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HIV Serostatus Among Young Black Men Who Have Sex with Men — Roles of Executive Functioning and Marijuana Use

By

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Introduction

Once seen as a terminal diagnosis, HIV can now be managed as a chronic disease for those with access to care and life-saving pharmaceuticals. However, while antiretroviral drugs (ARV) have contributed to a reduction in HIV-related deaths, progress in the fight to eradicate HIV – particularly in underserved communities – has stalled (CDC, 2020; Millett et al., 2012). Mitigation efforts aimed at reducing the disease burden have yet to produce widespread change; moreover, projections suggest that HIV disparities are likely to persist for decades to come (Rosenberg et al., 2014). Using data from Khanna and colleagues' (2016) uConnect study – a project examining the health of Young Black Men who have Sex with Men (YBMSM) from the South Side of Chicago – I aimed to identify the relationship between marijuana use, executive functioning, and HIV serostatus among members of this group. Specifically, I sought to understand how marijuana use and executive functioning interact with – and individually impact – HIV serostatus. In other words, does marijuana use impair executive functioning? Are higher levels of marijuana use associated with HIV seropositivity? Are impaired executive functions associated with HIV seropositivity? And summarily, does the potential negative impact of executive functioning mediate the relationship between marijuana use and health outcomes?

Previous research has found links between cognitive functioning and HIV care continuum outcomes among YBMSM and children with HIV (Ettenhofer et al., 2010; Malee et al., 2008). Ettenhofer et al. (2010) found strong reciprocal relationships between executive functions and medication adherence among YBMSM while findings from Malee et al. (2008) suggested that low cognitive functioning increased children’s odds of being nonadherent to ARV and that these effects were compounded by stressful life events. Facing stressful life events is not uncommon among YBMSM from Chicago’s South Side. Poverty, racism, stigma, community violence, unemployment, and other structural obstacles put YBMSM at particular risk for nonadherence (Phillips et al., 2014; Martinez et al., 2009). These same stressors that individually impact retention and adherence also threaten the development of executive functions, creating a toxic feedback loop that threatens YBMSM health outcomes. Moreover, YBMSM from Chicago often turn to substances to cope with life stressors: in two studies nearly seventy-five percent of YBMSM reported frequent to heavy marijuana use (Voisin et al., 2017; Morgan et al., 2016). Importantly, multiple studies have found that marijuana use impairs executive functions (O'Donnell et al., 2021; Rathee, 2021; Paige & Colder, 2020; Gonzalez et al., 2012; Crean et al., 2011). Thus, I sought to understand how marijuana use and executive functioning interact with – and individually impact – HIV serostatus. I hypothesized that higher levels of marijuana use would impair executive functioning across all domains, essentially increasing response score on the executive functioning measure (i.e. Behavioral Rating Inventory of Executive Functioning (BRIEF-A) (Roth, Isquith, Gioia, 2005). Moreover, higher levels of marijuana use and higher scores on the BRIEF-A were both thought to be associated a greater likelihood of being HIV seropositive. The metacognitive index (MI) – a subdomain of executive functions – was expected to be most affected by marijuana use and the strongest predictor of HIV serostatus. These analyses aimed to extend prior research that weighs the impact that health behaviors and neurocognitive abilities have on health and wellbeing; findings aim to guide risk assessment and medical decision making. What follows is a review of HIV among YBMSM from the South Side of Chicago, HIV care continuum outcomes, executive functioning, and marijuana use.

HIV among Young Black Men who have Sex with Men from Chicago

Of the groups most impacted by HIV in the United States, YBMSM shoulder the greatest disease burden relative to their proportion of the whole population (CDC, 2022; Prejean et al., 2011). YBMSM are three to five times as likely to be diagnosed with HIV compared to Latinos and Whites, with rates expected to increase (Millett, 2015), and about 1 in 2 YBMSM will be diagnosed with HIV in their lifetime (CDC, 2016). In 2014, Black men who have sex with men (BMSM) accounted for 37% of HIV diagnoses among gay and bisexual men (CDC, 2021); in 2018, 3 out of every 4 BMSM diagnosed with HIV were between the ages of 13 and 34 (CDC, 2021a). To put it another way, HIV disproportionately impacts Black men—of Black men diagnosed with HIV, *young* Black men represent a significant majority.

HIV outcomes are associated with age and race but geographical disparities also exist at the national, state, and community levels (G. Millett, 2015). The HIV incidence rate in Chicago, Illinois – and the city's South Side neighborhoods in particular – is two and a half times the national average (Hemmige et al., 2012) . Notably, 76.5% of the population in the South Side of Chicago is Black (CMAP, 2021). Of Black males aged 16-29 from the South Side of Chicago, 1 in 10 are men who have sex with men (MSM) (Livak et al., 2013).

The HIV Care Continuum

The HIV care continuum offers a framework for investigating disparities. The four stages of the HIV care continuum include engaging individuals in care, testing for HIV, ARV treatment, and retention and adherence to ARV long enough to reach viral suppression – the point at which a patient's viral load is at undetectable levels (i.e. Seek, Test, Treat, Retain) (Morgan et al., 2017). In 2015, the Obama administration updated their National HIV/AIDS Strategy for the United States calling for 85% of those with HIV to be linked to care within one month of their diagnosis, 90% to be retained in care, and 80% to reach viral suppression (OANP, 2015). The Biden administration updated the National HIV/AIDS Strategy calling for 75% reduction in HIV infections by 2025 and a 90% reduction by 2030 (OANP, 2021). In order to achieve these ambitious goals, a nuanced understanding of the myriad of factors that augment HIV disparities is needed; currently, little is known about which factors influence YBMSM care continuum outcomes. It is clear, however, that Black individuals are significantly less likely to reach viral suppression compared to their White counterparts (Buchacz et al., 2018).

Executive Functions

Executive functions are skills associated with goal-oriented behavior and they underscore an individual's ability to self-regulate, control, redirect, and manage their attention, cognitions, emotions, and behaviors (Roth, Isquith, & Gioia, et al., 2005). Executive functions are commonly referred to as the "canary in the coal mine" of cognitive functions – the first cognitive abilities impaired by organismic adversity (K. G. Quinn & Voisin, 2020). Of note, executive functions develop over time. The brain – and the frontal lobe which subserves most executive skills - experience dramatic growth as one progresses through development stages, from adolescent, to young adult, to adult years (Fiske & Holmboe, 2019; Best et al., 2009; Sowell et al., 2002; Sowell et al., 1999). Given the sensitive period of brain development YBMSM fall within, poor health outcomes may be augmented by specific threats to executive functions. Factors that may impede the development of executive functions and their subserving neurological structures include low SES and poverty (Ettenhofer et al., 2010; Noble et al., 2015), emotional and cognitive neglect (Rosen et al., 2020; King et al., 2019; McLaughlin et al., 2017; Sheridan et al., 2017), threats to one's safety (Sheridan et al., 2017), and substance use (Sheridan et al., 2017). Some of these experiences are ubiquitous to life for YBMSM from the South Side of Chicago (Voisin et al., 2017). Structural forms of adversity found to influence HIV care continuum outcomes include criminal justice involvement (Piche et al., 2018), community violence (Hotton et al., 2019), unemployment (Voisin et al., 2017), stigma (Voisin et al., 2017), lack of access to health services (McNulty & Schneider, 2018), lack of social support (Chen et al., 2020; Behler et al., 2018; Fujimoto et al., 2017; McFadden et al., 2014), and influences from sex networks (Morgan et al., 2017). For purposes of this study, I looked toward substance use (i.e. marijuana use) as a form of adversity that may impair executive functions given the high rates of use among YBMSM.

The BRIEF-A, while not the only instrument used to measure executive functions, is a useful tool for conceptualizing cognitive domains. The BRIEF-A is a well-validated measure developed by analyzing data from from rural, urban, and suburban community members and has been found to have high internal consistency and test-retest reliability (Roth, Isquith, Gioia, 2005). What follows is an overview of each of the cognitive domains tapped by the BRIEF-A instrument.

Behavioral Regulation Index (BRI)

Shifting

Shifting refers to the ability to switch and change between tasks or rules efficiently, the abilities to alter problem-solving strategies and think flexibly, and the ability to change attention. (Spaniol & Danielsson, 2022; Gioia & Isquith, 2004). Shifting is also often referred to as "attention switching" or "task switching" (Miyake et al., 2000). Miyake et al. (2000) note that shifting may be more than simply engaging and disengaging from tasks, but also involves the ability to perform new tasks in the face of interference or negative priming; this goes beyond simply switching spatial or visual attention. Frontal regions of the brain including the prefrontal cortex and the inferior frontal junction are implicated in the ability to shift (Fiske & Holmboe, 2019). Visual attentional shifting is primarily regulated by parietal lobes and the mid-brain (i.e. posterior attention network), whereas executive-dominant shifts are primarily regulated the frontal lobes, including the anterior cingulate (i.e. anterior attention network) (Miyake et al., 2000). Changes in activation occur throughout development. Fiske and Holmboe (2019) note that the right superior frontal sulcus activates during shifting tasks but that adults and not children activate the left superior parietal cortex and the thalamus. Tasks that tap the shifting dimension include the Wisconsin Card Sorting Task, the Plus-Minus Task (Jersild, 1927), the Number-Letter Task (Monsell, 1996), the Dimensional Change Card Sort Task (DCCS), and the Pet Store Stroop task among others (Fiske & Holmboe, 2019; Miyake et al., 2000).

Inhibition

Inhibition refers to the ability to intentionally inhibit an inappropriate automatic or prepotent response (Miyake et al., 2000). Daily activities that use inhibition include acting without thinking, being easily distracted, and being unable to sit still (Gioia & Isquith, 2004). In a review of the executive functioning literature, Diamond (2013) notes that the dorsal and ventro-medial prefrontal cortex are both implicated in inhibitory control tasks such as the Go/No-Go Task (Casey et al., 1997; Konishi et al., 1998; Tsujimoto et al., 1997). Fiske and Holmboe (2019) also cite evidence suggesting that parietal and striatum activation in inhibitory control tasks changes throughout development and that the right inferior frontal cortex plays a key role in inhibition (Verbruggen & Logan, 2008). Tasks that tap the construct of inhibition include the Tower of Hanoi Task (Welsh et al., 1999), Random Number Generator Task (Jahanshahi, 1998), Stroop Task (Stroop, 1935), Antisaccade Task (Hallett, 1978), Go/No-Go Task (Cheung et al., 2004); Stop-Signal Task (Logan et al., 2014), and the Delay Gratification Task (Mischel et al., 1972), among others.

Emotional Control

Emotional control refers to the ability to regulate emotions appropriately (Roth, Isquith, Gioia, et al., 2005). It is related to the ability to modulate responses and is assessed in the home and school environment more frequently than through tasks in a laboratory. An inability to control emotions may result in dramatic emotional reactions to minor events or as general affective reactivity (Gioia & Isquith, 2004). According to the BRIEF-A, emotional control belongs to the behavioral regulation index subdomain of executive functioning, however Egeland and Fallmyr (2010) argued that Emotional Control should fall within a separate subdomain or emotional regulation that also includes shifting. This three-factor model of executive functioning was supported by Gioia et al. (2002) but is notably different from the two-factor model used in the BRIEF-A (Roth, Isquith, Gioia, et al., 2005). According to Lamm & Lewis (2010) , the ventromedial prefrontal cortex is implicated in emotional control.

Self-Monitoring Behavior

The skill of being able to self-monitor includes being able to review one's own actions during and after tasks to support achieving a given goal (Gioia & Isquith, 2004). Children who struggle with being able to self-monitor make more mistakes on assignments and often rush through tasks. Moreover, deficits in self-monitoring may result in inaccurate perceptions of competence, difficulties with theory of mind skills, reduced confidence (Roebers, 2017), and challenges building relationships (Epstein et al., 2008). Luu et al. (2000) point to the anterior cingulate cortex as a key feature implicated in the ability to self-monitor. Specific tests that tap the construct of self-monitoring are not well established and have failed to identify differences in individuals with autism spectrum disorder – a population prone to deficits in self-monitoring (Robinson et al., 2009).

<u>Metacognition Index (MI)</u>

Initiation

Initiation refers to the ability to start a task and the process of generating ideas and problem-solving strategies (Gioia & Isquith, 2004). People struggling with initiation often struggle to start their work, get chores done, and require more prompts to complete an activity (Gioia & Isquith, 2004). Individuals with ADHD and autism often experience difficulties initiating tasks. The orbitofrontal cortex and the dorsolateral prefrontal cortex have both been implicated in the ability to initiate actions (Bramham et al., 2009). The Verbal Fluency Task is one measure used to identify initiative abilities (Bramham et al., 2009).

Working Memory

Working memory refers to the ability to hold information in mind and manipulate it (Gioia & Isquith, 2004). It is important for following and completing complex instructions and steps as well as math (Gioia & Isquith, 2004). Individuals who have working memory deficits may present as forgetful (Gioia & Isquith, 2004). Working memory heavily relies on the dorsolateral prefrontal cortex (Diamond, 2013; Fiske & Holmboe, 2019). Tasks that measure working memory include the Random Number Generator Task, the Operation Span Task and the A-not-B/Delayed Response Task (Miyake et al., 2000).

Planning/Organize

Planning and organizing is a high-level executive function that involves anticipating future events, setting goals, and developing steps to achieve those goals (Gioia & Isquith, 2004). Children who struggle to plan and organize might procrastinate on their work and fail to think ahead about future obstacles (Gioia & Isquith, 2004). Neural substrates that have been implicated in the ability to plan and organize tasks include the left prefrontal dorsolateral cortex, superior frontal cortex, premotor cortex, anterior cingulate and the right frontopolar region (Collette et al., 2006). Tasks that measure this construct include the Tower of Hanoi Task, the Truck Loading Task, and the Kitten Delivery Task (Carlson et al., 2004).

Task Monitor

Task monitoring refers to one's ability to check their own work and personal performance (Roth, Isquith, & Gioia, et al., 2005). Individuals who struggle to monitor their tasks often have a slower pace of work, difficulties multitasking, and make more errors. (Russell & Hill, 2001). Both the prefrontal cortex and anterior cingulate cortex have been implicated in the ability to monitor tasks (Osaka et al., 2004). Measures that are used to assess task monitoring include the Transparent Intentions Task and the Target Shooting Task (Russell & Hill, 2001).

Organization of Materials

Organization of materials refers to the ability to establish and maintain order within an activity and carry out a task systematically (Gioia & Isquith, 2004). Problems organizing materials may present as being easily overwhelmed by large assignments and messy personal spaces (Gioia & Isquith, 2004). Moreover, children who struggle to organize may struggle with independent study, time management, sequencing, prioritization, and note taking (Meltzer & Krishnan, 2007). Studies using the Rey Complex Figure Task have suggested that the prefrontal cortex plays a key role in the ability to organize materials (Meltzer & Krishnan, 2007).

While I have included the brain regions that subserve particular executive functions, it should be noted that pure localization of executive functions is not the case. Brain functioning is dynamic and cognitive skills rely on a network of interactions; thus, while it can be helpful to point to regions that play a particularly important role in any given skill, it is rarely the case that processes occur in isolation. Moreover, networks implicated in particular executive functions change as the brain develops and thus assessing change over time and using individuals at sensitive developmental periods is critical.

Table 1: Summary of Executive Functions

Executive Function	**Ability Measured**
Behavioral Regulation Index	
Shifting	Ability to switch or change between tasks or rules efficiently, the abilities to alter problem-solving strategies and think flexibly
Inhibition	Ability to intentionally inhibit an inappropriate automatic or prepotent response
Emotional Control	Ability to regulate emotions appropriately
Self-Monitoring	Ability to self-monitor includes being able to review one's actions during and after tasks to support achieving a given goal
Metacognition Index	
Initiation	Ability to start a task and the process of generating ideas and problem-solving strategies
Working Memory	Ability to hold information in mind and manipulate it
Planning/Organize	Ability to anticipate future events, set goals, and develop steps to achieve those goals
Task Monitor	Ability to check their own work and personal performance
Organization of Materials	Ability to establish and maintain order within an activity and carry out a task in a systematic manner
Global Executive Composite	

Executive Functions, Marijuana Use, and the HIV Care Continuum

Marijuana use is common among YBMSM from the South Side of Chicago (Voisin et al., 2017; Morgan et al., 2016). It is also clear that executive functions, substance use, and structural factors (e.g. access to health services, stigma, community violence) individually influence individuals' health behaviors and treatment outcomes. Less is clear about the dynamic interplay between factors. Executive functioning among YBMSM from the South Side of Chicago may link the relationship between marijuana use and HIV serostatus.

Previous findings suggest that individuals with impaired executive functions are more likely to engage in risky sex behaviors and take greater health-related risks (Reynolds et al., 2019; Dcruz, 2014; Hall et al., 2014; Magar et al., 2008). Additionally, studies of YBMSM have found significant associations between marijuana use and a lower intention to participate in HIV prevention, higher frequency of engagement in high-risk sex behaviors, higher likelihood of being seropositive unaware, and reduced adherence to medication (Maksut et al., 2016; Hall et al., 2014; Quinn et al., 2016; Ettenhofer et al., 2010; Brodbeck et al., 2006; Castilla et al., 1999). While a causal pathway that links each of these factors has eluded researchers, research into the effects marijuana use has on general cognitive functioning points to a possible mediating relationship.

Robust literature already exists linking marijuana use to cognitive functioning impairments. In a study of the acute effects of marijuana use, Ramaekers et al. (2006) found that, compared to placebo groups, subjects using THC were significantly more likely to make the wrong decision on a decision-making task and took longer to make those decisions. Residual effects (i.e. between 7 hours and 20 days after use) were found to significantly impair decision-making abilities and increase risk-taking (Whitlow et al., 2004). A seminal study on the long-term effects of marijuana use on inhibition and cognitive flexibility demonstrated that heavy marijuana users made significantly more errors on inhibitory tasks (Crean et al., 2011; Pope, 1996). Others have found significant impairments in executive functioning and increases in risk-taking among marijuana users (Verdejo-García et al., 2005). Findings from Fernández-Serrano et al. (2010) also suggested that marijuana use was associated with reduced verbal fluency and decision-making abilities as well as verbal working memory and analogical reasoning. Among YBMSM, however, many factors need to be considered when evaluating the impact of marijuana use on executive functions. For example, age of onset, duration of use, recency of use, quantity, and environmental factors leading to use are all important.

Having explored HIV disparities, the HIV care continuum, marijuana use, and executive functioning, I now will turn attention toward the methodology of the present study. This study aimed to build on previous research and explore how marijuana use and executive functioning interact and dynamically influence the HIV care continuum outcomes of YBMSM from Chicago's South Side neighborhoods.

Data and Measures

Data

The University of Chicago and its South Side community partners collaborate on the Urban Health Initiative, a community-engaged health research infrastructure that aims to eradicate HIV and make the South Side of Chicago one of the top three healthiest urban communities in the United States (Ramaekers et al., 2006). This mission reflects a broader healthcare revolution in the U.S. spearheaded by urban communities and their local academic medical centers (Hill, 2005). The uConnect project is the offspring of the partnership between the University of Chicago, the South Side community, and the Chicago Center for HIV Elimination (CCHE). uConnect was initiated to better understand features of YBMSM social networks were amenable to change, and how the beliefs, attitudes, and behaviors of YBMSM contributed to sexually transmitted infections. uConnect was also the first study of YBMSM characteristics related to pre-exposure prophylaxis (PrEP) engagement – a daily course of ARV (Khanna et al., 2016).

Participants in the uConnect cohort 1) self-identified as African American or black; 2) were born male; 3) were between 16 and 29 years of age; 4) reported oral or anal sex with a male within the past 24 months; and 5) resided in the South Side of Chicago (Khanna et al., 2016). 618 YBMSM were recruited between August 2013 and July 2014 using respondent driven sampling. 506 completed the BRIEF-A questionnaire; these 506 were used as the sample for all analyses. Seed participants were recruited through four methods: 1) a Federally Qualified Health Center that provides HIV primary care, 2) existing Effective Behavioral Intervention prevention programs, 3) fliers at substance use treatment centers, and 4) fliers at LGBTQ care centers. Seed participants were selected for being popular and having charismatic personality traits in order to optimize recruitment efforts. All participants received $50 for their participation. Interviews were conducted using either computer aided personal interviewing or self-administration.

Measures

Marijuana use habits among participants were assessed during a six month window. Use was defined as never, light, and heavy. Light use included any marijuana use up to and including multiple times per week. Heavy marijuana use was defined as daily use and more. The primary dependent variable was HIV serostatus which was defined as a binary yes/no response. Raw scores from the BRIEF were also recorded.

Executive functioning data was collected using the Behavioral Rating Inventory of Executive Functioning (BRIEF-A), developed by Roth, Isquith, and Gioia, et al. (2005). This test of executive functioning is a 75-question self-report survey that produces a Behavioral Regulation Index (BRI), a Metacognition Index (MI), and a Global Executive Composite (GEC) score. Questions asking about executive functioning difficulties are answered on a three-point Likert Scale: 1) never, 2) sometimes, and 3) often. The GEC is computed by combining scores from the BRI and MI, each of which can be broken down into further subdomains. The ability to shift attention between tasks, inhibit impulses and modify behavior, and control emotions fall under the broader BRI domain (Roth, Isquith, & Gioia, et al., 2005). Initiating tasks, holding information in mind (i.e. working memory), planning goals and anticipating future events, organizing materials, and monitoring one's own behavior are elements of the MI (Roth, Isquith, & Gioia, et al., 2005). While I conducted analyses examining all domains of executive functioning, it was thought that the MI would be the greatest predictor of adherence among YBMSM and also the domain most affected by marijuana use.

Sociodemographic data was also collected. This data included whether participants had been homeless in the past 12 months, whether they had ever been to jail, their student status, employment status, health coverage, and other drug use.

Method

The first relationship I examined was the relationship between marijuana use and executive functioning Second, I examined the relationship between marijuana use and HIV serostatus. Third, I looked to see if there was a relationship between executive functioning and HIV serostatus. Fourth, I conducted a mediation analyses to determine the role of executive functioning and marijuana use and their relationship with HIV serostatus.

The data analysis tool R-Studio was used for all analyses. Linear regressions were used to determine the relationships between marijuana use frequency and executive function composites and subdomains. Logistic regressions were used for binary outcomes, specifically marijuana's impact on HIV serostatus and executive functions' impact on HIV serostatus. Secondary models were created that adjusted for covariates recognized in relevant literature. Analyses with $p < 0.05$ were considered to be statistically significant, and slopes, 95% confidence intervals, and odds ratios were reported.

Results

Sample Characteristics

The overall sample included 506 YBMSM with an average age of 23 years old (SD = 3.1). Of those, 73% had smoked marijuana in the past six months, with 32% of those reporting heavy, daily use. 37% of YBMSM surveyed tested positive for HIV. Nearly 30% of the sample were unemployed, close to 43% did not have any form of health insurance, 25% reported having been homeless in the past twelve months, and 46% reported having been incarcerated at least once. After running chi-square analyses to test for associations between marijuana use and population characteristics, marijuana use was found to be significantly associated with employment ($p = 0.031$), homelessness ($p = 0.003$), incarceration ($p < 0.001$), and other drug use including ecstasy ($p < 0.001$), poppers ($p = 0.049$), and cocaine ($p = 0.032$). Analyses could not be run for associations between heroin, psychedelic, methamphetamine, and other drug use due to small sample sizes.

Table 2: Sample characteristics

Attributes	**Marijuana Use Frequency**[1]				
	Never n (%)	**Light n (%)**	**Heavy n (%)**	**(*p*)**	**Total Respondents n (%)**
Total Participants	137 (27.1)	208 (41.1)	161 (31.8)	--	506 (100.0)
Age M (SD)	22.8 (3.1)	23.0 (3.1)	23.2 (3.0)	0.517	23.0 (3.1)
HIV Serostatus				0.449	
HIV-	97 (30.8)	125 (39.7)	93 (29.5)		315 (62.3)
HIV+	40 (21.2)	83 (43.9)	66 (34.9)		189 (37.4)
Student Status				0.094	
Not a Student	96 (28.2)	128 (37.7)	116 (34.1)		340 (67.2)
Part-time	10 (20.0)	22 (44.0)	18 (36.0)		50 (9.9)
Full-time	31 (26.7)	58 (50.0)	27 (23.3)		116 (22.9)
Unemployed				0.031*	
No	100 (27.5)	160 (44.0)	104 (28.6)		364 (71.9)
Yes	37 (26.1)	48 (33.8)	57 (40.1)		142 (28.1)
Homeless[2]				0.003**	
No	105 (27.9)	168 (44.6)	104 (27.6)		377 (74.5)
Yes	32 (25.2)	40 (31.5)	55 (43.3)		127 (25.1)
Jail Ever				< 0.001***	
No	98 (36.2)	107 (39.5)	66 (24.4)		271 (53.6)
Yes	39 (16.7)	100 (42.7)	95 (40.6)		234 (46.3)
Insurance Coverage				0.878	
No	60 (27.8)	86 (39.8)	70 (32.4)		216 (42.7)
Yes	73 (26.2)	117 (42.0)	89 (31.9)		279 (55.1)
Other substance use[2]					
Ecstasy				< 0.001***	

No	134 (29.3)	190 (41.5)	134 (29.3)		458 (90.5)
Yes	3 (6.3)	18 (37.5)	27 (56.3)		48 (9.5)
Poppers				0.049*	
No	132 (28.6)	186 (40.3)	144 (31.2)		462 (91.3)
Yes	5 (11.4)	22 (50)	17 (38.6)		44 (8.7)
Cocaine				0.032*	
No	134 (27.9)	199 (41.5)	147 (30.6)		480 (94.9)
Yes	3 (11.5)	9 (34.6)	14 (53.6)		26 (5.1)
Heroin				--	
No	137 (27.2)	206 (41.0)	160 (31.2)		503 (99.4)
Yes	--	2 (66.7)	1 (33.3)		3 (0.6)
Psychedelics				--	
No	137 (27.4)	207 (41.3)	157 (31.3)		501 (99.0)
Yes	--	1 (30.0)	4 (80.0)		5 (1.0)
Methamphetamine				--	
No	137 (27.5)	205 (41.2)	156 (31.3)		498 (98.4)
Yes	--	3 (37.5)	5 (62.5)		8 (1.6)
Prescription Pain Drugs				0.9704	
No	131 (27.2)	198 (41.1)	153 (31.8)		482 (95.3)
Yes	6 (250.0)	10 (41.7)	8 (33.3)		24 (4.7)
Other Drugs				--	
No	137 (27.4)	205 (40.9)	159 (31.8)		501 (99.0)
Yes	--	3 (60.0)	2 (40.0)		5 (1.0)

[1]In past 6 months
[2]In past 12 months
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Influence of Marijuana Use on Executive Functioning

Means and standard deviations for each executive functioning domain are as followed: inhibition (M = 11.369, SD = 3.00), shift (M = 8.261, SD = 2.282), emotional control (M = 15.136, SD = 4.643), self-monitor (M = 8.471, SD = 2.599), initiation (M = 11.014, SD = 2.960), working memory (M = 11.035, SD = 3.033), plan/organize (M = 13.391, SD = 3.521), task-monitor (M = 7.971, SD = 2.100), organization of materials (M = 11.272, SD = 2.988), behavioral regulation index (M = 43.061, SD = 10.786), metacognitive index (M = 54.273, SD = 12.967), and global executive composite (M = 97.091, SD = 22.890).

After employing a linear regression using heavy marijuana use as the reference category for analyses, clear and significant relationships between the frequency of marijuana use and executive functioning were found; and results are displayed in Table 2. After adjustments for demographic and psychiatric variables, those who reported never having used marijuana showed significantly less executive impairment for each subdomain of the BRIEF-A, with the exception of shifting which was slightly out of the range of significance (β= -0.558, p = 0.051, 95% CI [-1.102, 0.012]). Differences between light users and heavy users of marijuana were less pronounced. As was hypothesized, of the subdomains that showed significant differences between light users and heavy users, each was associated with the metacognitive index (β = -2.852, p = 0.045, 95% CI [-5.843, 0.048]), including initiation (β = -0.661 , p = 0.039, 95% CI [-1.251, -0.005]), working memory (β= -0.744, p = 0.019, 95% CI [-1.321, -0.090]), and organization of materials (β = -0.747, p = 0.021, 95% CI [-1.363, -0.102]).

Table 3: Influence of Marijuana Use Frequency on Executive Functions[1]

Executive Functions	Never				Light			
	Model 1 Slope CI [95%]	**Model 1 (*p*)**	**Model 2 Slope CI [95%]**	**Model 2 (*p*)**	**Model 1 Slope CI [95%]**	**Model 1 (*p*)**	**Model 2 Slope CI [95%]**	**Model 2 (*p*)**
Behavioral Regulation Index	-4.629 [-7.160, -2.098]	< 0.001***	-3.556 [-6.054, -0.830]	0.008 **	-1.479 [-3.739, 0.781]	0.199	-1.140 [-3.290, -1.263]	0.329
Inhibit	-1.451 [-2.146, -0.756]	< 0.001***	-0.956 [-1.636, -0.216]	0.009 **	-0.573 [-1.194, 0.049]	0.071	-0.364 [-0.948, 0.288]	0.250
Shift	-0.689 [-1.218, -0.160]	0.011*	-0.558 [-1.102, 0.012]	0.051	-0.257 [-0.730, 0.217]	0.287	-0.273 [-0.724, 0.238]	0.269
Emotional Control	-1.679 [-2.754, -0.603]	0.002 **	-1.128 [-2.198, -0.001]	0.046 *	-0.589 [-1.557, 0.380]	0.233	-0.385 [-1.307, 0.615]	0.435
Self-Monitor	-1.139 [-1.670, 0.494]	< 0.001***	-0.973 [-1.506, -0.254]	0.003 **	-0.365 [-0.895, 0.165]	0.180	-0.365 [-0.870, 0.220]	0.196
Metacognition Index	-5.980 [-9.025, -2.934]	< 0.001***	-4.693 [-7.888, -1.536]	0.004 **	-2.975 [-5.721, -0.230]	0.034 *	-2.852 [-5.483, 0.048]	0.045 *
Initiate	-1.408 [-2.086, -0.730]	< 0.001***	-1.188 [-1.902, -0.476]	0.001 **	-0.678 [-1.288, -0.068]	0.030 *	-0.661 [-1.251, -0.005]	0.039 *
Working Memory	-1.412 [-2.108, -0.716]	< 0.001***	-1.121 [-1.805, -0.385]	0.002 **	-0.847 [-1.473, -0.221]	0.008 **	-0.744 [-1.321, -0.090]	0.019 *
Plan/Organize	-1.394 [-2.209, -0.578]	< 0.001***	-1.138 [-2.002, -0.284]	0.010 *	-0.685 [-1.415, 0.044]	0.066	-0.602 [-1.328, 0.157]	0.115
Task-Monitor	-0.860 [-1.342, -0.378]	< 0.001***	-0.723 [-1.209, -0.204]	0.005 **	-0.314 [-0.749, 0.122]	0.158	-0.327 [-0.741, 0.136]	0.145
Organization of Materials	-1.275 [-1.970, -0.581]	< 0.001***	-0.877 [-1.610, -0.152]	0.020 *	-0.720 [-1.336, -0.090]	0.025 *	-0.747 [-1.363, -0.102]	0.021 *
Global Executive Composite	-10.066 [-15.519, -4.612]	< 0.001***	-7.974 [-13.472, -2.224]	0.006 **	-4.087 [-8.980, 0.806]	0.101	-4.105 [-8.720, 1.097]	0.104

[1] Heavy marijuana use used as reference category

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

- Model 1 represents differences in executive functions associated with marijuana use frequency without controlling for demographic and psychiatric variables
- Model 2 represents differences in executive functions associated with marijuana use frequency after controlling for age, serostatus, homelessness, employment status, imprisonment, education, student status, other drug use, insurance coverage, alcohol use frequency, depression, anxiety

Influence of Marijuana Use on HIV Serostatus

Table 4 displays the results of logistic regression analyses that aimed to determine the relationship between marijuana use frequency and HIV serostatus. Regressions revealed that heavy users were more likely to test positive for HIV than YBMSM who never smoked marijuana (OR = 0.587, 95% CI [0.360, 0.950]). However, after controlling for demographic and psychiatric variables, the relationship was no longer significant (p = 0.16).

Table 4: Influence of Marijuana Use on HIV Serostatus

Marijuana Use	**Serostatus**			
	Model 1 OR [95% CI]	**Model 1 (*p*)**	**Model 2 OR [95% CI]**	**Model 2 (*p*)**
Never	0.587 [0.360, 0.950]	0.0313 *	0.679 [0.439, 1.170]	0.165
Light	0.946 [0.622, 1.440]	0.794	1.083 [0.677, 1.740]	0.740

[1] Heavy Marijuana use used as reference category
* $p < 0.05$
- Model 1 represents differences in HIV serostatus associated with marijuana use frequency without controlling for demographic and psychiatric variables
- Model 2 represents differences in HIV serostatus associated with marijuana use frequency after controlling for age, homelessness, employment status, imprisonment, education, student status, other drug use, insurance coverage, alcohol use frequency, depression, anxiety

Influence of Executive Functioning on HIV Serostatus

Table 5 displays results from unadjusted and adjusted logistic regression analyses of the relationship between executive functions and HIV serostatus. Prior to adjustments, higher scores in the metacognitive index (OR = 10.015, CI 95% [1.000, 1.029]) and initiate subdomain (OR = 1.064, CI 95% [1.001, 1.132]) were significantly associated with seropositivity which was in accordance with my hypothesis. However, after adjusting for demographic and psychiatric variables, these relationships were no longer significant.

Table 5: Influence of Executive Functions on HIV Serostatus

Executive Functions	**Serostatus**			
	Model 1 OR [95% CI]	**Model 1 (*p*)**	**Model 2 OR [95% CI]**	**Model 2 (*p*)**
Behavioral Regulation Index	1.010 [0.992, 1.030]	0.300	1.004 [0.984, 1.024]	0.688
Inhibit	1.028 [0.967, 1.093]	0.372	1.016 [0.947, 1.092]	0.665
Shift	1.053 [0.972, 1.140]	0.199	1.048 [0.975, 1.147]	0.313
Emotional Control	1.016 [0.974, 1.059]	0.438	1.011 [0.974, 1.059]	0.647
Self-Monitor	1.007 [0.939, 1.079]	0.849	0.990 [0.916, 1.070]	0.801
Metacognition Index	1.015 [1.000, 1.029]	0.044*	1.012 [0.995, 1.029]	0.159
Initiate	1.064 [1.001, 1.132]	0.046*	1.055 [0.984, 1.132]	0.134
Working Memory	1.034 [0.974, 1.098]	0.270	1.028 [0.957, 1.103]	0.450
Plan/Organize	1.034 [0.982, 1.089]	0.201	1.025 [0.966, 1.087]	0.409
Task-Monitor	1.047 [0.960, 1.142]	0.294	1.038 [0.939, 1.147]	0.460
Organization of Materials	1.047 [0.985, 1.113]	0.137	1.030 [0.961, 1.105]	0.399
Global Executive Composite	1.007 [0.999, 1.015]	0.095	1.005 [0.995, 1.014]	0.337

* $p < 0.05$
- Model 1 represents differences in HIV serostatus associated with executive functions without controlling for demographic and psychiatric variables
- Model 2 represents differences in HIV serostatus associated with executive functions after controlling for age, homelessness, employment status, imprisonment, education, student status, other drug use, insurance coverage, alcohol use frequency, depression, anxiety

Discussion

Previous studies have looked at the negative impact marijuana use has on executive functioning; others have also looked at the impact marijuana use as well as executive functioning separately and together have on health behaviors. Few, however, have looked at these relationships in the context of overall HIV serostatus among YBMSM. I hypothesized that higher levels of marijuana use would impair executive functioning across all domains included on the BRIEF-A. Moreover, higher levels of marijuana use and higher scores (more negative) scores on the BRIEF-A were both thought to be associated a greater likelihood of being HIV seropositive. The MI was believed the index most likely affected by marijuana use, and therefore, the strongest predictor of HIV serostatus.

Data from this study suggests that heavy levels of marijuana use are associated with poorer executive functioning across all domains and indexes. While analyses did suggest that the MI was the index most closely associated with HIV serostatus, this relationship was insignificant. Overall, after controlling for demographic and psychiatric variables, analyses failed to find any significant relationships between marijuana use, executive functioning, and HIV serostatus. Thus, the hypothesis that marijuana use and executive are significantly associated with HIV serostatus among YBMSM was not supported by the data. These findings were unexpected given previous research has linked marijuana use and HIV care continuum outcomes (Maksut et al., 2016; Quinn et al., 2016; Hall et al., 2014; Ettenhofer et al., 2010; Brodbeck et al., 2006; Castilla et al., 1999) as well as executive functioning and high-risk sex behaviors (Reynolds et al., 2019; Dcruz, 2014; Hall et al., 2014; Magar et al., 2008). One potential reason that there appeared to be no significant relationship between marijuana use, executive functioning, and HIV serostatus despite previous studies suggesting clear links between substance use, executive functioning, and high-risk sex behaviors is that YBMSM face unique structural barriers.

There remains a need for interventions tailored to an individual's neuropsychological functioning and health behaviors (e.g. marijuana use), however, this research also raises the notion that structural forms of adversity (e.g. community violence, incarceration, unemployment, poverty, stigma, racism, access to care) exert significant influence on HIV outcomes in distinct geographic an racially diverse regions. Illuminating the interactions between environmental factors such is necessary for alleviating compounding disparities and informing health-promoting behavior. These relationships are likely characterized by complex transactions, cascades, and feedback loops between functional domains and health outcomes. For example, YBMSM who have been exposed to community violence may experience intrusive and distressing thoughts that impair their working memory, a core component of executive functioning. In turn, neurocognitive impairments resulting from community violence exposure may make YBMSM less likely to remember to take their medication and adhere to doctor's recommendations, thus preventing them from reaching viral suppression. Failing to reach viral suppression may result in lower self-efficacy. This may create a vicious cycle wherein lower self-efficacy results in further impairment of executive functions, further augmenting the risk of falling out of care. These feedback loops are important because they increase the threat posed by the initial experience, in this case, the exposure to violence. Needless to say, these interactions are multifactorial and difficult to extricate. Thus, research is needed to illuminate the pathways through which neurocognition, environmental context, and behavior interact and influence the health and wellbeing of YBMSM.

Limitations

This study has a few limitations that suggest the need for future research. First, there is a question as to whether the measures used were sensitive enough to detect associations with HIV serostatus given the array of SES issues and the intersection of contextual variables that also influence executive functions and are associated with higher rates of marijuana use. Without a larger sample, it is challenging to know what drives health disparities in this population. Prior to controlling for these variables psychiatric and environmental variables, significant differences in HIV serostatus did exist when comparing heavy marijuana users to light users. Moreover, as was expected, the metacognitive index was associated with HIV serostatus before taking into account contextual factors. Because of the many potential relationships that could exist between structural barriers, executive functioning, marijuana use, and serostatus, it's hard to identify specific mediators and moderators. Correcting for this would require larger longitudinal studies that assess factors such as community violence, poverty, incarceration, trauma, and other potential mediators that influence health maintenance.

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