches and found that groups who were most severely and chronically depressed were more likely to be in groups that had the poorest performance on tests of attention and executive function (127, 133, 134). Executive function appears to be particularly susceptible to the effects of depression (135). In this study, we found that enacted sexual minority stigma was most reliably associated with poor executive function which may be partially explained by the mediating role of depression.

The hypothesis that MSM may have unique risk factors that predispose them to poor cognitive function is also grounded in the observation that Black and Hispanic/Latino populations in the United States experience disproportionately high rates of impairments in cognitive function compared to white individuals (16, 43). Racial and ethnic minorities are also disproportionately impacted by a myriad of social and cultural factors, many of which have been shown to contribute to poor cognitive function (44-46). For example, one study found a relationship between perceived discrimination and episodic memory among Black older adults (45). Our study shows that psychosocial risk factors such as enacted sexual minority stigma may have similar effects for MSM. Importantly, MSM who encounter multiple forms of oppression along lines of age, race/ethnicity, sexual identity, and HIV status have the potential to face compounding and intricately linked forms of stigma which may implicate additional risk of poor cognitive function (136).

We found several disparities among MSM who identified as bisexual compared to those who identified as gay. In this study, bisexual MSM reported experiencing more domains of enacted sexual minority stigma compared to MSM who identified as gay or other sexual identity. Bisexual men experience stigma both from within and outside the LGBT community (137). Our measure of enacted sexual minority stigma did not assess the source of the stigma, but it is possible that biphobia experienced from both gay and straight communities accounted for the increased prevalence among bisexual MSM in our sample. In addition, bisexual MSM had higher TMT A scores and lower SDMT scores compared to gay MSM, indicating poorer processing speed and information processing, respectively. These effects were notable given that bisexual MSM comprised only 5% of the overall sample. Nevertheless, in the broader research literature bisexual men consistently have higher rates of adverse psychosocial and behavioral health outcomes compared to

gay men (138). These results demonstrate that these health disparities may extend into cognitive function as well.

This study has several limitations. The *Healthy Aging Study* collected data over 2 years. Since cognitive performance diminishes with age, longer-term follow-up may detect additional changes (139). The present analysis also included only three tests of cognitive function to have sufficient repeated measures over the period of data collection. A full neuropsychological battery testing additional domains such as memory or motor skills may reveal additional effects of enacted sexual minority stigma. Additionally, this analysis may have reduced external validity because the sampling design included a convenience sample of MSM from the MACS and may not be generalizable to all midlife and older MSM in the US and globally. The small sample sizes of racial or ethnic minorities and non-gay identified MSM limited our ability to explore potentially important differences within these subgroups of MSM.

There are also limitations to our index of enacted sexual minority stigma. We gave equal weight to all five manifestations of stigma; however, different forms of enacted sexual minority stigma (e.g., threatened with a weapon) may be more harmful than others (e.g., verbal insults). Also, we did not assess the frequency of enacted sexual minority stigma experiences. Experiencing persistent enacted sexual minority stigma likely has a different effect on cognitive function than a single occurrence. Our index did not assess other forms of enacted sexual minority stigma that are often included in other scales such as receiving poorer services in restaurants, stores, or other businesses, unfair treatment at work or school, or being denied or given lower quality health care (129, 140, 141). Finally, we asked participants to recall experiences of stigma based on their actual or perceived sexual identity over the past 12 months. Therefore, this analysis is subject to recall bias.

MSM may have also faced enacted sexual minority stigma due to other factors such as race/ethnicity, age, or HIV status. The individual and intersecting effects of these other forms of stigma were not analyzed in this study, but are important areas of focus for future research.

Missing data may also have affected our results. First, 12.7% of the sample was missing all neuropsychological outcome data. The excluded participants were more likely to be white, HIV negative, and older and it is unknown how the cognitive function of these participants differed from those included in the study. Second, between 815 and 880 out of 1,056 participants answered any enacted sexual minority stigma questions at each visit. These participants were more likely to be racial/ethnic minorities, unemployed, and have less education. If these participants were more likely to have experienced stigma, the results might be biased towards the null.

There remain gaps in knowledge about what factors can mitigate the negative effects of enacted sexual minority stigma on cognitive function. These factors could inform interventions to ensure healthy cognitive aging among MSM. Unlike other risk factors for poor cognitive function such as age, race/ethnicity, some chronic health conditions, and lower education quality, psychosocial risk factors such as enacted sexual minority stigma are modifiable. At the same time, greater emphasis should be placed on the social context as a target for intervention to prevent of experiences enacted sexual minority stigma before they occur.

Conclusion

In summary, this study shows that enacted sexual minority stigma is associated with poor cognitive function, particularly the TMT B to A ratio that measures executive function. Efforts to study factors that mitigate the negative effects of enacted sexual minority stigma are needed to

inform future interventions to promote the healthy aging of MSM. Furthermore, social and structural changes that prevent or reduce the occurrence of enacted sexual minority stigma may be significant benefits for many health outcomes for MSM, including cognitive function.

5.0 Enacted Sexual Minority Stigma Throughout the Life-course, Social Support, and Cognitive Function Among Midlife and Older Men Who Have Sex with Men from the Multicenter AIDS Cohort Study

5.1 Introduction

Gay, bisexual, and other men who have sex with men (MSM) disproportionately experience adversities throughout the life-course, which may put them at risk for mental and physical health disorders in midlife and older adulthood (52, 53). One such adversity is stigma, defined as "the co-occurrence of labeling, stereotyping, separation, status loss, and discrimination in a context in which power is exercised" (128). When this stigma is manifested as overt violence, rejection, and discrimination, it is considered to be *enacted sexual minority stigma* (54). For MSM, enacted sexual minority stigma experienced during adolescence and adulthood has been associated with depression in adulthood (129, 142). However, less is known about how experiences of enacted sexual minority stigma throughout the life-course affect other health outcomes in adulthood.

One outcome potentially affected by enacted sexual minority stigma is cognitive function. Current estimates indicate that over 30% of MSM living with HIV as well as their HIV-negative counterparts experience any severity of cognitive impairment (9). Previous research has identified sociodemographic and disease-based risk factors that affect cognitive function in MSM living with HIV such as depression, hepatitis C virus, older age, and less education (127). However, these variables do not fully explain why some MSM develop impairments in cognitive function while others do not. Enacted sexual minority stigma may also contribute to poor cognitive function among MSM through the effects of stress, including inflammation, cardiovascular strain, increased

circulation of cortisol, hypothalamic-pituitary-adrenal (HPA) axis dysregulation, and structural changes in the hippocampus (82, 97).

Enacted sexual minority stigma experienced in both adolescence and adulthood may negatively impact cognitive function among MSM in midlife and older adulthood. Studies among the general population have provided evidence that cognitive impairment in later life is rooted at least in part in childhood (68). Adolescence is a time in which many MSM move through the coming-out process, referring to the gradual recognition, rejection, acceptance, and integration of one's sexual minority identity (71). As such, adolescence may be a critical or sensitive window in which the exposure to enacted sexual minority stigma has a stronger effect on subsequent cognitive function outcomes compared to other time periods (67).

There is also little understanding of how witnessing enacted sexual minority stigma directed towards other people effects cognitive function. It is unknown whether witnessing enacted sexual minority stigma versus experiencing it directly may result in similar, greater, or less severe outcomes. However, the association between vicarious trauma, also known as secondary traumatic stress or compassion fatigue, and stress reactions is well-established among individuals in caregiving professions (e.g., therapists, rescue workers, doctors) (143). Vicarious trauma is a term used to describe the pattern of psychological symptoms that approximate symptoms of post-traumatic stress disorder (PTSD) due to indirect exposure to a traumatic event (144). Vicarious trauma has also been extended to refer to race-based stress reactions that are triggered among Black Americans through a third party – like social media or national news events (145). It is possible that witnessing enacted sexual minority stigma triggers a similar stress response among MSM.

Even outside a critical or sensitive window, it is still possible to modify or reverse disease outcomes (67). Therefore, it is also possible that the effects of experiencing or witnessing enacted

sexual minority stigma during adolescence may be mitigated by positive adulthood experiences. Social support may be an important factor that assists MSM in being resilient to social adversities including enacted sexual minority stigma. Indeed, social support appears to have positive health effects for other outcomes among MSM including viral load suppression (100), physical and mental health-related quality of life (HRQoL) (101), psychological distress (102), and depression (117).

The purpose of this study was to examine the effects of enacted sexual minority stigma during adolescence and adulthood on cognitive function among midlife and older MSM and to determine whether social support moderates the effect of enacted sexual minority stigma on cognitive function. We hypothesized that experiencing and witnessing enacted sexual minority stigma during adolescence would negatively affect cognitive function, independently from enacted sexual minority stigma experienced during adulthood. We hypothesized that enacted sexual minority stigma experienced during adulthood would also be independently associated with poorer cognitive function. Finally, we hypothesized that social support would modify these effects, such that experiencing and witnessing enacted sexual minority stigma would negatively affect cognitive function only in the presence of low social support.

5.2 Methods

5.2.1 Study Design

To address these research questions, we conducted a secondary analysis of data collected

by the Multicenter AIDS Cohort Study (MACS). The MACS, now part of the MACS-WIHS Combined Cohort Study (MWCCS) is an ongoing study of the natural and treated history of HIV infection among gay, bisexual, and other MSM. The MACS includes men living with HIV as well as HIV-negative men (118). The study design of the MACS has been described in several prior studies (119, 120). Briefly, participants were enrolled in one of four sites (Los Angeles, Pittsburgh, Chicago, and Baltimore/Washington). Enrollment occurred in three cohorts: in 1984–1985, 1987–1991, and 2001–2003. Each center recruited men through combinations of notices placed in gay bars, newspapers, and community centers, promotional offerings (e.g., medical screening), and connections to medical centers that served largely gay and bisexual men. Enrollees were also encouraged to tell friends about the study. Participants return to MACS sites every six months for a battery of medical and behavioral surveys, physical and neuropsychological examinations, and specimen collection. All study procedures were approved by the Institutional Review Boards at each of the local study sites. Informed consent was obtained from all participants at the beginning of each study visit.

The details of the neuropsychological testing have been described previously (31). The MACS administers a full battery of neuropsychological tests at baseline and every 2 years for all participants as well as a brief battery during each semi-annual visit. The MACS neuropsychological evaluation includes tests from multiple cognitive domains including executive function, speed of information processing, attention and working memory, learning, memory, and motor speed/coordination. The brief battery consists of the Standard Trail Making Test (TMT) Parts A and B and the Symbol Digit Modalities Tasks (SDMT) corresponding to attention and processing speed, executive function, and information processing, respectively.

The present analysis was restricted to participants enrolled in the *Healthy Aging Study*, a sub-study of the MACS (10). To be eligible for the study, participants had to have been present at two consecutive MACS visits, report an age at or above 40 years, and report having had sex with another man at least once since enrolling into the MACS. This analysis utilized data from 1,318 participants (~20% of the entire MACS cohort) at visits 66–70 from October 2016 to March 2019 who had at least one score from the brief neuropsychological battery administered during these visits.

5.2.2 Measures

Demographic characteristics. Self-reported demographic characteristics included age at the time of the study visit (40-64 years, 65 years or older), sexual identity (gay, bisexual, other [i.e., queer, pansexual, heterosexual/straight]), race/ethnicity (non-Hispanic white, non-Hispanic Black, Hispanic/Latino, non-Hispanic other race [i.e., American Indian/Alaska native, Asian, multiple races]), HIV status (HIV-positive, HIV-negative), employment (employed full-time or part-time, unemployed [i.e., unemployed, a student, or unable to work due to disability] or retired), educational attainment (high school or less, some college or more), and relationship status (partnered or married, single). Other variables included in this analysis were study site (Baltimore/Washington, Chicago, Pittsburgh, Los Angeles) and wave of enrollment (pre-1987, post-2001).

Adulthood Enacted Sexual Minority Stigma. An index was created to measure enacted sexual minority stigma in adulthood. This variable was measured during *Healthy Aging Study* visits 66 (baseline) and visits 67-70. Participants were asked if any of the following happened to them within the past 12 months because they were or were thought to be gay or bisexual: (1) verbally

insulted; (2) threatened with physical violence; (3) had an object thrown at them; (4) punched, kicked, or beaten; or (5) threatened with a knife, gun, or another weapon. The response options were yes or no. Responses of "I don't know" or "prefer not to say" were coded as "no". The number of "yes" responses was totaled, reflecting the number of different domains of enacted sexual minority stigma reported. Recent research has shown that experiencing multiple forms of victimization (i.e., polyvictimization) results in mental and physical health consequences above and beyond single-type victimization victimization (131, 132). Therefore, we chose to score the responses from 0 (none of the events reported) to 5 (all domains reported). This variable was treated as continuous in the analyses to allow for more variability in participant responses.

Adolescent Enacted Sexual Minority Stigma. Two variables were created to measure enacted sexual minority stigma in adolescence (146). Participants were asked to think about events that may have happened in junior high or middle school from about age 12 through 14 because they were or were thought to be gay or bisexual. Specifically, the survey asked how often participants had been: (1) verbally insulted; (2) threatened with physical violence; (3) had an object thrown at them; (4) punched, kicked, or beaten; or (5) threatened with a knife, gun, or another weapon. Response options varied from "never" to "about once a week or more". Responses of "unsure/don't know" and "refused" were coded as missing. To be consistent with the measure of adult enacted sexual minority stigma, we also created a continuous variable to reflect the total number of domains of enacted sexual minority stigma that were experienced. The scores range from 0 (none of the events reported) to 5 (all domains reported). Second, participants were asked whether they witnessed these events happening to someone else because that person was or was thought to be gay or bisexual. A similar continuous variable was created to reflect the number of domains (from 0 to 5) of enacted stigma witnessed.

Social support. Social support was measured by the Social Provisions Scale (SPS) (121). The instrument contains 24 items, four for each of the following constructs: attachment; social integration; reassurance of worth; reliable alliance; guidance; and opportunity for nurturance. The respondents indicated on a 4-point Likert scale the extent to which each statement describes their current relationships with all people in their lives (friends, family members, coworkers, community members, and so on). Responses range from 1 (strongly disagree) to 4 (strongly agree). After reversal of negatively worded items, a total score was computed by averaging all items for each subscale individually, and then averaging the subscale scores to generate an overall score. Scores range from 1 to 4, with higher scores indicating more social support. To retain as many participants as possible, we calculated sub-scale averages using all available responses. For example, if a participant answered 3 out of the 4 items in a sub-scale, the score for that sub-scale was the average of the 3 answered items.

Standard Trail Making Test (TMT) Parts A and B. The instructions for TMT A and TMT B require that the tests must be performed as quickly and accurately as possible. In TMT A, participants are asked to draw lines sequentially connecting in ascending order 25 encircled numbers randomly distributed on a piece of paper. In TMT B, participants are asked to connect numbers (1-13) and letters (A-L) while alternating between them (i.e., 1-A-2-B, etc.). The test proctor immediately stops the participant when a mistake occurs and prompts correction. The time to complete TMT A and TMT B are recorded as the main outcome. We used the TMT A score as a measure of psychomotor ability. We also used the ratio of the TMT B to TMT A scores as a measure of executive function, while accounting for the effects of psychomotor speed and visual searching ability. Higher ratio scores indicate poorer set-shifting ability (an aspect of executive function). We log transformed tests scores from the TMT A and TMT B to approximate a normal distribution.

Symbol Digit Modalities Tasks (SDMT). The SDMT asks participants to use a coded key to match nine abstract symbols paired with numerical digits. After completing the first 10 items with guidance, the subject is timed to determine how many responses can be made in 90 seconds. We used the SDMT as a measure of information processing ability. Lower scores indicate poorer information processing.

5.2.3 Missing Data Analysis

Of the 1,318 eligible participants, 94 (7.13%) were missing demographic data (sexual identity, employment status, educational attainment, or relationship status) and were removed from the analysis. Of the remaining 1,224 participants, 155 (12.7%) were missing all TMT A, TMT B and SDMT scores in visits 66–70. Participants with missing data were more likely to be older ($p < 0.001$), Non-Hispanic white ($p < 0.001$), retired ($p = 0.001$), HIV-negative ($p = 0.048$), enrolled pre-1987 ($p = 0.001$), and from the Los Angeles study site ($p < 0.001$). No statistically significant differences were observed by sexual identity, educational attainment, or relationship status. These participants were removed from the analysis. Of the remaining participants, 13 (1.2%) were missing responses for adulthood enacted sexual minority stigma and 52 (4.9%) were missing responses for adolescent enacted sexual minority stigma at all study visits. Participants with missing adolescent enacted sexual minority stigma data were more likely to be Non-Hispanic Black ($p = 0.02$), have lower education attainment ($p = 0.006$), be HIV-positive ($p < 0.001$), enrolled after 2001 ($p = 0.001$), and from the Baltimore/Washington study site ($p < 0.001$). These participants with missing data were removed from the analysis, creating a final analytic sample of $N = 1{,}004$ midlife and older MSM.

5.2.4 Statistical Analyses

First, descriptive statistics were generated for sociodemographic, enacted sexual minority stigma, and cognitive function variables at baseline. We then compared the sociodemographic characteristics of groups of men who reported experiencing frequent, less frequent, or no enacted sexual minority stigma using bivariate tests of association (e.g., *t-tests, one-way ANOVA).* Next, we conducted a cross-sectional analysis using a series of multivariable linear regression models to estimate the association between enacted sexual minority stigma and cognitive function at baseline. First, we computed the associations between enacted sexual minority stigma experienced in adolescence and enacted sexual minority stigma witnessed in adolescence as continuous variables while adjusting for sociodemographic covariates. Next, we added adulthood enacted sexual minority stigma to the model too determine the effects of witnessing or experiencing enacted sexual minority stigma in adolescence after controlling for that experienced in adulthood. Finally, we assessed whether social support moderated the effect of adolescent and adulthood stigma on cognitive function by adding interaction terms to the model (Adolescent Enacted Sexual Minority Stigma Experienced*Social Support; Adolescent Enacted Sexual Minority Stigma Witnessed*Social Support, Adulthood Enacted Sexual Minority Stigma Experienced*Social Support). Each series of analyses was conducted separately for the TMT A, TMT B to A ratio, and SDMT.

Next, we conducted a longitudinal analyses using linear mixed models with repeated measures to assess the association between enacted sexual minority stigma and cognitive function across a 2-year period (visits 66-70) using the same series of models as the cross-sectional analysis. Full-information maximum likelihood parameter estimation was used to account for missing data. For the model using the TMT A score as the dependent variable, a likelihood ratio test determined

that a random slopes model fit the data best. Time-fixed predictors included sexual identity, employment status, relationship status, HIV status, enrollment wave, and study site. Random effects were modeled for time (coded as 0, 6, 12, 18, and 24 months). Random effects allow for the slopes between time and the dependent variable to differ across participants. For the model using the TMT B to A ratio as the dependent variable, a likelihood ratio test determined that a random intercept model fit the data best, and the cognitive function scores at baseline were allowed to differ across participants. Time-fixed predictors included age, education, race/ethnicity, sexual identity, employment status, relationship status, HIV status, enrollment wave, and study site. Finally, for the model using the SDMT score as the dependent variable, a likelihood ratio test determined that a random slopes model fit the data best. Time-fixed predictors included sexual identity, employment status, relationship status, HIV status, enrollment wave, and study site. Random effects were modeled for time. Random effects allow for the slopes between time and the dependent variable to differ across participants. All analyses were conducted using Stata version 16.0 (StataCorp, College Station, TX, USA).

5.3 Results

Table 10 provides a description of the overall sociodemographic characteristics of our sample at baseline. Of the men included in this sample, 30.9% were age 65 or older. The sample was predominantly gay (90.5%), white (69.8%), employed (55.6%), and had attended some college or more (89.5%). Approximately half (50.4%) of participants were married or partnered and living with HIV (48.9%). Finally, the highest proportion of the sample was recruited prior to 1987 (64.3%) and attended the Baltimore/Washington study site (31.1%).

Adolescent Enacted Sexual Minority Stigma

Among the participants in the sample, 272 (27.1%) reported experiencing any type of enacted sexual minority stigma in adolescence, and 166 (16.5%) reported experiencing two or more types. Similarly, 143 (14.2%) participants reported witnessing any type of enacted sexual minority stigma in adolescence, and 78 (7.8%) reported witnessing two or more types (Table 11). Table 10 also presents the differences in sociodemographic characteristics of the participants by frequency of enacted sexual minority stigma experienced in adolescence. Compared to participants who reported no experiences of enacted sexual minority stigma during adolescence, those who did were more likely to be midlife ($p < 0.001$), gay ($p = 0.004$), Hispanic ($p < 0.001$), and unemployed ($p < 0.001$). No statistically significant differences were found by education, relationship status, HIV status, enrollment wave, or study site.

Baseline Analysis

The unadjusted mean (SD) TMT A score at visit 66 was 20.97 (7.94) seconds. The highest mean TMT A scores (indicating poorer psychomotor speed) were found among MSM who were older ($p < 0.001$), bisexual ($p < 0.001$), Non-Hispanic Black ($p < 0.001$), unemployed ($p < 0.001$), had lower educational attainment ($p < 0.001$), single ($p < 0.001$), HIV-positive ($p < 0.01$), enrolled after 2001 ($p < 0.002$), and from the Chicago study site ($p < 0.001$). The unadjusted mean (SD) for the TMT B to A ratio at visit 66 was 2.29 (0.89). The highest mean TMT B to A ratio scores were found among MSM who were Hispanic/Latino ($p < 0.001$), unemployed ($p = 0.002$), had lower educational attainment ($p < 0.001$), HIV-positive ($p = 0.019$), enrolled after 2001 ($p < 0.001$), and from the Baltimore/Washington study site ($p < 0.001$). Finally, the unadjusted mean (SD) SDMT

score at visit 66 was 54.95 (14.02) correct answers. Lower SDMT scores (indicating poorer information processing) were found among MSM who were older ($p < 0.001$), other sexual identity ($p < 0.001$), Hispanic/Latino ($p < 0.001$), unemployed ($p < 0.001$), had lower educational attainment ($p < 0.001$), single ($p < 0.001$), HIV-positive ($p = 0.004$), and enrolled after 2001 ($p < 0.001$) (data not shown).

Table 12 presents the associations between enacted sexual minority stigma and TMT A score at baseline. We found no statistically significant differences in the TMT A score by enacted sexual minority stigma experienced or witnessed during adolescence. Furthermore, after adding adulthood enacted sexual minority stigma to the model, we found no statistically significant differences in the TMT A score by enacted sexual minority stigma experienced or witnessed during adolescence or enacted sexual minority stigma experienced in adulthood. There were no statistically significant moderating effects of social support on the TMT A score.

Table 13 presents the associations between enacted sexual minority stigma, and the TMT B to A ratio at baseline. We found no statistically significant differences in TMT B to A ratio by enacted sexual minority stigma experienced or witnessed during adolescence. After adding adulthood enacted sexual minority stigma to the model, we found no statistically significant differences in TMT B to A ratio by enacted sexual minority stigma experienced or witnessed during adolescence. However, participants who reported higher events of enacted sexual minority stigma during adulthood had higher TMT B to A ratios (indicative of worse set-shifting performance) ($b = 0.14$, 95% CI = 0.05, 0.22). Finally, social support had a significant moderating effect on the relationship between enacted sexual minority stigma witnessed during adolescence and the TMT B to A ratio ($b = -0.17$, 95% CI = -0.32, -0.03). For a given increase in stigma, the time it takes to finish the task is lower if social support is higher. (Figure 7).

Table 14 presents the associations between enacted sexual minority stigma and SDMT score at baseline. We observed no statistically significant differences in SDMT score by number of events experienced enacted sexual minority stigma experienced during adolescence. However, individuals who reported witnessing more events of enacted sexual minority stigma during adolescence had fewer correct answers on the SDMT (b = -1.28, 95% CI = -2.40, -0.16). After adding adulthood enacted sexual minority stigma to the model, we found no statistically significant differences in SDMT score by enacted sexual minority stigma experienced or witnessed during adolescence. However, participants who reported higher events of enacted sexual minority stigma during adulthood had had fewer correct answers on the SDMT (b = -1.42, 95% CI = -2.66, -0.18). Finally, social support had a significant moderating effect on the relationship between enacted sexual minority stigma experienced during adulthood and the SDMT score (b = 2.54, 95% CI = 0.17, 5.06). For a given increase in stigma, the number of correct answers on the SDMT is higher if social support is higher (Figure 8).

Longitudinal Analysis

Tables 15-17 present the longitudinal associations between enacted sexual minority stigma and the TMT A score, TMT B to A ratio, and SDMT score, respectively. We observed no statistically significant differences in the TMT A score by enacted sexual minority stigma experienced or witnessed during adolescence. Similarly, after adding adulthood enacted sexual minority stigma to the model, we found no statistically significant differences in the TMT A score by enacted sexual minority stigma experienced or witnessed during adolescence or enacted sexual minority stigma experienced in adulthood. Social support had a significant moderating effect on the relationship between enacted sexual minority stigma experienced during adulthood and the TMT A

score (b = -0.55, 95% CI = -0.94, -0.16) For a given increase in stigma, the time it takes to finish the TMT A task is lower if social support is higher (Figure 9).

For the TMT B to A ratio, we observed no statistically significant differences by number of events of enacted sexual minority stigma experienced or witnessed during adolescence. After adding adulthood enacted sexual minority stigma to the model, we found that participants who reported higher events of enacted sexual minority stigma during adulthood had higher TMT B to A ratios (indicative of worse set-shifting performance) (b = 0.04, 95% CI = 0.006, 0.07). There were no statistically significant moderating effects of social support on the TMT B to A ratio. Finally, for the SDMT score, in unadjusted models we found no statistically significant differences by enacted sexual minority stigma experienced or witnessed during adolescence. Similarly, after adding adulthood enacted sexual minority stigma to the model, we found no statistically significant differences in the SDMT score by enacted sexual minority stigma experienced or witnessed during adolescence or enacted sexual minority stigma experienced in adulthood. Social support had a significant moderating effect on the relationship between enacted sexual minority stigma experienced during adulthood and the SDMT score (b = 0.66, 95% CI = 0.18, 1.15) For a given increase in stigma, the number of correct answers on the SDMT is higher if social support is higher (Figure 10).

Table 10. Sociodemographic Characteristics of Midlife and Older MSM in the MACS at Baseline (10/2016-3/2017), n = 1,004

Sociodemographic Variables	n (%)
Age Cohort	
Midlife (40-64 years)	694 (69.1)
Older (65+ years)	310 (30.9)
Sexual Identity	
Gay	909 (90.5)
Bisexual	50 (5.0)
Other[a]	45 (4.5)
Race/Ethnicity	
Non-Hispanic white	701 (69.8)
Non-Hispanic Black	191 (19.0)
Hispanic/Latino	91 (9.1)
Non-Hispanic other races	21 (2.1)
Employment	
Employed	558 (55.6)
Unemployed[b]	159 (15.8)
Retired	287 (28.6)
Education	
High school or less	105 (10.5)
Some college or more	899 (89.5)
Relationship Status	
Married or partnered	506 (50.4)
Single	498 (49.6)
HIV Status	
Negative	513 (51.1)
Positive	491 (48.9)
Enrollment Wave	
Pre-1987	646 (64.3)
Post-2001	358 (35.7)
Study Site	
Baltimore/Washington	312 (31.1)
Chicago	203 (20.2)
Pittsburgh	260 (25.9)
Los Angeles	229 (22.8)

[a] Includes Queer, pansexual, heterosexual
[b] Includes people who were unemployed, students, or unable to work due to disability

[a] Includes Queer, pansexual, heterosexual
[b] Includes people who were unemployed, students, or unable to work due to disability

Table 11. Frequency of Enacted Sexual Minority Stigma Experienced or Witnessed During Adolescence, n = 1,004

	Adolescent Enacted Stigma (Experienced)	Adolescent Enacted Stigma (Witnessed)
	n (%)	**n (%)**
0 Events	732 (72.9)	861 (85.8)
1 Event	106 (10.6)	65 (6.47)
2 Events	65 (6.47)	30 (2.99)
3 Events	61 (6.08)	22 (2.19)
4 Events	31 (3.09)	20 (1.99)
5 Events	9 (0.90)	6 (0.60)

Table 12. Associations Between Enacted Sexual Minority Stigma on TMT A and Effect Modification by Social Support among MSM in the MACS at Baseline (10/2016 – 3/2017), n = 796

	Model 1	**Model 2**	**Model 3**
	***b* (95% CI)**	***b* (95% CI)**	***b* (95% CI)**
Adolescent Enacted Stigma (Experienced)	0.19 (-0.32, 0.71)	0.20 (-0.32, 0.72)	1.09 (-2.47, 4.65)
Adolescent Enacted Stigma (Witnessed)	0.28 (-0.35, 0.91)	0.27 (-0.41, 0.96)	-3.52 (-7.39, 0.34)
Adult Enacted Stigma	-	-0.09 (-0.78, 0.59)	2.11 (-0.14, 0.86)
Adolescent Enacted Stigma (Experienced)*Social Support	-	-	-0.27 (-1.37, 0.83)
Adolescent Enacted Stigma (Witnessed)*Social Support	-	-	1.22 (-0.007, 2.44)
Adult Enacted Stigma *Social Support	-	-	-0.78 (-2.17, 0.61)

Note: All models adjusted for age, sexual identity, race/ethnicity, educational attainment, employment status, relationship status, HIV status, enrollment wave, study site

Table 13. Associations Between Enacted Sexual Minority Stigma on TMT B/A and Effect Modification by Social Support among MSM in the MACS at Baseline (10/2016 – 3/2017), n = 795

	Model 1	**Model 2**	**Model 3**
	***b* (95% CI)**	***b* (95% CI)**	***b* (95% CI)**
Adolescent Enacted Stigma (Experienced)	0.04 (-0.01, 0.09)	0.01 (-0.05, 0.08)	-0.32 (-0.75, 0.11)
Adolescent Enacted Stigma (Witnessed)	0.07 (-0.01, 0.14)	0.05 (-0.04, 0.13)	0.58 (0.12, 1.05)*
Adult Enacted Stigma	-	0.14 (0.05, 0.22)*	0.36 (-0.14, 0.86)
Adolescent Enacted Stigma (Experienced)*Social Support	-	-	0.10 (-0.03, 0.24)
Adolescent Enacted Stigma (Witnessed)*Social Support	-	-	-0.17 (-0.32, -0.03)*
Adult Enacted Stigma *Social Support	-	-	-0.08 (-0.24, 0.09)

Note: All models adjusted for age, sexual identity, race/ethnicity, educational attainment, employment status, relationship status, HIV status, enrollment wave, study site

* $p < 0.01$

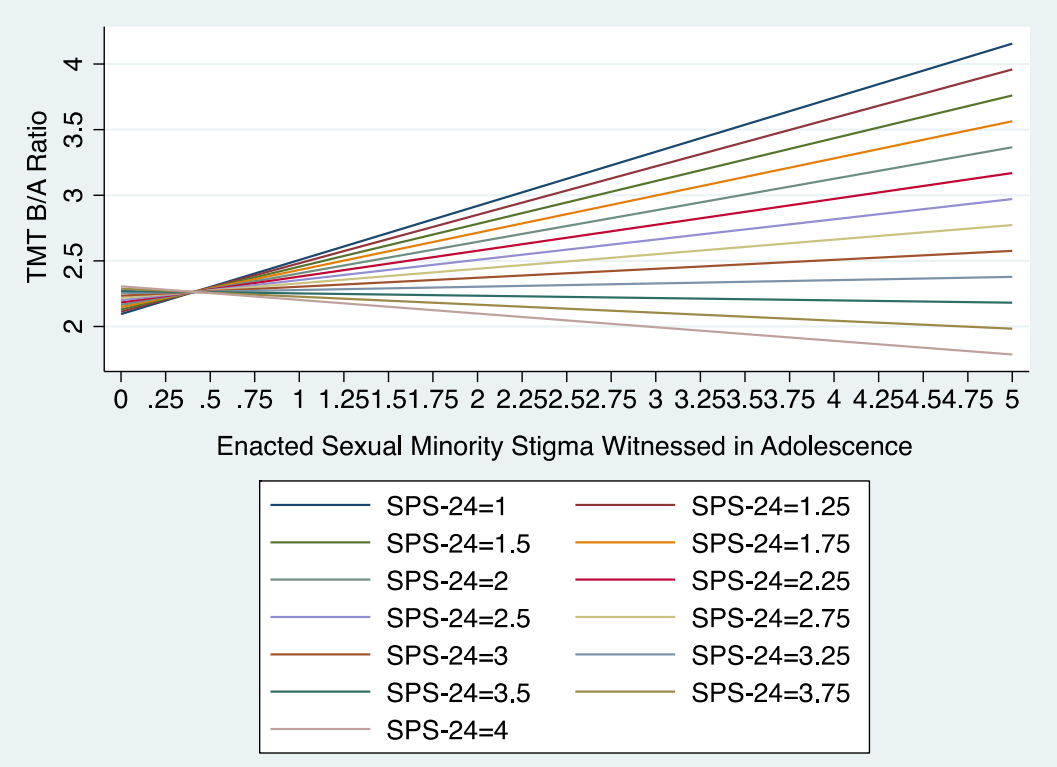

Figure 7. Effect Modification by Social Support of the Relationship Between Enacted Sexual Minority Stigma Witnessed During Adolescence on TMT B to A Ratio at Baseline (10/2016 – 3/2017)[1]

[1] The interaction is shown using simple slopes, i.e., the slopes of the dependent variable on the independent variable when the moderator is held constant at different combinations of values from low to high.

Table 14. Associations Between Enacted Sexual Minority Stigma on SDMT and Effect Modification by Social Support among MSM in the MACS at Baseline (10/2016 – 3/2017), n = 794

	Model 1	Model 2	Model 3
	b (95% CI)	*b* (95% CI)	*b* (95% CI)
Adolescent Enacted Stigma (Experienced)	-0.02 (-0.89, 0.85)	-0.13 (-1.08, 0.82)	-1.67 (-8.14, 4.80)
Adolescent Enacted Stigma (Witnessed)	-1.30 (-2.36, -0.25)*	-0.92 (-2.16, 0.33)	2.36 (-4.66, 9.38)
Adult Enacted Stigma	-	-1.42 (-2.66, -0.18)*	-8.73 (-16.23, -1.22)*
Adolescent Enacted Stigma (Experienced)*Social Support	-	-	0.45 (-1.54, 2.44)
Adolescent Enacted Stigma (Witnessed)*Social Support	-	-	-1.03 (-3.26, 1.19)
Adult Enacted Stigma *Social Support	-	-	2.54 (0.17, 5.06)*

Note: All models adjusted for age, sexual identity, race/ethnicity, educational attainment, employment status, relationship status, HIV status, enrollment wave, study site
* $p < 0.01$

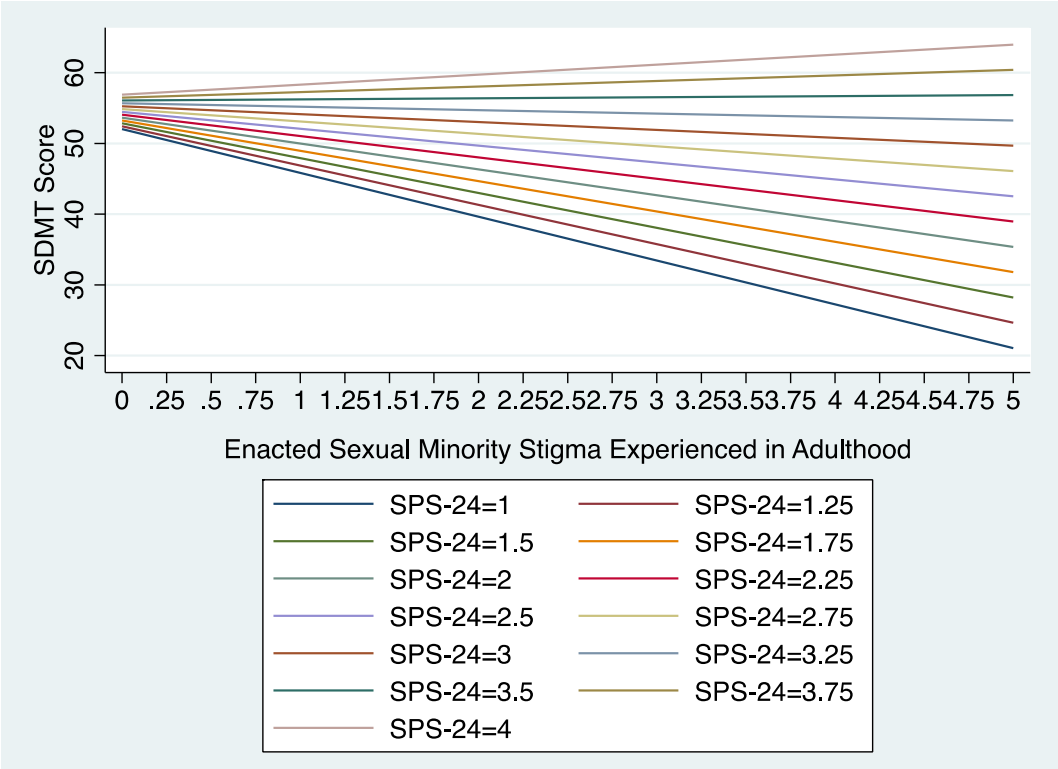

Figure 8. Effect Modification by Social Support of the Relationship Between Enacted Sexual Minority Stigma Experienced During Adulthood on SDMT Score at Baseline (10/2016 – 3/2017)

Table 15. Associations Between Enacted sexual minority stigma on TMT A and Effect Modification by Social Support among MSM in the MACS from Visits 66-70 (10/2016 – 3/2019), n = 1,004

	Model 1	Model 2	Model 3
	***b* (95% CI)**	***b* (95% CI)**	***b* (95% CI)**
Adolescent Enacted Stigma (Experienced)	0.01 (-0.43, 0.45)	0.08 (-0.36, 0.52)	-0.38 (-2.50, 1.75)
Adolescent Enacted Stigma (Witnessed)	0.13 (-0.43, 0.69)	0.07 (-0.50, 0.64)	-0.08 (-2.40, 2.23)
Adult Enacted Stigma	-	0.004 (-0.20, 0.21)	1.69 (0.48, 2.91)*
Adolescent Enacted Stigma (Experienced)*Social Support	-	-	0.13 (-0.52, 0.78)
Adolescent Enacted Stigma (Witnessed)*Social Support	-	-	0.03 (-0.70, 0.76)
Adult Enacted Stigma *Social Support	-	-	-0.55 (-0.94, -0.16)*

Note: All models adjusted for age, sexual identity, race/ethnicity, educational attainment, employment status, relationship status, HIV status, enrollment wave, study site, time (0, 6, 12, 18, 24 months)
* $p < 0.01$

Table 16. Associations Between Enacted Sexual Minority Stigma on TMT B/A and Effect Modification by Social Support among MSM in the MACS from Visits 66-70 (10/2016 – 3/2019), n = 1,002

	Model 1	Model 2	Model 3
	***b* (95% CI)**	***b* (95% CI)**	***b* (95% CI)**
Adolescent Enacted Stigma (Experienced)	0.02 (-0.15, 0.06)	0.001 (-0.04, 0.04)	-0.19 (-0.35, 0.16)
Adolescent Enacted Stigma (Witnessed)	0.03 (-0.02, 0.07)	0.02 (-0.03, 0.08)	0.01 (-0.18, 0.20)
Adult Enacted Stigma	-	0.04 (0.006, 0.07)*	0.28 (0.001, 0.55)*
Adolescent Enacted Stigma (Experienced)*Social Support	-	-	0.03 (-0.05, 0.11)
Adolescent Enacted Stigma (Witnessed)*Social Support	-	-	-0.08 (-0.17, 0.005)
Adult Enacted Stigma *Social Support	-	-	0.008 (-0.05, 0.07)

Note: All models adjusted for age, sexual identity, race/ethnicity, educational attainment, employment status, relationship status, HIV status, enrollment wave, study site, time (0, 6, 12, 18, 24 months)
* $p < 0.01$

Table 17. Associations Between Enacted Sexual Minority Stigma on SDMT and Effect Modification by Social Support among MSM in the MACS from Visits 66-70 (10/2016 – 3/2019), n = 1,000

	Model 1	Model 2	Model 3
	***b* (95% CI)**	***b* (95% CI)**	***b* (95% CI)**
Adolescent Enacted Stigma (Experienced)	-0.32 (-1.02, 0.37)	0.02 (-0.79, 0.83)	-0.05 (-3.08, 2.99)
Adolescent Enacted Stigma (Witnessed)	-0.94 (-1.92, 0.05)	-0.86 (-1.90, 0.19)	-1.23 (-4.59, 2.03)
Adult Enacted Stigma	-	0.14 (-0.10, 0.39)	-1.90 (-3.42, -0.39)*
Adolescent Enacted Stigma (Experienced)*Social Support	-	-	0.02 (-0.90, 0.94)
Adolescent Enacted Stigma (Witnessed)*Social Support	-	-	0.15 (-0.87, 1.18)
Adult Enacted Stigma *Social Support	-	-	0.67 (0.18, 1.15)*

Note: All models adjusted for age, sexual identity, race/ethnicity, educational attainment, employment status, relationship status, HIV status, enrollment wave, study site, time (0, 6, 12, 18, 24 months)
* $p < 0.01$

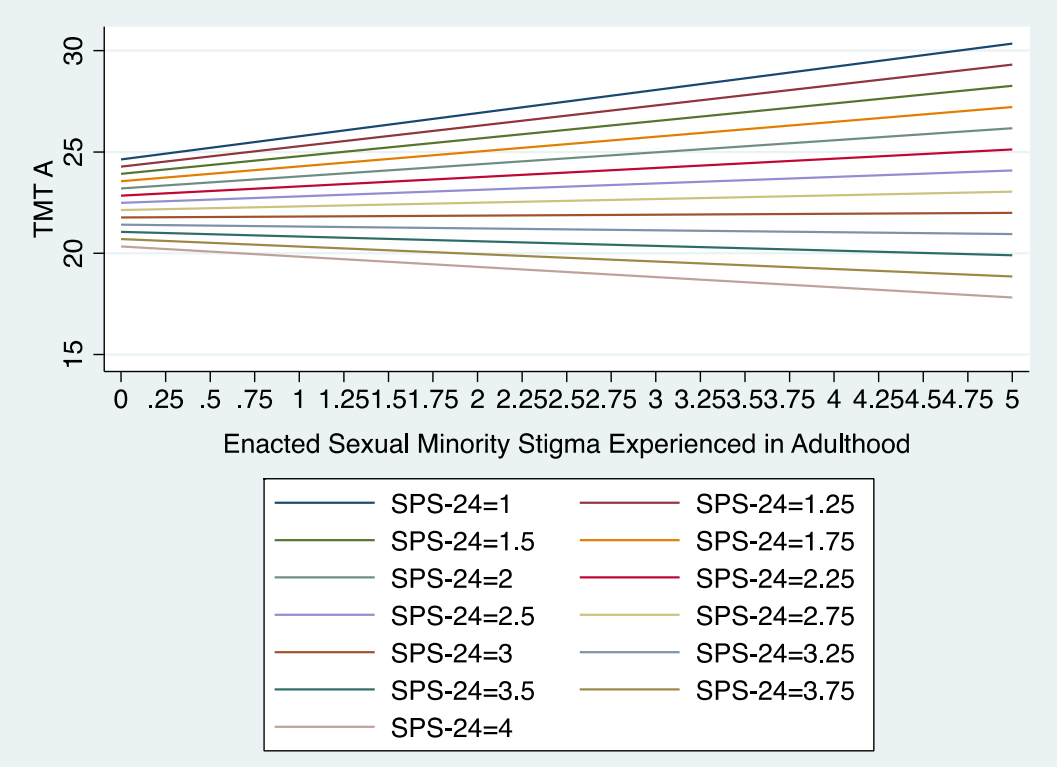

Figure 9. Effect Modification by Social Support of the Relationship Between Enacted Sexual Minority Stigma Experienced During Adulthood on TMT A Score from Visits 66-70 (10/2016 – 3/2019)

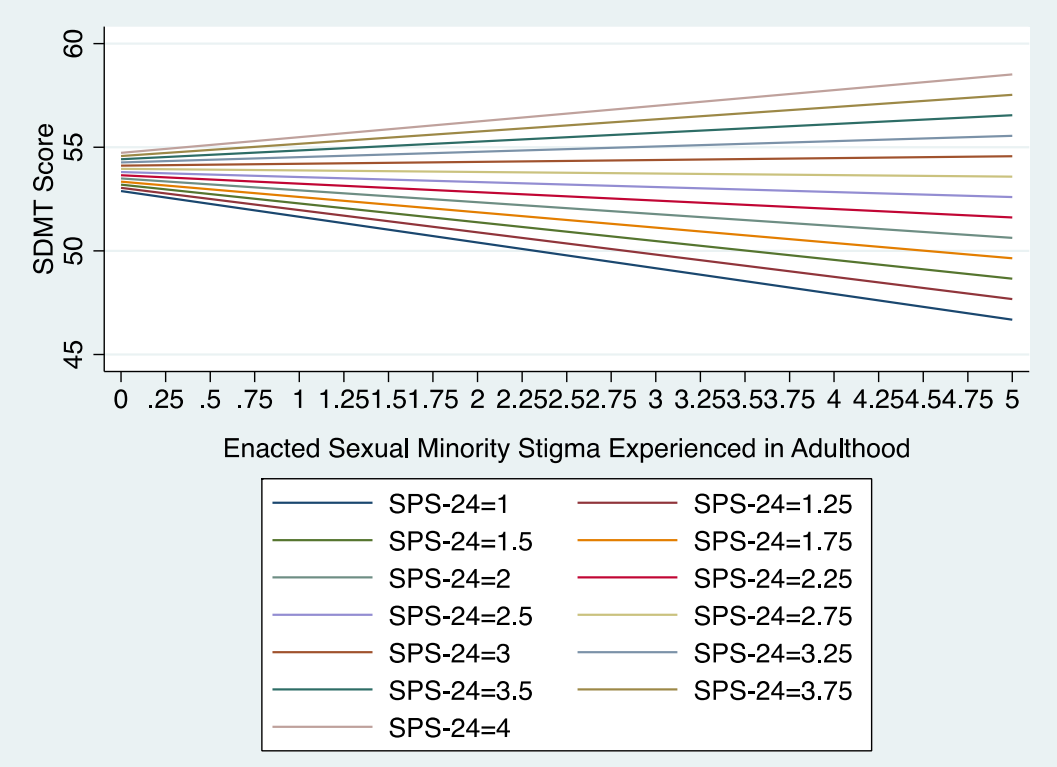

Figure 10. Effect Modification by Social Support of the Relationship Between Enacted Sexual Minority Stigma Experienced During Adulthood on SDMT Score from Visits 66-70 (10/2016 – 3/2019)

5.4 Discussion

In this study, we found that 27.1% of midlife and older MSM experienced any type of enacted sexual minority stigma in adolescence, and 16.5% experienced two or more types. Similarly, 14.2% witnessed any type of enacted sexual minority stigma in adolescence, and 7.8% witnessed two or more types. The prevalence of enacted sexual minority stigma experienced in adolescence was lower than the prevalence suggested by the most recent National School Climate Survey. In the survey, 68.7% of sexual or gender minority adolescents and young adults experi-

enced verbal harassment (e.g., called names or threatened), 25.7% experienced physical harassment (e.g., pushed or shoved), and 11.0% were physically assaulted (e.g., punched, kicked, injured with a weapon) based on sexual identity (147). Previous work from the MACS found that 82% of MSM experienced any type and 61% experienced two or more types of victimization in adolescence (142). However, this prior study measured overall violence victimization, whereas our study measured violence victimization that participants directly attributed to being gay or bisexual. Our estimate likely underestimates the true prevalence of enacted sexual minority stigma, particularly if participants were reluctant to attribute the violence victimization to their sexual identity or if the reason for the violence victimization was unclear.

Contrary to our hypothesis, the results demonstrated that experiencing or witnessing enacted sexual minority stigma during adolescence did not have a robust effect on cognitive function in midlife and older adulthood. At baseline, witnessing enacted sexual minority stigma in adolescence was associated with poorer information processing ability, but this association did not remain after adjusting for enacted sexual minority stigma experienced in adulthood. On the other hand, enacted sexual minority stigma experienced in adulthood was associated with poorer aspects of executive function and information processing ability at baseline. Adulthood enacted sexual minority stigma was also associated with poorer executive function in the longitudinal analysis. It appears that the effects of stigma experienced in adulthood surpass any downstream effects of stigma experienced in adolescence.

We observed significant moderating effects of social support. At baseline, social support moderated the associations between witnessing enacted sexual minority stigma in adolescence and executive function, and enacted sexual minority stigma experienced in adulthood and information processing ability. Longitudinally, social support moderated the association between adulthood

enacted sexual minority stigma and processing speed and information processing. In other words, for an increase in enacted sexual minority stigma the effect of the stigma on cognitive function was smaller if social support was higher. These results add to the literature showing social support's protective effect for other outcomes among older MSM including mental HRQoL, resilience and mastery, and depression (101, 114, 117). Social support may confer benefits for cognitive function by providing psychological and material resources needed to cope with stress, by influencing health behaviors, promoting access to social activities, or increasing access to healthcare (87, 96).

The results of this study should be interpreted while considering several limitations. The *Healthy Aging Study* collected data over 2 years. Since cognitive performance diminishes with age, longer-term follow-up may detect additional changes (139). The present analysis also included only three tests of cognitive function to have sufficient repeated measures over the period of data collection. A full neuropsychological battery testing additional domains such as memory or motor skills may reveal additional effects of enacted sexual minority stigma. Additionally, this analysis may have reduced external validity because the sampling design included a convenience sample of MSM from the MACS and may not be generalizable to all midlife and older MSM in the US and globally. The small sample sizes of racial or ethnic minorities and non-gay identified MSM limited our ability to explore potentially important differences within these subgroups of MSM.

There are also limitations to our measure of enacted sexual minority stigma experienced or witnessed during adolescence. We asked participants to recall experiences of violence victimization that occurred, at the minimum, thirty years prior to the administration of the survey. Therefore, the measure is subject to recall bias which may account for the lower prevalence of enacted sexual

minority stigma than expected or a weakened association between enacted sexual minority stigma experienced or witnessed in adolescence and cognitive function. On the other hand, the effect enacted sexual minority stigma witnessed or experienced during adolescence may be biased away from the null if the participants who experienced more severe events were more likely to recall them, compared to less severe events which may be been forgotten.

Our measure of adult enacted sexual minority stigma is also subject to recall bias. We asked participants to recall experiences of stigma based on their actual or perceived sexual identity over the past 12 months. MSM may have also faced enacted sexual minority stigma due to other factors such as race/ethnicity, age, or HIV status. The individual and intersecting effects of these other forms of stigma were not analyzed in this study. We also did not assess other forms of enacted sexual minority stigma that are often included in other scales such as receiving poorer services in restaurants, stores, or other businesses, unfair treatment at work or school, or being denied or given lower quality health care (129, 140, 141).

Missing data may also have affected our results. First, 12.7% of the sample was missing all neuropsychological outcome data. The excluded participants were more likely to be white, HIV negative, and older and it is unknown how the cognitive function of these participants differed from those included in the study. Second, 4.9% were missing responses for adolescent enacted sexual minority stigma at all study visits. These participants were more likely to be Non-Hispanic Black ($p = 0.02$), have lower education attainment ($p = 0.006$), be HIV-positive ($p < 0.001$), enrolled after 2001 ($p = 0.001$), and from the Baltimore/Washington study site ($p < 0.001$). If these participants were more likely to have experienced stigma, the results might be biased towards the null.

Social support has emerged as a critical resource for MSM. Importantly, social support can be fostered at both individual and community levels. Efforts are needed to investigate how social support can be incorporated into interventions that promote healthy aging of MSM. At the same time, there remain gaps in knowledge about the mechanisms by which social support affects cognitive function. Weiss hypothesized that a deficiency in social support may lead to loneliness, and that this loneliness subsequently leads to poor health outcomes (148). Indeed, in studies from the general population, reductions in loneliness have been shown to account for the beneficial effect of social support on cognitive functioning (88). This theory should be empirically tested among MSM as well.

Finally, future research regarding the effects of stigma on cognitive function should focus on whether the effects of enacted sexual minority stigma are more pronounced among certain subgroups of MSM, including racial or ethnic minorities, MSM living with HIV, or bisexual men. Furthermore, future research efforts should examine the health and well-being of midlife and older MSM from an intersectionality lens, acknowledging that enacted sexual minority stigma may operate to affect cognitive function at the intersection of various identities and attributes including age, race, HIV, biphobia, and disability status.

Conclusion

This study is the first to investigate how experiences of enacted sexual minority stigma during adolescence and adulthood affect cognitive function of midlife and older MSM. Our results suggest that enacted sexual minority stigma experienced during adulthood has a more salient and negative effect on cognitive function compared to that experienced during adolescence. Importantly, we identified social support as one factor that appears to buffer the negative effects of stigma on cognitive function.

6.0 Conclusion

6.1 Summary of Main Findings

The results from these studies advance the literature on cognitive function among midlife and older MSM in several important ways. Overall, they provide evidence that psychosocial factors such as sexual minority stigma may contribute to additional risk for poor cognitive function among MSM. On the other hand, our findings elucidate that social support may be an important resource for MSM that can be used to promote healthy aging and mitigate the negative effect of social stressors on cognitive function.

In the first study, we tested the association between social support using the *Social Provisions Scale* and cognitive function using the *Standard Trail Making Test (TMT) Parts A and B* and the *Symbol Digit Modalities Tasks (SDMT*) in analyses at baseline and across a 2-year period. We used the TMT A score as a measure of psychomotor ability, the ratio of the TMT B to TMT A scores as a measure of executive function, while accounting for the effects of psychomotor speed and visual searching ability, and the SDMT as a measure of information processing ability. In the baseline analyses, we found that social support was associated with a lower TMT A score (b = -2.01, 95% CI = -3.24, -0.77). In the longitudinal analysis, we found that social support was associated with a lower TMT A score (b = -1.76, 95% CI = -2.42, -1.10). These results show that participants with higher social support took less time to complete the TMT A task, indicating better psychomotor ability. Social support was also associated with a higher Symbol Digit Modalities Tasks (SDMT) score at baseline (b = 2.28, 95% CI = 0.22, 4.34) and across 2 years (b = 1.05, 95% CI = 0.20, 1.90). These results show that participants with higher social support had more correct

answers on the SDMT, indicating better information processing.

In the second study, we examined the effects of enacted sexual minority stigma on cognitive function using the same analyses and outcomes as the first study. At baseline, experiencing more events of enacted sexual minority stigma was associated with higher TMT B to A ratios, indicating worse set-shifting performance (b = 0.14, 95% CI = 0.06, 0.22) and fewer correct answers on the SDMT, indicating poorer information processing (b = -1.63, 95% CI = -2.81, -0.44). In the longitudinal analyses, experiencing more events of enacted sexual minority stigma was associated with higher TMT B to A ratios, indicating worse set-shifting performance (b = 0.04, 95% CI = 0.01, 0.07).

In the third study, we examined the effects of enacted sexual minority stigma experienced or witnessed during adolescence on cognitive function, while accounting for the effects of enacted sexual minority stigma experienced in adulthood. We also sought to determine whether social support modifies the association between enacted sexual minority stigma and cognitive function. Contrary to our hypotheses, the results demonstrated that experiencing or witnessing enacted sexual minority stigma during adolescence were not associated with cognitive function in midlife and older adulthood after adjusting for enacted sexual minority stigma experienced in adulthood. However, we observed significant moderating effects of social support at baseline between witnessing enacted sexual minority stigma in adolescence and the TMT B to A ratio, and enacted sexual minority stigma experienced in adulthood and the SDMT score. Longitudinally, social support moderated the association between adulthood enacted sexual minority stigma and the TMT A and SDMT scores. In other words, for an increase in enacted sexual minority stigma the effect of the stigma on cognitive function was smaller if social support was higher.

6.2 Implications for Future Research

The analyses completed in this dissertation contribute to the nascent body of literature that seeks to describe, understand, and prevent impairments in cognitive function among MSM. The findings from this research draw attention to several areas of focus for future research. First, these analyses should be replicated among other sexual and gender minority populations. Little is known about cognitive health among sexual minorities who do not have HIV or the mechanisms underlying the development of cognitive impairment, AD, or other dementias in these populations. However, it is likely that sexual minority women, transgender, and non-binary older adults share similar experiences of enacted sexual minority stigma that also function as a risk factor for poor cognitive function.

Furthermore, this research should also be replicated with larger sample sizes of MSM who are bisexual or do not identify as gay and who are racial and ethnic minorities. In our analyses, these men were at greater risk of poor cognitive function and low social support. The small sample sizes of these subgroups in our study prevented us from conducting within-group analyses. Increasing the size of these subgroups will help achieve greater representativeness in the sample. Additionally, there will be greater power to detect important differences among these MSM and to explore what other social and cultural factors contribute to their health disparities relative to other MSM. It is also imperative to explore the intersections of stigma due to age, race, HIV status, and other factors and their effects on cognitive function.

Future research would benefit from resolving measurement challenges we encountered in these analyses. Specifically, enacted sexual minority stigma was measured differently in the adolescent and adulthood questionnaires in the *Healthy Aging Study*. The adulthood questionnaire asked respondents to indicate with a yes or no whether they experienced up to 5 different types of

enacted sexual minority stigma. On the other hand, the adolescent questionnaire asked respondents to indicate the frequency with which they experienced up to 5 types of enacted sexual minority stigma. It remains unknown what factors are more salient to cognitive function: the frequency of enacted sexual minority stigma experiences, the number of different forms of stigma experienced, or a certain type of experience. We also did not assess other forms of enacted sexual minority stigma that are often included in other scales such as receiving poorer services in restaurants, stores, or other businesses, unfair treatment at work or school, or being denied or given lower quality health care. Measures of enacted sexual minority stigma among MSM should be standardized and validated to compare results across studies and to replicate analyses in the future. We were also only able to examine the effect of witnessing enacted sexual minority stigma during adolescence. The stress-related health effects of witnessing enacted sexual minority stigma or other experiences of vicarious trauma during adulthood should be explored.

Our results demonstrated that all variables – cognitive function, social support, and enacted sexual minority stigma – were relatively stable across the 2-year period. Following these variables for a longer time may display different temporal patterns. Interestingly, we observed an increase in enacted sexual minority stigma at visit 67. The timing of this visit corresponded to the election and inauguration of Donald Trump as President of the United States. While not conclusive, this observation suggests that MSM in midlife and older adulthood continue to endure experiences of social discrimination. The focus of this dissertation on intra- and inter-individual risk and protective factors (i.e., enacted sexual minority stigma and social support) should not over-shadow how the social and structural context also contributes to health disparities for MSM. Furthermore, at the time of writing, the COVID-19 pandemic has decreased opportunities for social support and has drastically changed what social support even looks like. Given the effects of the pandemic, it

is important to re-examine the patterns of social support over time, as well as investigating and ameliorating any negative consequences of this interruption in social support.

Finally, given that social support had both direct and indirect benefits for cognitive function, our findings have significant public health implications for future interventions. Social support can be fostered and older adults can be taught strategies for enhancing social support. Despite considerable evidence for the benefits of social support, there are few interventions to improve social support for MSM, and even less evidence about how, and how well, social support interventions work. Earlier work from our group using the *Healthy Aging Study* demonstrated that regarding depression outcomes, the source of social support may not be as important as simply having *any* type of support. Therefore, social support could take the form of improved connection to family, friends, community engagement, or other social programs tailored for sexual minority older adults. Continuing to use theory-driven approaches to developing and testing social support interventions will also help overcome many of the conceptual and measurement issues that plague this area of research. Interventions should be also designed to improve health outcomes for midlife and older MSM with poor cognitive function. One existing program, *Innovations in Dementia Empowerment and Action (IDEA),* presents an innovative approach to improving quality of life among sexual and gender minority older adults with memory problems. IDEA is evidence that culturally competent and effective interventions are possible and can positively impact individuals and the broader LGBT community.

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