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Social Cognitive Influences on HIV vs. STI Testing Behaviors

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Abstract

Background. Rates of common bacterial sexually transmitted infections (STIs) are at an all-time reported high in the United States, while rates of new human immunodeficiency virus (HIV) infections are declining. Among HIV-negative men and transgender women who have sex with men, whom are theoretically at risk for both HIV and bacterial STI infection, more than twice as many individuals report being tested for HIV in the last year than report being tested for other STIs. Understanding the factors that influence HIV testing and how those factors differ from those that influence STI testing could help explain this disparity in testing rates. The present study proposes a social cognitive model of HIV and STI testing behavior based on Social Cognitive Theory. *Method.* Participants were HIV-negative adults who endorsed male assigned sex at birth and identify as a sexual or gender minority (n = 164) who completed a health needs survey in a region where HIV and STI rates are among the highest in the nation. Structural equation modeling was used to test the proposed social cognitive model separately with HIV and STI testing outcomes. Several additional models specified in advance were also tested using the same procedure. *Results.* The social cognitive model and all *a priori* modifications to it were found to be poor fits for both HIV and STI testing outcomes. *Post hoc* models were created in response to these results and tested in the same manner. All *post hoc* models were also found to be a poor fit for both HIV and STI testing outcomes. *Conclusions*. Analyses failed to identify social cognitive models that were a good fit for either HIV or STI testing behavior. The study suffered from several limitations, including being underpowered, significantly limiting the interpretation of the statistical results. These limitations are discussed and recommendations are made for future studies that intend to use theoretical models to understand the differences in HIV and STI testing behaviors.

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Introduction

Bacterial sexually transmitted infection (STI) rates have been increasing in the United States (US) in recent decades. Combined cases of syphilis, gonorrhea, and chlamydia reported in 2018 marked an all-time high (Centers for Disease Control and Prevention [CDC], 2019c). These infections have been mostly curable since the advent of penicillin in the 20th century, although antibiotic-resistant strains are becoming increasingly common and are considered an urgent public health threat (CDC, 2019a; Unemo & Nicholas, 2012). Moreover, if untreated, these infections can cause severe health problems including infertility and blindness (CDC, 2019b). These infections can also present asymptomatically, potentially leaving many infected individuals unaware of their infections and at risk of spreading them to others (CDC, 2019b). The increase in reported rates of STIs, though in some part possibly due to the development of better testing technology and wider availability of testing, demonstrates how widespread these infections are.

In contrast to STIs, while human immunodeficiency virus (HIV) remains a significant health problem, new rates of HIV infections in the US are decreasing, even among groups who were seeing increasing rates only a few years ago (e.g., young men who have sex with men; CDC, 2018b). There is some overlap in behaviors that heighten the risk for acquiring HIV and for acquiring other STIs, and active STIs also increase the risk of becoming infected with HIV (Fleming & Wasserheit, 1999; Gross & Tyring, 2011). Groups at the highest risk for HIV infection have increasingly reported being recently tested for HIV (Pitasi et al., 2018). Yet, there is evidence that STI testing rates have not increased accordingly. Only 23.9% of men who have sex with men (MSM) in one study endorsed not being tested for HIV in the previous 12 months (Reilly et al., 2014) while nearly twice as many (45.8%) report that they had not been tested for other STIs in the previous 12 months (Grey, 2013). Rising rates of bacterial STIs, increased antibiotic resistance, potentially dangerous health outcomes including increased risk for HIV infection, and the potential for infections remaining undetected, indicate an urgent need for STI prevention efforts similar to efforts that have focused on HIV prevention.

Ever since research demonstrated conclusively that HIV-positive individuals on successful antiretroviral therapy are at substantially (92%-96%) reduced risk of transmitting the virus, treatment has become a key component of HIV prevention (Hull & Montaner, 2013). Identifying and treating HIV infections early has joined safer sex messaging and the prophylactic use of antiretroviral drugs as prominent strategies to reduce rates of HIV infection (Baeten & Grant, 2013; CDC, 2016d; Grant et al., 2010; Hull & Montaner, 2013). There is evidence that a similar focus on treatment as prevention (TasP) can be an effective strategy with other STIs as well (Whitlock et al., 2018). Just as testing is a critical component of HIV TasP, STI testing can play a key role in preventing the spread of these infections by identifying cases early and enabling them to be treated.

Though most HIV infections are spread through sexual contact, for historic, political, and logistical reasons, the infrastructure to identify HIV infections developed separately from the extant STI testing paradigm (CDC, 2018b; Institute of Medicine, 2011; Scott, 2003). This separate infrastructure is likely responsible for some of the disparity between testing numbers in the same at-risk populations. Comprehensive testing for bacterial STIs can require samples of blood and urine and may require rectal and pharyngeal swabs, depending on an individual's risk profile (Gross & Tyring, 2011). HIV testing, on the other hand, can often be done with a rapid pin-prick test that can be administered by non-clinical staff in non-clinical settings (CDC, 2016b). Being tested for other STIs may include being tested for HIV (Thornton et al., 2012), but being tested for HIV at a public event or using a self-test kit does not offer the possibility of being tested for other STIs at the same encounter.

For example, a gay man who chooses to engage in condomless anal sex with multiple male partners and is regularly tested for HIV, may never consider the need for an STI test even if he is infected. Unless he experiences symptoms that alert him to a possible infection, this man may experience a false sense of security regarding his risk for STIs. Despite being conscientious about HIV testing, at-risk individuals could still be unconsciously spreading STIs to their partners. From the standpoint of prevention, those who know they are at elevated risk for HIV need to know they are also at risk for other STIs. If they have primarily accessed HIV testing in non-clinical settings, they may need to consider adding STI testing from an appropriate clinic to their sexual health regimen, and either consolidating their HIV and STI testing or supplementing HIV tests provided in non-clinical settings with clinical STI testing.

Understanding the observed disparities in current HIV and STI testing rates is an important area of research that can inform future interventions intended to reduce rates of new STI infections through promoting testing and treatment. Such interventions would be the most impactful and are thus most needed in communities with particularly high rates of HIV and other STIs. One such region, the Central Savannah River Area (CSRA) region of the Southeastern US, has some of the highest rates of HIV and other STIs in the nation (CDC, 2018b, 2019b). Stepleman et al. (2019), in a community health needs assessment that surveyed sexual and gender minority individuals in this region, found that more than half the survey respondents (56.10%) who identified as gay or bisexual men or transgender women endorsed having an HIV test in the past year. Yet, the same survey found a substantially smaller proportion (36.59%) endorsed being tested for other STIs in the same period. Only 10.98% of this sample had never been tested for HIV, while more than twice that number (23.17%) had never been tested for other STIs (Stepleman et al., 2019).

The present study intended to address the larger question of why, in a population at risk for both HIV and other STIs, individuals are not getting tested for STIs as frequently as for HIV. It intended to do so by a) considering factors that might motivate HIV testing behavior, b) factors that might motivate STI testing behavior, c) differences in which factors influence which behaviors and, d) when the same factors influence both outcomes, differences in interactions between factors. After a brief discussion of terminology, we will review extant literature on factors that influence HIV and STI testing. This will be followed by a more detailed description of the study's aims, a description of the development of the social cognitive model of HIV and STI testing, and hypotheses. Details of the study's methodology and a description of the analytical approach will be presented next. Finally, statistical results will be presented followed by an interpretation and discussion of those results, limitations of the study, and areas for future research.

Terminology

A few words are warranted on the use of certain terms in the present study and how they relate to previous research. This background should facilitate the interpretation of this study's results in the context of prior research cited.

Orientation, Identity, and Behavior

There is no consensus in the scientific community about the best way to operationalize sexual and gender identities, orientation, and behavior (Eliason, 2014). A number of terms have been used historically to refer to individuals who identify as either male or female and are attracted to other males or other females. Examples of such terms include gay, lesbian, bisexual, homosexual, and queer. These words constitute identities and are used by individuals to describe themselves, though in common parlance, they are often used to describe others based on their observed or assumed sexual behavior. Other terms have been used at various times to describe different aspects of biological sex, and—when recognizing the cultural construction of gender—gender identity, and gender expression. Some of these, like “transgender” or “transsexual,” often (but not always) rely on the notion that there are two distinct genders. Others, like “gender non-conforming” or “gender queer” are intended to transcend or deny the traditional binary conceptualization of gender (Fiani & Han, 2019).

Both non-heterosexual and gender non-conforming identities are included in common acronyms such as LGBT (lesbian, gay, bisexual, transgender), LGBTQ (lesbian, gay, bisexual, transgender, queer), or LGBTQQAI (lesbian, gay, bisexual, transgender, queer, questioning, allies, intersex; Eliason, 2014). These acronyms are sometimes used with the intent to be inclusive of all non-heterosexual and non-cisgender identities (Eliason, 2014). They are also frequently used to describe a loosely defined “community” united through physical spaces, social spaces, political causes, or simply differentness (Formby, 2017). Although Petrow (2014) refers to an LGBTQ “community” in passing, his dissection of the acronym itself does not render for the reader a clear picture of what is actually meant by “community” in this context.

For consistency, the present study uses the phrase “sexual and gender minority” to refer to any individual who does not identify as cisgender male or female (whose gender identity is male or female and matches the sex they were assigned at birth) and/or who does not identify as heterosexual or “straight.” When sexual behavior between males alone is relevant, such as when identifying risk groups, the term MSM is used irrespective of the sexual identities that may be represented.

Literature cited herein refers to populations with various combinations of biological sex, gender identity, sexual identity, sexual behavior, and cultural communities. Citing these studies side by side is not intended to convey an equivalence in the populations studied. When citing this literature, the original terms used are replicated here for precision. Findings in a paper that studied “gay men” may or may not apply to “the LGBT community” and may or may not generalize to “MSM,” depending on the details of the study. Any literature review including studies of these overlapping, but distinct populations is fraught with the potential to include studies with results that may be relevant to the present study but also difficult to compare with one another.

Sexually Transmitted Diseases and Infections

There is an ongoing dialog in the literature regarding whether sexually transmitted diseases (STDs) is a more appropriate term to describe STIs (Handsfield, 2015; Rietmeijer, 2015). The primary advantage of the term STD is historical use, while STI is broadly considered less stigmatizing (Handsfield & Rietmeijer, 2017). The present study will use the term STI, while some works cited may use the term STD to refer to the same concept.

There are more than 30 known bacteria, viruses, and other parasites that are known to be sexually transmissible (Gross & Tyring, 2011; World Health Organization, 2019). The present study is mainly concerned with the bacterial STIs gonorrhea, chlamydia, and syphilis, because they are common, increasing in incidence, curable, and commonly tested for (CDC, n.d., 2019c). When this study makes claims about STIs and STI testing, the claims may or may not apply to all STIs but are intended to be accurate as it concerns these three specific bacterial STIs.

The focus on these three bacterial STIs is not intended to identify them as the only STIs that represent a health risk for MSM. For example, human papillomavirus (HPV) infection can cause anogenital warts and make certain cancers, such as anal cancer, more likely, especially in HIV-positive individuals (CDC, 2016c; Mann et al., 2019). HPV infections are frequently asymptomatic but can be tested for in men using an anal pap test (CDC, 2016c). However, as the most common STI, most sexually active adults who are not vaccinated against HPV will get infected with HPV during their lifetimes (CDC, 2016c). Moreover, there are no current recommendations for testing for HPV infections before there are signs or symptoms and there are no specific treatments for HPV infection itself (CDC, 2016c). Herpes simplex virus (HSV) infections (including the variants HSV-1 and HSV-2) are also common among sexually active adults and are also frequently asymptomatic. However, like HPV, HSV is not included in most routine STI testing. HSV is most commonly diagnosed by sight only, and only when symptoms present (CDC, 2017). For this reason, HSV is excluded from the present analysis despite availability of treatments for HSV symptoms that also reduce risk of transmission (CDC, 2017).

Sexual Risk

Terminology related to sexual risk provides another opportunity for imprecision and confusion (Kraemer et al., 1997; Marcus & Snowden, 2020). What constitutes risk as it pertains to the acquisition of HIV and other STIs is entirely dependent on a variety of contextual factors that are not always considered in research that intends to study these risks. With modern biomedical treatments for HIV and pre-exposure prophylaxis (Cairns, 2012; CDC, 2018a; Cohen & Gay, 2010; Dieffenbach & Fauci, 2009; Grant et al., 2010; Harper, 2016; Hull & Montaner, 2013; San Francisco AIDS Foundation, 2014; Thigpen et al., 2012; Volk et al., 2015), anal sex without a condom can be at least as safe as anal sex with a condom, depending on other contextual factors, when considering HIV alone (Fonner et al., 2016; Smith et al., 2015). The same behavior may or may not put one at risk for one or more other STIs, which do not all share a single route of transmission and which are thus not all mitigated by the same safety measures (Gross & Tyring, 2011).

Literature Review

High rates of HIV testing among MSM and decreasing rates of new HIV infections (CDC, 2018b; Finlayson et al., 2011) suggest that public health efforts to promote HIV testing have been successful. To similarly promote and increase STI testing, it is necessary to understand the factors that may separately influence STI and HIV testing behaviors. Just as HIV and other STIs have shared risk factors, both domains appear to be influenced by some of the same intrapsychic and interpersonal factors and in similar ways. Yet, HIV and STI testing behaviors are usually studied separately and few studies have directly examined the similarities or differences in how these factors may differentially influence HIV and STI testing. Table 1 provides a comparison of literature reviewed in this section and the domains they cover compared to the domains covered by the present study.

Factors Influencing STI Testing

Grey (2013) conducted an online survey of MSM to evaluate internet methodologies for obtaining reliable measures of sexual behavior and STI testing and to use these validated methods to examine correlates of having had an STI test in the previous 12 months. This study identified several variables associated with being tested for STIs in the past year, including age, education, annual income, city residence, and openness with others about their sexual orientation, HIV status, and recent sexual partners. Younger men, and those who endorsed some college education but no college degree, were more likely to have recent STI tests. The findings of this study, however, may be limited to college students, who may receive targeted messaging from campus organizations and free healthcare. Recent STI tests were also more likely among men that were more open about their sexual orientation and resided in urban areas, suggesting that shame or social isolation may deter testing. HIV-positive individuals were more likely to be tested for STIs than HIV-negative individuals, likely because the standard of care for HIV-positive individuals who are sexually active includes regular STI testing (Workowski & Bolan, 2015). Finally, having a sexual partner in the past three months predicted more recent testing; sexual health is likely not as salient among individuals when they are not sexually active. These findings demonstrate that many domains can influence STI testing behavior, including demographics, personal cognitive factors, social factors, and environmental factors.

De Visser and O'Neill (2013) conducted a mixed-methods study of university students in the United Kingdom and identified other factors that influenced STI testing behavior and intentions to be tested, including both descriptive norms (i.e., one's perceptions of how peers are actually behaving) and injunctive norms (i.e., the behavior that one's peers promote or endorse). This study also explicitly identified shame as a factor that deters STI testing. As expected, past testing behavior and perceived risk of infection influenced intentions to be tested. Injunctive, but not descriptive norms, as well as greater openness to sharing one's sexual history also influenced intentions to be tested, highlighting the role that community and other social factors play in influencing testing behaviors. Qualitative interviews with a subsample of participants identified themes of vulnerability to infection, community norms, shame, and ease of testing, which further supported quantitative results.

Factors Influencing HIV Testing

Studies of HIV testing behavior identify many factors similar to those found to influence STI testing. For instance, younger age is also associated with increased HIV testing (Reilly et al., 2014). Perceived risk, too, has been consistently associated with HIV testing, although with more qualifications than with STI testing. Notably, there is evidence that perceived risk can both motivate and deter testing (de Wit & Adam, 2008; Lorenc et al., 2011). Perceiving oneself at risk can motivate testing, but fear of testing positive for HIV and the personal and social consequences of being diagnosed can demotivate testing. Put another way, not knowing one's status might motivate testing to find out and receive treatment if needed, but *not wanting to know* one's status can deter testing (de Wit & Adam, 2008; Feinstein et al., 2017; Lorenc et al., 2011; Mustanski et al., 2014). Given these findings, risk perception alone is not likely to be a useful predictor of HIV testing behavior. This aspect of risk perception highlights how negative outcome expectancies, discrimination, and fear of rejection influence HIV testing behavior (de Wit & Adam, 2008). Although expecting positive outcomes from testing is motivating, it is only weakly associated with HIV testing (de Wit & Adam, 2008). These results make it clear that to understand HIV testing behaviors, it is crucial to understand the social context of these behaviors, including the social meaning given to these behaviors and the social consequences of testing positive.

Other findings again highlight the salience of cognitive, behavioral, and environmental factors when considering what influences HIV testing. In the cognitive domain, Lorenc and others (2011) found that a sense of responsibility for caring for the health of oneself or one's partner motivates HIV testing more consistently than the presence or absence of risk behaviors. Among MSM, openly identifying as gay is associated with more frequent testing and *not* identifying as gay is associated with less frequent testing (Reilly et al., 2014). Behaviorally, not seeing any healthcare provider in the previous year was found to predict less HIV testing (Reilly et al., 2014). In terms of environmental factors, individuals were more likely to obtain HIV testing when it was confidential, based in their community, and from service providers who were gay-positive and nonjudgmental (Lorenc et al., 2011).

Theoretical Models

Explanations of human behavior are most useful when based on theoretical models, especially those which have been demonstrated to be useful in similar domains. Social cognitive models of health behavior include a range of theoretical models that examine individual (personal cognitive and behavioral) as well as interpersonal (social and environmental) factors. Previous research has used social cognitive theories to model HIV testing intentions. Several studies, for example, have demonstrated the explanatory power of two social cognitive models, the Theory of Planned Behavior (TPB; Ajzen, 1991) and the AIDS Risk Reduction Model (Catania et al., 1994) on HIV testing intentions (Ayodele, 2017; Mirkuzie et al., 2011; Mo et al., 2018; Salud et al., 2014). Similarly, many studies in the STI testing literature demonstrate that TPB and other social cognitive models can help to explain STI testing intentions (Booth et al., 2014; Dillow & Labelle, 2014; Powell et al., 2016; Wombacher et al., 2018). Regarding behavioral outcomes, Mirkuzie and others (2011) did not find that TPB explained HIV testing behavior despite its success predicting intentions (Mirkuzie et al., 2011).

While no study to date has similarly examined STI testing outcomes using a theoretical model, Wilkerson and others (Wilkerson et al., 2014) examined HIV and STI testing outcomes together by using logistic regression to test a social cognitive model of testing behaviors. Because it collapsed STI and HIV testing into a single outcome, however, it was not able to explain differences in testing rates. Adam and others (2014) considered HIV and STI testing outcomes separately from a social cognitive perspective and was able to make some comparisons. Several differences were identified, including that knowledge of HIV and perceived severity of becoming infected with HIV were associated with more regular/recent HIV tests, whereas knowledge of STIs and perceived severity of contracting one were not associated with STI testing behaviors (Adam et al., 2014). Age (e.g., being over the age of 26 years) was among two demographic factors most associated with more regular HIV and STI testing (Adam et al., 2014; Wilkerson et al., 2014).

The other significant demographic factor was having a university degree, which influenced HIV but not STI testing (Adam et al., 2014). Studies that looked at HIV and STI testing separately found that completing a university degree was associated with more HIV testing (Reilly et al., 2014) but less STI testing (Grey, 2013). These discrepant findings indicate an opportunity for more research to clarify how education affects testing behaviors. While Adam and others (2014) compared social cognitive influences, this study did not endorse any particular theory or test a statistical model. Moreover, data were gathered from two separate samples, one for STIs and one for HIV. Models of HIV and STI testing based on an appropriate theory of health behavior and tested statistically using data from one sample could greatly enrich our current understanding of what factors influence these behaviors and highlight differences among these factors.

Summary

In sum, many studies have separately explored various factors that influence HIV or STI testing behaviors. Other studies have hypothesized that certain social cognitive models of health behavior explain HIV or STI testing intentions. One study that looked at HIV testing outcomes found a model based on TPB to be a poor predictor of HIV testing behavior. No studies, however, have examined STI testing behavior using a theoretical model. One study has tested a social cognitive model of testing behavior but collapsed HIV and STI testing into one outcome.

Only one study has compared influences on HIV and STI testing behaviors from a social cognitive perspective; however, it did not propose or test any statistical model.

No study to date has proposed and tested theoretical models of both HIV and STI testing behavior using data from the same sample. Disparities in rates of HIV versus STI testing in the same populations suggest that real differences in motivating factors exist. Studying factors that influence STI and HIV testing within the same sample avoids confounds inherent in comparing studies that use different samples and methodologies. Understanding these factors within the same sample may offer a nuanced view of STI testing behavior as similar to, but not the same as, HIV testing behavior and would highlight where STI prevention efforts may most effectively target interventions to increase STI testing.

Social Cognitive Theory

One social cognitive theory, the aptly named Social Cognitive Theory (SCT; Bandura, 1986) was applied to HIV prevention behavior early in the pandemic by its originator (Bandura, 1990, 1992). SCT represents a broad learning theory frequently used for understanding the initiation and maintenance of health behaviors (Bandura, 1998). SCT explains how people acquire and maintain behaviors based on “reciprocal determinism”—the continuous reciprocal interaction of cognitive factors (e.g., affect, knowledge, and attitudes), environmental factors (e.g., access to health care or peer behavior), and behavioral skills (e.g., partner communication, or negotiating condom use). In the cognitive domain of SCT, one of the key factors believed to predict HIV prevention and other health behaviors is self-efficacy, which describes an individual’s beliefs regarding how effectively they can execute a particular task (Bandura, 1990).

As of 2007, more than half of the sex and HIV education interventions targeted at those aged 25 years or under and many of the most effective evidence-based interventions for HIV prevention have been based on SCT (Kirby et al., 2007; Lyles et al., 2007). More than a quarter of the evidence-based interventions for HIV prevention among MSM and transgender women listed with the CDC since 2007 have also been based on SCT; another third are based on the Information-Motivation-Behavioral Skills model, another social cognitive model which is frequently used with HIV prevention but has not previously been applied to HIV or STI testing behaviors (HIV/AIDS Prevention Research Synthesis Project, 2020). The widespread adoption of social cognitive models reflects a great deal of evidence that they do well explaining HIV prevention (Dilorio et al., 2000) including HIV and STI testing. SCT was chosen over other social cognitive models for use in this study because of its early successful application to HIV prevention and its prominence among effective evidence-based HIV prevention interventions (Bandura, 1990, 1992; HIV/AIDS Prevention Research Synthesis Project, 2020; Kirby et al., 2007; Lyles et al., 2007).

Study Aims

The goal of the present study is to help explain why individuals at risk for both HIV and other STIs are being tested for HIV more frequently than other STIs by considering the different social cognitive factors that influence HIV versus STI testing behaviors. Specifically, this study aimed to accomplish this goal by a) describing a model of social-cognitive factors that theoretically might influence or that are known to influence HIV or STI testing behavior; b) statistically evaluating this model separately for HIV and STI testing outcomes, with the aim of assessing if the way the proposed model predicted HIV testing outcomes differed from the way it predicted STI testing outcomes; and c) if so, to describe and explore these differences.

A Theorized Social Cognitive Model of Testing Behavior

To address the first study aim, this study proposed an SCT-based model of HIV and STI testing behavior ("the social cognitive model of HIV and STI testing behavior," "the initial model," or "the model"), depicted in Figure 1. The review of literature has demonstrated various factors that have been found to influence HIV and STI testing behavior in various populations. The social cognitive model of HIV and STI testing behavior was developed using a data set including survey responses from MSM and transgender women (see *Method* below) and includes constructs represented in that data set that were chosen based on the following considerations: a) empirical support informed by the review of the factors found previously to influence HIV and STI testing behavior in various populations; b) theoretical support based on SCT; c) amount of variance represented in the data set for the construct; and d) the amount of data missing from the data set for the construct. Constructs with more empirical support, more theoretical support, more variance, and fewer missing data points were preferred when developing the model. The ten final constructs included in the model are described below, grouped by their inclusion in the cognitive, behavioral, or environmental SCT domains.

Cognitive Factors

Depression. While no previous research links depression with HIV or STI testing outcomes, there is evidence that depression is linked with self-efficacy. It is not clear if depression precedes lower self-efficacy or if self-efficacy leads to depression (Bandura et al., 1999; Kavanagh & Bower, 1985). Either way, depression is theoretically one cognitive factor that could influence HIV and STI testing behaviors.

Internalized Stigma. Many thoughts and beliefs about the self may be relevant to HIV and STI testing. Among sexual and gender minority individuals or MSM more broadly, cognitions about sexual orientation, gender identity, or sexual behavior may affect testing behavior (Pyun et al., 2014). Internalized stigma against sexual minorities, commonly called internalized homophobia, describes the internalization of societal stigma against same-sex attraction and behavior by individuals with same-sex attraction or sexual behavior (Berg et al., 2016). Internalized homophobia has been linked to less HIV and STI testing behavior (Pyun et al., 2014).

Community Identity. Previous research that found MSM who did not identify as gay (e.g., bisexual men) are less likely to have had a recent HIV test (Reilly et al., 2014) hypothesized that this may be because these individuals are less aware of the need for frequent HIV testing. Based on this theory, lower testing rates may be explained by their disconnection from the LGBTQ+ community and health messaging targeted to that community. For example, a man who has sex with other men but does not engage socially with them or visit bars or other establishments that cater to gay men is less likely to encounter messaging related to HIV testing that is targeted towards gay men.

Behavioral Factors

Utilizing outpatient healthcare. While HIV testing is routinely performed in outpatient clinics, as noted previously, HIV testing in non-clinical settings is also quite common (CDC, 2016b). MSM who visit social establishments catering to that population may be tested for HIV in both clinical and non-clinical environments, or even exclusively non-clinical environments. Being tested for other STIs, on the other hand, often requires interfacing with an outpatient medical clinic of some kind (Gross & Tyring, 2011). Someone who regularly visits such clinics demonstrates an ability to make use of these resources and a history of doing so.

Use of PrEP. PrEP refers to the taking of antiretroviral medication to prevent HIV infection (Grant et al., 2010). It is vital to ensure people taking antiretrovirals prophylactically remain HIV-negative; the prophylactic medication is not enough to control an active HIV infection (CDC, 2018a). Clinical practice guidelines recommend that patients on PrEP be seen at least every 3 months for HIV testing. These guidelines also recommend that those with symptoms of an STI or any MSM who has had syphilis, gonorrhea, or chlamydia at prior visits or who have multiple sex partners receive STI testing as well (CDC, 2018a).

Condom use. Engaging in anal intercourse can put an individual at elevated risk for HIV and other STIs. Individuals who perceive anal sex as risky for HIV acquisition may use condoms or other preventative measures (such as PrEP) to mitigate their risk (Grant et al., 2010; Smith et al., 2015). Perception of HIV risk may also be influenced by partner characteristics, when those characteristics are known to mitigate HIV risk (e.g., an HIV-positive partner with an undetectable viral load or an HIV-negative partner who is taking PrEP; Cohen & Gay, 2010; Grant et al., 2010). HIV risk also differs for the insertive versus the receptive partner during anal intercourse (Jin et al., 2010). The details regarding differential risk are not widely disseminated in popular safer sex messages (e.g., Johns Hopkins Medicine, n.d.; New South Wales Health, n.d.), and partner characteristics are not always known. In these contexts, use of a condom during anal sex represents a behavioral skill as it pertains to mitigating HIV risk. PrEP use and partner characteristics regarding HIV status and prevention behavior do not affect STI risk, so condom use during anal sex still represents a behavioral skill pertaining to mitigating STI risk, except when an individual is in a monogamous relationship with an STI-free and faithful partner.

Use of condoms could relate to HIV and STI testing behavior in multiple ways. Conscientiousness about HIV and STI prevention behavior could be paired with increased testing behavior. Confidence that one’s risk mitigation strategies were effectively protecting from infection, on the other hand, might motivate less testing behavior. In the case of STIs, symptomatic STI infections that may result from less condom use might motivate STI testing. However, gonorrhea and chlamydia can be spread through oral sex, and using condoms reduces but does not remove risk, so symptomatic infections are not necessarily related to condom use (CDC, 2020). Condom use is an imperfect measure of behavioral skills that might relate to HIV and STI testing, but there remain many ways it could be relevant to either.

Environmental Factors

Having health insurance and a primary provider. Being covered by health insurance, having a regular place of care, and receiving optimal primary care from that place of care are all predictive of receiving preventive care (Bindman et al., 1996).

Providers who discriminate or are not adequately trained. Not being able to speak comfortably with a provider about matters of sexual health discourages STI testing among MSM (Mimiaga et al., 2007) and MSM express a preference for HIV testing services to be community based, non-judgmental, and gay-positive (Lorenc et al., 2011). If a region lacks competent providers who can discuss sexual health with sexual and gender minorities in a non-judgmental manner, individuals may be more reluctant to seek testing.

Relationships between variables

Constructs included within the cognitive, behavioral, and environmental domains are expected to be related to each other. Consistent with reciprocal determinism as proposed by SCT, bidirectional relationships are also expected between the cognitive, behavioral, and environmental domains. The model also includes expected interrelationships between certain predictor variables across SCT domains. The first of these is a relationship between internalized stigma and condom use. Internalized stigma has been found to be correlated with more and less condom use (Dawson et al., 2019; Huebner et al., 2002). The second is a relationship between

LGBTQ+ community identity and having ever used PrEP; more LGBT community involvement is associated with higher probability of PrEP uptake and adherence (CDC, 2018b, 2019b). Depression is associated with higher healthcare utilization (Moraska et al., 2013; Snell et al., 2014); this is the basis for the model's inclusion of a relationship between depression and outpatient clinic utilization. Depression is also associated with less consistent use of condoms for penetrative sex (Brawner et al., 2012; Wagner et al., 2011); the model therefore includes a relationship between depression and condom use.

Hypotheses

At the outset of the study, it was hypothesized that the initial proposed model would not be found to be a good statistical fit for both HIV and STI testing outcomes. It was also expected that after any modifications to the initial model, the two models found to be good statistical fits for predicting HIV testing behavior and for predicting STI testing behavior would contain different predictors and/or would demonstrate different relationships between these predictors.

Method

Overview

The present study used Structural Equation Modeling (SEM; Kline, 2016; Ullman & Bentler, 2013) to test the social cognitive model of STI and HIV testing behavior. These models were tested using data from a health needs survey conducted among sexual and gender minority individuals in the CSRA, a geographic area including parts of Georgia and South Carolina (Stepleman et al., 2019). Consistent with the aims of the study and the expectation that the initial model would not be a good statistical fit for both HIV and STI testing outcomes, two sets of modifications were also proposed before the main statistical analyses proceeded. These modifications specified a series of additional models that could be tested for each behavioral outcome, in sequence, until one was found to be a good fit. These proposed modifications are detailed below in the *Alternate Models* section. Additional models were created and tested *post hoc,* based on the results of the original analyses and supported by theory and extant literature. These models are detailed below in the *Results* section. After testing all models, the model that fit the data to predict STI testing behavior was intended to be interpreted alongside the model that fit the data to predict HIV testing behavior, with the intention of identifying potential differences in the ways that cognitive, behavioral, and environmental factors relate to HIV vs. STI testing behaviors.

The Health Needs Assessment

Stepleman and others (2019) describe the CSRA LGBT Health Needs Survey ("the health needs assessment"), which was administered in 2016 to adults in the CSRA who identified as sexual or gender minorities. Sexual and gender minority individuals experience a number of physical and mental health disparities (Mayer et al., 2008; Williams & Mann, 2017). The 2016

Municipal Equality Index identified the largest city in the CSRA, Augusta, GA, as one of the least hospitable cities in the nation for sexual and gender minorities (Human Rights Campaign Foundation, n.d.). The survey was performed to assess physical and mental health problems in this population, as well as to understand the health care experiences and needs of this population.

Participants in the health needs assessment were adults at least 18 years of age who resided in the CSRA and who self-identified as a sexual or gender minority. Participants were recruited using venue sampling; additional participants were recruited through snowball sampling. The survey itself was administered on the Internet using Qualtrics, a Web-based survey tool (Qualtrics, 2016). Venue sampling involved volunteers recruiting participants in area establishments catering to sexual and gender minorities. When recruiting in this way, tablet computers were available for participants to complete the survey on-site. The survey could also be completed off-site via computer, smartphone, or tablet device. Participation was voluntary and anonymous; participants who chose to provide contact information were entered into a drawing to win a VIP ticket to the Augusta Pride festival or one of four $25 gift cards. Because the health needs assessment was deemed to involve minimal risk and collected data anonymously from the community, it was determined to be exempt from review by the Institutional Review Board (IRB) of Augusta University prior to data collection (Stepleman et al., 2019).

Participants

Of the 436 participants included in the original analysis (Stepleman et al., 2019), only individuals who endorsed male sex assigned at birth and endorsed negative HIV status, unknown HIV status, or left their HIV status blank were included in the present analysis (n = 164). Demographic details of the sample used in this study can be found in *Results*, below, and in

Tables 2 and 3. The present study is a secondary analysis of non-identifiable data that was not collected during a larger-scoped human subjects research study. As such, it did not meet the criteria of the Northwestern University IRB to require review.

Measures

The health needs survey itself was based on an examination and analysis of previous surveys conducted to identify health needs among sexual and gender minority populations (Boog et al., 2011; CDC, 2014, 2016a; Heckman et al., 1998; Lambda Legal, 2010). Stepleman and others (2019) describe the prioritization of physical and mental health concerns when developing the survey, including consideration of access to and utilization of health care, mental health, and prevention services. The final survey also assessed health behaviors (e.g., smoking, exercise), disclosure of sexual and/or gender minority status, perceived community stigma, and centrality of community identification. The survey also asked each respondent their opinion regarding areas where the community lacked services or otherwise had unfulfilled needs. The complete survey consisted of 86 questions (Stepleman et al., 2019).

The items that correspond with the variables included in the social cognitive model of STI and HIV testing and used in all statistical analyses are described below.

Cognitive Factors

Depression is represented in statistical analyses by the participant’s score on the Patient Health Questionnaire-2, a validated two-item measure commonly used to screen for potential depressive disorders (Arroll et al., 2010). The two items assess, using a 4-point Likert-like scale from “not at all” (0) to “nearly every day” (3), how many days in the past two weeks a respondent has experienced anhedonia and depressed mood. Items are summed to produce a scale score, with values ranging from 0 to 6, with higher values representing higher levels of depression. This measure demonstrated acceptable reliability in the current sample (α = .76). In tables and figures referenced in the *Results* section, this variable is named DEPRESS.

Internalized stigma is represented in statistical analyses by an adapted version of the Sexual Identity Distress Scale (SIDS; Wright & Perry, 2006). The SIDS was originally administered orally by an interviewer using terms for sexual identity adapted to participant preferences. Following Frazer and Howe (2016), the original SIDS items were modified for self-report use by using the terms "my sexual orientation" or "LGBT." Sample items read "I wish I weren't LGBT" and "I have a positive attitude about my sexual orientation." In addition to use of the transgender-inclusive term "LGBT," additional items were added to specifically assess attitudes towards one's gender identity (Stepleman et al., 2019) . These items read: "I have a positive attitude about my gender identity," "I feel uneasy about people who are very open in public about their gender identity," and "It doesn't matter to me whether my friends are cisgender or transgender." The resulting 11-item measure assesses internalized stigma towards both sexual orientation and gender identity. The author is unaware of literature validating the SIDS or the version used here including internalized gender identity stigma. Responses are recorded on a 5-point Likert-like scale ranging from "Strongly Disagree" (0) to "Strongly Agree" (4). Five items are reverse coded; after recoding, item scores are averaged to produce a scale score. This scaled score was used in the present study. Higher values represent more internalized stigma. This measure demonstrated good reliability in the current sample (α = .84). In tables and figures referenced in the *Results* section, this variable is named STIGMA.

Connection with the LGBTQ+ community is represented in statistical analyses by the Brief Sense of Community Scale (BSCS), a validated 8-item measure of an individual's perceived connection to the LGBTQ+ community (Griffin et al., n.d.). Examples of items include

"I belong to this community" and "I feel connected to this community." Each item is scored on a 5-point Likert-like scale with answers ranging from "Strongly Disagree" (0) to "Strongly Agree" (4). Item scores were averaged to produce a scale score which was used in the present analysis. Higher scores represent stronger identity with the LGBTQ+ community. This measure demonstrated good reliability in the current sample ($\alpha = .95$). In tables and figures referenced in the *Results* section, this variable is named COMMUNIT.

Behavioral Factors

Utilization of healthcare from outpatient clinics is represented in statistical analyses with data from an item which reads "Rate the frequency for which you use each of the following healthcare venues" followed by several venues including "Emergency Room (ER)/Emergency department," "Urgent care/Prompt Care," "Personal doctor/Private doctor's office," and "Health department/Sliding scale/Public clinic." Responses were "Often," "Sometimes," "Hardly ever," and "Never / Not at all." Responses were used to put participants into a category representing those who "sometimes" or "often" utilized urgent care, private doctor's office, or public clinics versus those who endorsed less or no access to these venues. This variable is coded 0 for those who did not endorse sometimes or often using the listed outpatient venues and 1 for those who did. In tables and figures referenced in the *Results* section, this variable is named OUTPT.

Having ever used PrEP is represented in statistical analyses using data from an item reading "Have you ever taken PrEP?" which can be answered yes or no. This variable is coded 0 for those who answer no and 1 for those who answer yes. In tables and figures referenced in the *Results* section, this variable is named USEDPREP.

Condom use is represented in statistical analyses using data from an item that reads, "How often do you or your partner(s) use a barrier while you are giving or receiving the following types of sex?" with those types including "anal" and with the response options: "I never use a barrier," "I sometimes use a barrier," "I always use a barrier," "I have never had this type of sex," and "Prefer not to answer." Condom use coded using an ordinal value representing always using condoms for anal sex (0), sometimes using condoms for anal sex (1), or never using condoms for anal sex (2), with higher values representing less condom use[1]. In tables and figures referenced in the *Results* section, this variable is named CONDOM.

Environmental Factors

Insurance coverage is represented in statistical analyses using data from an item assessing coverage that reads, "What type(s) of health insurance do you use to pay your medical bills? (Select all that apply)" followed by a list of possible insurance payers including Medicaid, Military Insurance, and different kinds of private insurance, as well as no insurance. Responses were dichotomized to represent any health insurance coverage (coded 1) versus no health insurance coverage (coded 0). In tables and figures referenced in the *Results* section, this variable is named INSURED.

Having a PCP is represented in statistical analyses using data from an item that reads, "Do you have someone you think of as your personal doctor or health care provider?" Three response choices allowed a participant to endorse having one person they think of as a primary provider, more than one such person, or no such person. Responses were dichotomized to represent having at least one primary provider (coded 1) versus having no primary provider (coded 0). In tables and figures referenced in the *Results* section, this variable is named HASPCP.

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[1] This is counterintuitive but correct. It is an artifact of this variable originally representing perceived risk, with higher values representing more perceived risk. This counterintuitive coding of the CONDOM variable should be taken into account when interpreting any relationships between CONDOM and other variables.

Community providers not adequately trained to work with sexual and gender minority individuals is represented in statistical analyses using data from an item that is prefaced with, “Please rate the extent to which each of these is a problem for you:” and reads, “The lack of health care professionals who are adequately trained and competent in LGBT health care.” Responses are along a 4-point Likert-like scale with responses ranging from “Not a problem at all” (0) to “Major problem” (3), with higher values representing belief that untrained providers are more of a problem in the community. This is used as a proxy for a real lack of untrained providers in the community, with higher values intended to proxy for fewer trained providers in the community. In tables and figures referenced in the *Results* section, this variable is named NOTRAIN.

Community providers who discriminate against sexual and gender minorities is represented in statistical analyses using data from the same item prefaced with, “Please rate the extent to which each of these is a problem for you:” and reads, “Medical personnel (e.g., physicians, nurses), who discriminate against LGBT people when providing direct care.” Responses are along a 4-point Likert-like scale ranging from “Not a problem at all” (0) to “Major problem” (3), with higher values representing belief that providers discriminating against sexual and gender minorities is more of a problem in the community. This is used as a proxy for providers in the community who do discriminate against sexual and gender minorities, with higher values intended to proxy for more providers who discriminate. In tables and figures referenced in the *Results* section, this variable is named DISCRIM.

Dependent Variables

Outcomes in the HIV testing model are recency of last HIV test. Similarly, outcomes in the STI testing model are recency of the last test for other STIs. Recency of last HIV and STI test were represented in statistical analyses using data from items that read “Please indicate how long ago, if at all, you have received each of the following:” followed by “HIV test” and “Sexually Transmitted (STI) testing (other than HIV testing).” Responses were on a 5-point Likert-like scale with responses “Not at all; Never” (0), “More than two years” (1), “1-2 years” (2), and “less than 12 months” (3). Higher values represent more recent testing. Previous research uses the 12-month timeframe when assessing recent STI and HIV testing (Grey, 2013; Reilly et al., 2014). In tables and figures referenced in the *Results* section, these variables are named RECHIVT and RECSTIT. Figures 2 and 3 depict the social cognitive model of STI and HIV testing behavior separately with HIV and STI testing outcomes.

Power Analysis

Power analysis was performed for initial HIV and STI models using the calculator provided by Preacher and Coffman (2006) and null and alternate RMSEA values from MacCallum and others (1996). Model degrees of freedom are 32. Power was calculated with a specified alpha value of 0.05 for the sample described in *Participants* (n = 164). Using an RMSEA value of 0.05 for the null model and an RMSEA value of 0.08 for the alternate model, the present study had a power of 0.51 to detect models closely fitting the data. Using an RMSEA value of 0.01 for the alternate model, the present study had a statistical power of 0.34 to detect models not closely fitting the data. Using the same calculator, it was determined that approximately 300 to 350 participants would have been necessary for the present study to reach a statistical power of 0.80. All but four of the 28 additional SEM models tested had fewer than 23 degrees of freedom, indicating they had even less statistical power than the original HIV and STI models.

Alternate Models

One of the expectations of this study was that factors that influence HIV and STI behavior differ, even when there is substantial overlap. Consistent with this expectation, two sets of alternative models were specified prior to running the main analyses. These alternative models were based on modifications to the initial HIV and STI models. These sets of alternative models are referred to as “Plan 1” and “Plan 2.” Each set contains four models. HIV and STI models both have a Plan 1 and a Plan 2, representing 16 additional models in total. These models are identified by whether they refer to HIV or STI outcomes, the plan they are a part of, and the order in which they were to be evaluated, referred to as “steps.” For example, the first alternative HIV testing model in Plan 1 is referred to as HIV Plan 1 Step 1. Each plan starts with the original model and each step in a plan is a modification to that plan’s previous step. More details about the procedure to analyze these models is found below in *Procedure.*

Plan 1 (HIV and STI)

Step 1. The first proposed modification to the original model is to remove the depression variable. Although there is a theoretical rationale for inclusion of depression (see *A Theorized Social Cognitive Model of Testing Behavior*, above), there is no prior empirical support that depression is related to either STI or HIV testing behavior. Figures 4 and 5 depict the Plan 1 Step 1 models.

Step 2. The second proposed modification to the original model was to remove the variables representing insurance coverage and having a primary care provider. These were expected to be closely related and were removed together, since HIV testing is often free and administered by non-clinical staff. Figures 6 and 7 depict the Plan 1 Step 2 models.

Step 3. The third proposed modification to the original model was to remove the variable representing PrEP use. This variable was missing in 47 of 164 participants. It was included in the original model because it is highly theoretically relevant. The removal of the PrEP variable in this step was also informed by early attempts to run the initial models in MPlus. The MPlus output indicated that the correlation between the PrEP variable and the outcome variables was high enough to create problems in analysis and interpretation. Figures 8 and 9 depict the Plan 1 Step 3 models.

Step 4. The fourth proposed modification to the original model was to consider conceptually how the latent variables as specified in Step 3 might affect each other, and to simplify the structural model (i.e. to remove the requirement that the latent variables reciprocally determine each other) and to only include regressions that made sense at this point. This explicitly violates the reciprocal determinism assumptions of SCT and was based solely on an intuition about what the latent factors might represent. The intention was to simplify the analysis by increasing degrees of freedom and reducing bidirectional causality in the structural model. By Plan 1 Step 4, cognitive factors were represented by the variables representing internalized stigma and community identity, behavioral factors by variables representing outpatient clinic utilization and condom use, and environmental factors by variables representing providers in the community who discriminate, and providers in the community who are not adequately trained. Given this, the regression model was modified to remove the direct effects of behavioral factors on environmental and cognitive factors. Figures 10 and 11 depict the Plan 1 Step 4 models.

Plan 2 (HIV and STI)

Step 1. If none of the models in Plan 1 were found to have a good fit, Plan 2 starts over with the original model with the variable representing internalized stigma removed. The scale used to represent internalized stigma is not validated and contains items regarding attitudes towards gender identity which may confound interpretation of scale values in a mixed sample of cisgender and transgender individuals. In addition, data were missing for 25 of 164 cases. Figures 12 and 13 depict the Plan 2 Step 1 models.

Step 2. The next proposed modification is to remove the variables representing providers who are not adequately trained or who discriminate against sexual and gender minorities at the same time. Similar to the removal of variables representing insurance coverage and having a PCP together in Step 2 of Plan 1, these two variables were expected to be highly correlated. Additionally, they were included as proxies for environmental conditions, but themselves represent cognitions. Actual values represented beliefs that certain problems existed and could reflect personal biases or be influenced by other cognitions more than actual environmental realities. Figures 14 and 15 depict the Plan 2 Step 2 models.

Step 3. As in Plan 1, the next proposed modification is to remove the variable representing PrEP use, for the same reasons it is removed in Step 3 of Plan 1. Figures 16 and 17 depict the Plan 2 Step 3 models.

Step 4. As in Plan 1, the next proposed modification is to simplify the relationships between latent variables for the same reasons and using the same criteria. By Plan 1 Step 4, cognitive factors were represented by the variables representing depression and community identity, behavioral factors by variables representing outpatient clinic utilization and condom use, and environmental factors by variables representing health insurance coverage and having a PCP. Given this, the regression model was modified to remove the direct effects of behavioral factors on environmental and cognitive factors and to remove the direct effects of cognitive factors on environmental factors. Figures 18 and 19 depict the Plan 2 Step 4 models.

Statistical Analysis

Models were evaluated using structural equation modeling (SEM), a powerful, multivariate technique that allows for all complex interrelationships between model variables to be tested in one analytical step (Bryan et al., 2007; Buhi et al., 2007; Schwarzer, 2008). SEM's ability to efficiently test the significance of multiple mediators, identify directionality in relationships, minimize error, and address shared variance make it the most efficient way to test a theoretical model like the present model. This is evidenced by previous published studies which test theoretical models of health behavior using SEM (including HIV prevention behaviors; e.g., Espada et al., 2016; Noar & Morokoff, 2002).

Software Tools

Data from the health needs survey was received in SPSS format (IBM Software Business Analytics, 2019). SPSS was used to a) select the cases relevant for the present study according to the criteria specified in *Participants;* b) compute the variables included in the model from the original data; c) perform bivariate correlations between demographic, predictor, and outcome variables; d) obtain details of sample demographics; and e) ensure missing data would be interpreted appropriately by other software. The SPSS syntax that performs these functions was written by the author and is available on request. A dataset containing only the variables and cases to be analyzed was saved as a portable CSV file for use in other tools.

Early versions of the models were evaluated using MPlus (Muthén & Muthén, 2011) and lavaan (a popular open-source R package; Rosseel, 2012). The results reported in *Results* were obtained using semopy, a package for the Python programming language developed to enable flexible analysis of SEM models and easy integration into other research procedures involving Python code (Igolkina & Meshcheryakov, 2020). Semopy is mature (version 2.013 was used for the present analyses) and has been demonstrated to exceed lavaan both in speed and accuracy (Igolkina & Meshcheryakov, 2020). Semopy borrows its model syntax from lavaan, and all models are specified in lavaan syntax within the Python code responsible for all SEM analyses. This code was written by the author and is available on request. The code was written and executed in a Jupyter Lab notebook (Kluyver et al., 2016) to enhance usability and ensure reproducibility. Diagrams included as Figures 2-33 were created by semopy (with code modifications made by the author and available on request) which in turn uses the open-source graph drawing tool Graphviz (Gansner, 2010).

All SEM analyses using semopy utilized full information maximum likelihood (FIML) estimation and the sequential least squares programming (SLSQP) optimizer. FIML estimation handles missing and ordinal data, although there is evidence that variants of FIML may provide more accurate parameter estimates under some conditions (Chen et al., 2020).

Treatment of Ordinal Variables

Binary predictor variables, since they are coded 0 to specify the lack of a characteristic and coded 1 to specify the presence of that characteristic, are treated as ordinal. Documentation for both lavaan and semopy indicates that ordinal categorical predictor variables can be treated as continuous for the purposes of the analysis, but that ordinal outcomes should be specified as such. This proved non-trivial when performing the analyses. The analyses reported in *Results* treat the ordinal outcome variables with 4 possible values as continuous variables, following Johnson and Creech (1983) who suggest that analyses of multiple indicator models (such as the present SEM analyses) are not likely to yield seriously biased estimates when treating ordinal data as continuous, although it does warn that this advice is most robust when variables have at least 5 possible values; they advise that treating variables with fewer than 5 ordinal categories as continuous, especially in small samples, may bias parameter estimates.

Procedure

The planned procedure for evaluating the models of HIV and STI testing behavior was as follows: First, for the model of HIV testing, the initial model was to be evaluated for goodness of fit as described above, using the χ^2 goodness of fit, root mean square error of approximation (RMSEA) fit index, and Tucker-Lewis fit index (TLI). χ^2 goodness of fit assesses the overall fit of the model by testing the null hypothesis that the null model fits the data perfectly; overall fit is considered good if χ^2 significance $p > 0.05$, indicating a rejection of the null hypothesis. RMSEA is an absolute fit index where values closer to 0 indicate better fit; model fit is considered good if RMSEA < 0.08. The TLI (also known as the non-normed fit index or NNFI) is a relative fit index preferred to the normed fit index (NFI) in smaller samples. TLI values represent improvement over the null model; model fit is considered good if TLI values are > 0.95, representing improvements of at least 95% over the null model (Hooper et al., 2008; Kline, 2016). If the original model of HIV testing behavior was not found to fit the data well, the models in Plan 1 were to be evaluated one by one, in sequence, until a model was identified that did demonstrate good statistical fit. If no models in Plan 1 fit the data well, the models in Plan 2 similarly were to be evaluated in the same manner. If the original models and none of the models in either Plan 1 or Plan 2 fit the data well, further models were to be specified and analyzed *post hoc,* informed by the results of the planned analyses. The procedure for evaluating models of STI testing is identical, starting with the original model, and proceeding, if necessary, to the proposed alternate models in the analogous Plan 1 and Plan 2 for STI models.

If models are identified for both HIV and STI testing that fit the data well, these models were then to be interpreted and discussed side-by-side to highlight differences in the factors that influence each outcome, drawing on the statistical significance, strength, and direction of the standardized regression coefficients calculated during SEM analysis. If no well-fitting model was found for either HIV or STI testing, even after *post hoc* models were evaluated, no such interpretation was to be performed, since interpretation of parameter estimates is only meaningful in the context of models that fit the data well (Kline, 2016).

Results

Sample

Participant ages ranged from 18 to 73 years (*M* = 34.6, *SD* = 13.2). The majority of individuals in the sample used for this analysis identified as White/Caucasian (68.3%) with 18.9% identifying as Black/African American and 4.9% identifying as Hispanic. Most endorsed a current male gender identity, with 15.9% identifying as transgender or gender non-binary. Regarding their sexual orientation, 70.1% identified as gay, with 13.4% identifying as bisexual and 16.3% endorsing one of six other identity options or preferred not to endorse any. See Tables 2 and 3 for further demographic details of the sample used for this study. Tables 4 through 6 contain sample data in terms of the predictor and outcome variables included in SEM models.

Bivariate Correlations

Table 7 contains bivariate correlations between selected demographic factors, all predictor variables and the two outcome variables. These correlations treat ordinal data as continuous and Pearson's *r* is reported. This is consistent with these data being treated as continuous during SEM analysis as detailed above. Bivariate correlations between predictor variables and between predictor variables and outcomes were notable for not identifying all expected relationships. None of the correlations between predictor variables that were hypothesized to covary were statistically significant. Of relationships between cognitive predictors, only internalized stigma and community identity were significantly statistically correlated ($r = 0.228$, $p < 0.01$). Of the relationships between behavioral predictors, none were significantly statistically correlated. Of the relationships between environmental predictors, insurance coverage and having a PCP were significantly correlated ($r = 0.492$, $p < 0.01$) and the proxies for providers who discriminate and providers who are not adequately trained were significantly correlated (r = 0.590, $p < 0.01$). Of the relationships between predictor variables and recency of HIV testing, only the relationships with condom use (r = 0.245, $p < 0.01$), PrEP use (r = 0.211, $p < 0.05$), and internalized stigma (r = 0.190, $p < 0.05$) were statistically significant. Similarly, only these three predictors had statistically significant correlations with recency of STI testing: with condom use (r = 0.188, $p < 0.05$), PrEP use (r = 0.320, $p < 0.01$), and internalized stigma (r = 0.249, $p < 0.01$). Given the small sample size and limited power to detect small effects, some relationships between predictor variables and outcome variables that do not reach the same criteria for statistical significance are also reported. These are the relationships between recent STI testing and providers who discriminate (r = 0.138, $p < 0.10$) and providers who are not adequately trained (r = 0.125, $p < 0.15$) and between recent HIV testing and use of outpatient healthcare clinics (r = 0.121, $p < 0.15$). The two outcome variables, recency of HIV testing and recency of STI testing were highly correlated (r = 0.597, $p < 0.01$).

Several relationships between predictor variables were identified that were not hypothesized. These include: a) relationships between depression and insurance coverage (r = -0.344, $p < 0.01$), having a PCP (r = -0.222, $p < 0.01$), providers that discriminate (r = 0.158, $p < 0.05$), and providers that are not adequately trained (r = 0.188, $p < 0.05$); b) the relationship between community identity and providers that are not adequately trained (r = -0.214, $p < 0.05$) and use of outpatient healthcare clinics (r = 0.257, $p < 0.01$); and c) relationships between utilizing outpatient healthcare clinics and having insurance coverage (r = 0.296, $p < 0.01$) and having a PCP (r = 0.418, $p < 0.01$).

Regarding relationships between demographic factors and variables included in the model, education was statistically significantly correlated with age (r = 0.271, $p < 0.01$) and income ($r = 0.266$, $p < 0.01$), which does not violate expectations. Age and race were correlated ($r = 0.159$, $p < 0.05$), representing the tendency for older participants to be more likely to identify as White.

Model Fit

The initial model of social cognitive factors that influence HIV testing behavior was evaluated as described in the *Procedure* section. Fit indices indicated poor fit ($\chi^2 = 181601.56$, $p < 0.01$; RMSEA = 5.90; TLI = 0.29). Each of the models in HIV Plan 1 were tested sequentially, none of them being found to be a good fit: Step 1 ($\chi^2 = 125427.56$, $p < 0.01$; RMSEA = 5.547; TLI = 0.39), Step 2 ($\chi^2 = 148429.52$, $p < 0.01$; RMSEA = 9.54; TLI = -0.24), Step 3 ($\chi^2 = 175439.51$, $p < 0.01$; RMSEA = 14.67; TLI = -1.06), and Step 4 ($\chi^2 = 176028.28$, $p < 0.01$; RMSEA = 12.42; TLI = -0.47). Each of the models in HIV Plan 2 were then tested, none of which were found to be a good fit: Step 1 ($\chi^2 = 159968.15$, $p < 0.01$; RMSEA = 6.39; TLI = 0.15), Step 2 ($\chi^2 = 105503.03$, $p < 0.01$; RMSEA = 8.48; TLI = -0.17), Step 3 ($\chi^2 = 132595.62$, $p < 0.01$; RMSEA = 14.26; TLI = -1.28), and Step 4 ($\chi^2 = 132595.62$, $p < 0.01$; RMSEA = 10.78; TLI = -0.30). All fit indices for these models can be viewed in Tables 8 and 9.

The original model of social cognitive factors that influence STI testing behavior was also evaluated as described in *Procedure*. Fit indices indicate poor fit ($\chi^2 = 188560.52$, $p < 0.01$; RMSEA = 6.01; TLI = 0.24). Each of the models in STI Plan 1 were then tested in order, none of them being found to be a good fit: Step 1 ($\chi^2 = 131635.89$, $p < 0.01$; RMSEA = 5.68; TLI = 0.34), Step 2 ($\chi^2 = 154447.94$, $p < 0.01$; RMSEA = 9.73; TLI = -0.34), Step 3 ($\chi^2 = 181520.47$, $p < 0.01$; RMSEA = 14.92; TLI = -1.19), and Step 4 ($\chi^2 = 181896.13$, $p < 0.01$; RMSEA = 12.63; TLI = -0.57). STI Plan 2 models were subsequently tested and again none were found to be a good fit: Step 1 ($\chi^2 = 165009.75$, $p < 0.01$; RMSEA = 6.49; TLI = 0.09), Step 2 ($\chi^2 = 110298.45$,

$p < 0.01$; RMSEA = 8.67; TLI = -0.27), Step 3 (χ^2 = 137561.27, $p < 0.01$; RMSEA = 14.53; TLI = -1.45), and Step 4 (χ^2 = 138213.89, $p < 0.01$; RMSEA = 11.01; TLI = -0.41). All fit indices for these models can be viewed in Tables 10 and 11.

Diagrams of the models tested, including parameter estimates and significance are available as Figures 2 through 19.

Positive Definite Covariance Matrices

Some SEM analyses reported here required the use of the Moore-Penrose inverse of the Fisher Information Matrix (FIM) instead of the Cholesky decomposition because the FIM was not positive definite. Li and others (2012) demonstrate that using the Moore-Penrose inverse is a valid choice when encountering non-positive definite FIMs. MPlus, lavaan, and semopy all recognized that covariance matrices of some models were non-positive definite. This is a condition that can result from missing data or when multicollinearity is present in the data (Yuan & Chan, 2008). Semopy automatically applied the Moore-Penrose inverse to produce a positive definite matrix that allowed these analyses to proceed.

Post Hoc Analyses

Some analyses produced negative estimates for covariances. Valid variance and covariance values are squares, and thus negative values are not possible. Several *post hoc* modifications were made to the initial HIV and STI models, the HIV and STI Plan 1 Step 1 models, and the HIV and STI Plan 2 Step 2 models, with the hope of eliminating negative estimates of covariance and producing models with better fit. All *post hoc* models had poor statistical fit. Fit indices for *post hoc* models are available in Tables 12 through 17. Diagrams of *post hoc* models, including parameter estimates and significance, are depicted in Figures 20 through 33.

Discussion

This study is the first known study to statistically test separate theory-based models of factors influencing HIV and STI using the same data. The sample used for the analysis came from a geographic region where sexual and gender minority individuals (mostly identifying as cisgender gay men and transgender women), a population at heightened risk for both HIV and other STIs, report being tested for HIV in the past 12 months almost twice as often as they report being tested for other STIs in the same period. Unfortunately, neither the initial model, the *a priori* modifications, nor the *post hoc* models identified models that were good fits for either HIV or STI testing behavior.

Limitations

The sample studied was likely not representative of all HIV-negative gay men and transgender women (and other sexual and gender minority individuals who were assigned male sex at birth but identify differently) in the CSRA. The sample included a smaller proportion of Black participants than in the population of two of the largest metropolitan areas in the CSRA (18.90% Black in this study; 35.09% Black in Augusta-Richmond County, GA; 28.5% Black in Aiken, SC). Median income for males in Augusta-Richmond County, GA is $34,574; median income in the sample studied was in the $40,000 to $49,999 range.

Variables included in the model do not represent all relevant social cognitive factors that might influence HIV or STI testing behavior. The variables included were selected from the items included on the health needs assessment. Each item or set of items that formed a scale were assessed regarding their potential relevance to HIV and STI testing behavior based on literature review and theory. Final items included were based on whether candidates were single items or scales, whether scales were validated or not, the amount of missing data, item/scale variance, amount of support in the literature, and theoretical support. Candidate items were available by convenience and the health needs assessment was not originally designed with the intent of capturing all (or even any) social cognitive factors that influence HIV and STI testing. Final variables included in the model represent a second level of convenience, since some variables were excluded purely on grounds of low variance in the model studied, and not because they were not theoretically relevant. Therefore, the models analyzed do not represent all possible cognitive, behavioral, and environmental factors that might influence HIV and STI testing.

The study was underpowered to detect all but the largest of effects; nearly twice as many participants would have been necessary to reach the conventionally accepted statistical power of 0.80. A misunderstanding of degrees of freedom in SEM models early on in the development of the initial model led to design decisions excluding other relevant variables that were available in the health needs assessment data, limiting statistical power. While FIML estimation was used to handle missing data, missing data could have distorted the findings. Missing data, by model variable, is reported in Tables 4 through 6.

The results of the study could be influenced by the use of χ^2, which can be a poor estimate of model fit for SEM (Joreskog, 1993). Moreover, the use of FIML may have inflated χ^2 values. RMSEA and TLI fit indices are conservative and tend to show poorer fit in smaller samples (Hu & Bentler, 1999). These values may underestimate the goodness of model fit. Non-positivity of covariance matrices during some analyses and the necessity to use an alternate method to obtain the inverse matrices may have distorted parameter estimates. A confident interpretation of parameter estimates outside the context of models that fit the data well are not possible and *any* interpretation would be speculative.

The values reported for RMSEA are all well beyond the theoretical range of 0 to 1 (Buhi et al., 2007) . RMSEA is derived from the χ^2 statistic. The author has manually calculated several of the RMSEA values reported here from the χ^2 values and achieved the same results reported by semopy, implying that it is the χ^2 that may be distorted.

The inability of the analyses performed here to identify models of HIV and STI testing behavior that fit the data well may reflect all the above limitations and others not considered here. The nature of these limitations means that these findings do not necessarily indicate that the models considered are wrong. Instead, the study's low statistical power implies that the study as designed simply was not able to detect if the models as specified were good fit with the data.

Another limitation is related to the choice of semopy to run SEM analyses. While the choice is defensible based on its convenience (for example, by automatically handling non-positive definite covariance matrices) and its demonstrated accuracy (Igolkina & Meshcheryakov, 2020), it does not compute the SRMR fit index or confidence intervals of parameter estimates, both of which would facilitate interpretation of results.

Risk perception and behavioral skills

Interpretation of the condom use variable is made unintuitive by how it was coded before analysis (see *Measures*). This coding was an artifact of the variable originally being considered a proxy for a cognitive factor of risk perception. Some of the nuances regarding the difficulty of interpreting condom use as representing an actual heightened risk of HIV or other STI acquisition have already been reviewed in *Model Development*. Furthermore, there is no existing literature supporting condom use as a predictor of HIV or STI testing behavior. There are, on the other hand, several studies that find risk perception to influence testing behavior (Adam et al., 2014; de Visser & O'Neill, 2013; Grey, 2013). Including condom use as a behavioral skill in this context may have been an error.

Correlates of HIV and STI testing behaviors

While the parameter estimates produced during SEM analysis cannot be confidently interpreted, bivariate correlations do indicate several factors that are significantly correlated with HIV and STI testing behaviors. Income was significantly correlated with more recent HIV testing in our sample while previous literature has found a relationship between income and STI testing (Grey, 2013). Less consistent condom use during anal intercourse was associated with more recent HIV and STI testing; if condom use is interpreted as a proxy for risk perception as discussed above, this is consistent with previous findings that risk perception is associated with HIV testing (Adam et al., 2014; Lorenc et al., 2011) and STI testing. Higher levels of internalized stigma in the sample studied are correlated with more recent HIV and STI testing. Previous literature has not identified internalized stigma as a factor that predicts HIV and STI testing behavior. However, potentially associated factors such as openness about one's sexual orientation predicting more recent STI testing (Grey, 2013), shame predicting less recent STI testing (de Visser & O'Neill, 2013), openness about sharing sexual history predicting more recent STI testing (de Visser & O'Neill, 2013), and identifying as gay predicting more recent HIV testing (Reilly et al., 2014) have previous support for influencing testing behavior. Especially in the context of findings regarding potentially related factors, it is difficult to interpret why more internalized stigma would predict more recent testing. This relationship is likely explained by other variables and would benefit from being analyzed as part of a multiple indicator model such as other SEM models or simpler moderation or mediation analyses. Having ever used PrEP is highly correlated in the sample studied with both recent HIV and recent STI testing. This is consistent with Centers for Disease Control clinical practice guidelines (CDC, 2018a). Finally, recent HIV testing and recent STI testing are highly correlated.

Unexpected covariances between predictors

In retrospect, the correlations between having a PCP and being covered by health insurance with utilization of outpatient clinics is easy to understand and may represent an oversight when considering predictor covariance during model development. The relationships between depression and characteristics of providers in the community could be interpreted in different ways. For example, experiencing untrained or discriminating providers could be upsetting and trigger depression. Another interpretation is that individuals who are depressed could have outlooks that predispose them to negative beliefs about others and their own experiences. Using assessments of beliefs as proxies for environmental realities, as highlighted here, has the potential to misrepresent environmental factors.

Negative covariances

In several models tested, SEM analyses produced negative estimates for the relationship between community identity and having ever used PrEP and for the relationship between internalized stigma and condom use. The covariance of community identity and having ever used PrEP is consistently estimated to be negative but the value is always near zero (e.g., -0.02 in the initial HIV testing model) and never reaches statistical significance. This statistically non-significant covariance estimate that is close to 0 most likely represents no covariance at all beyond that accounted for elsewhere in the model. Similarly, when the covariance of internalized stigma with condom use is negative, it is near zero (e.g., -0.05 in the HIV Plan 1 Step 2 model). In other models where this parameter estimate is positive, it is still near zero (e.g., 0.05 in the HIV Plan 1 Step 1 model). In no model is this parameter statistically significant. These negative covariance estimates in this context again likely represent no covariance at all between internalized stigma and condom use except that which is accounted for elsewhere in the model. Confidence intervals, if computed, would help clarify this interpretation.

Opportunities for future research

The limitations discussed imply multiple avenues for future research, both using the same techniques and data in this study, and when designing future studies with similar aims. Analyzing similar models using more of the available potentially relevant variables (e.g., outness regarding sexual orientation, recency of non-sexual health preventive medical tests, substance use behaviors, or distance and transportation barriers, among others) would increase model degrees of freedom and increase statistical power. Adding three or four predictor variables, depending on the number of additional hypothesized covariances among predictors, would increase statistical power to near 0.75 or 0.80. As discussed, condom use could be reconceived as risk perception and included as a cognitive factor. The items acting as proxies for provider characteristics could be reconceived as cognitive factors relevant to the individual's phenomenological interpretation of their experiences. If abandoning the method used here of starting with identical models for both outcomes, HIV testing could be included as a predictor for STI testing, and vice versa, given their close association.

Including both cisgender MSM and transgender women in the same analysis could have confounded findings. While there is support for studying these populations together, factors that influence HIV and STI testing behaviors may operate in different ways in these populations and when evaluating statistical models, they might better be examined separately. Future research should calculate internalized stigma differently based on the sexual orientation or gender identity of each participant, selectively calculating the scale based on inclusion of the items solely focused on sexual orientation or gender identity, as relevant. Future research should also examine and report demographic and predictor correlations separately for MSM and transgender women. If relationships between variables are different enough to warrant it, future research would benefit from focusing on one sexual or gender minority subpopulation.

Future research with similar aims using other method and data would significantly benefit from designing their study from the ground up with these aims in mind and selecting validated measures (when available) for all relevant constructs, based on the theory chosen and extant literature. Ideally, larger sample sizes should be used, although the necessity of this would be determined by the actual models being tested. Scales, even when validation has not been demonstrated. and continuous predictor and outcome variables will make models easier to analyze in more available software packages without the difficulties ordinal variables introduce to analysis and interpretation.

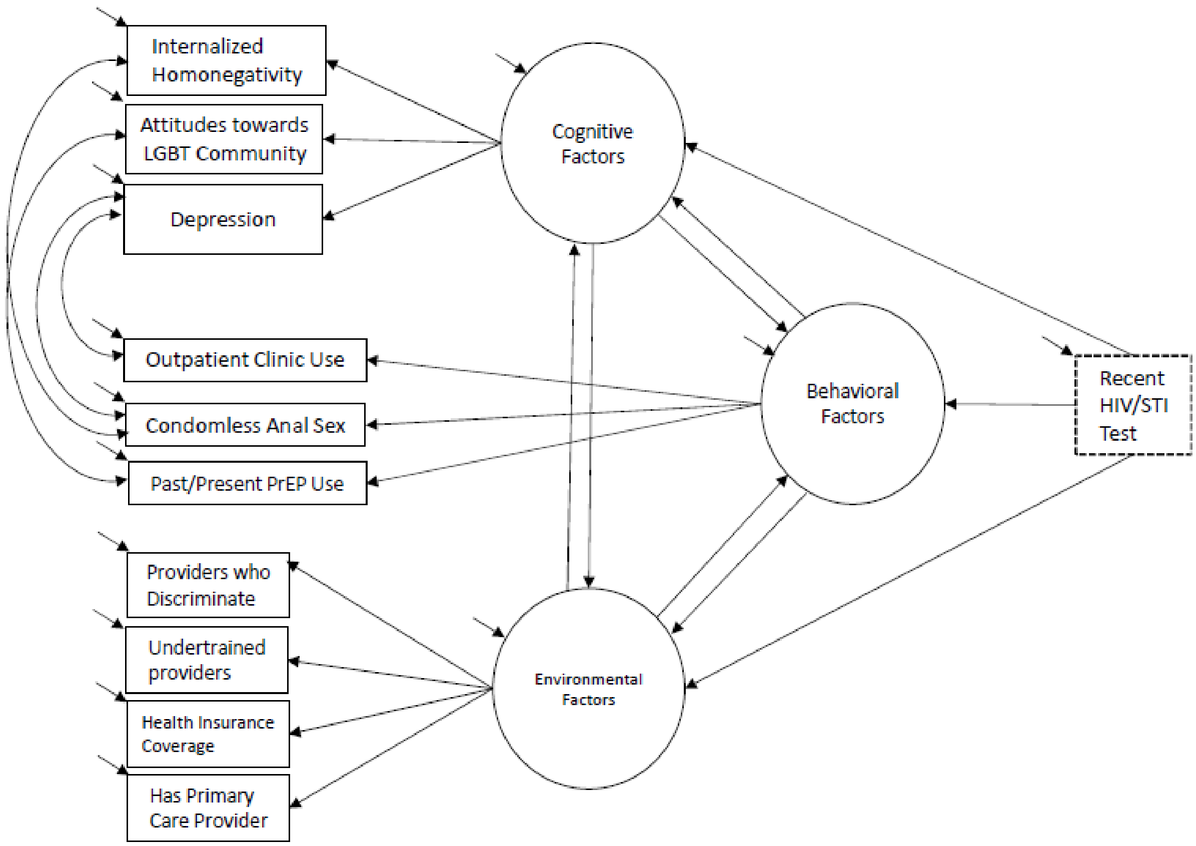
Conclusions

All the models tested in the present study were poor fits for the data and multiple factors likely contribute to these findings. Most significantly, the study was underpowered to detect all but the largest of effects; thus, poor statistical fit in this context does not necessarily mean the models tested are wrong. The limitations of the present study imply many improvements that could be incorporated into future analyses using the same methods and data. Moreover, limitations of the present study highlight areas that future research with similar aims should consider in order to be more likely to identify good statistical models of HIV and STI testing behavior.

Figures

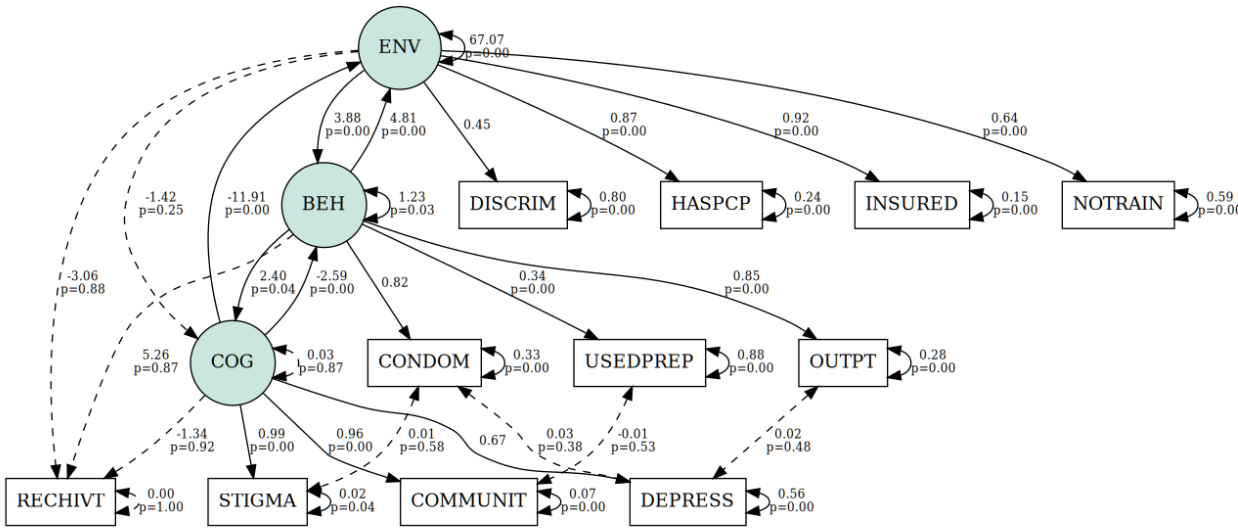
Figure 1

The social cognitive model of HIV and STI testing behavior



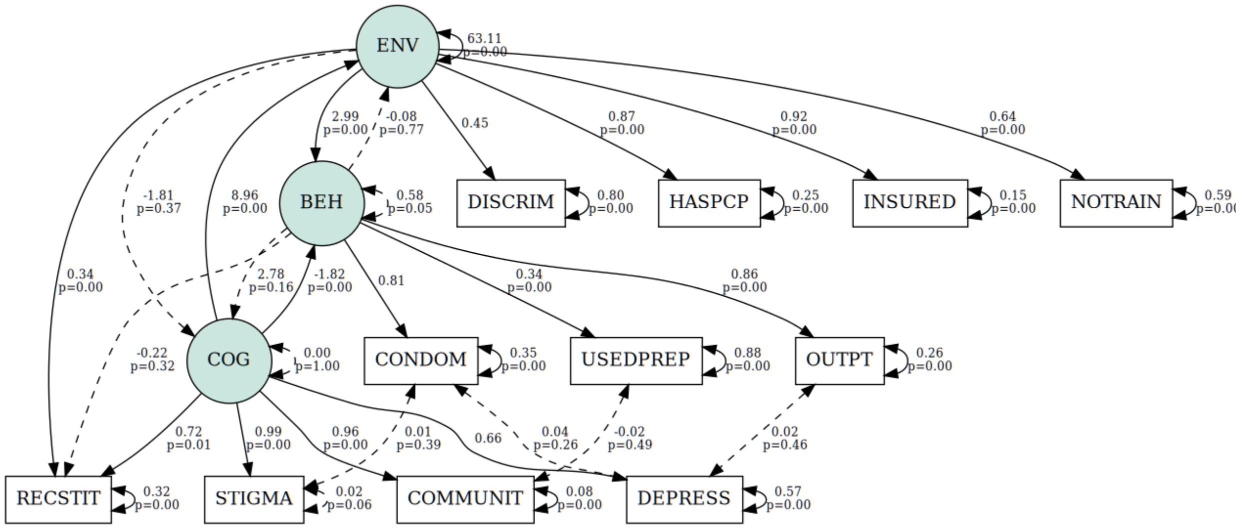
Note: Figure includes exogenous observed (predictor) variables (10), endogenous latent variables (3), and endogenous observed (outcome) variables (1 per model, with figure representing two identically specified models, one with recency of last HIV test as predicted outcome, and one with recency of last STI test as predicted outcome). Relationships represented in the figure include the measurement model, i.e., which predictor variables comprise each latent factor (3 for Cognitive, 3 for Behavioral, and 4 for Environmental factors), the structural model, i.e. regressions involving the latent variables and the outcome variable (6 regressions representing the reciprocal determinism of the latent factors and 3 representing the hypothesized predictive power of the latent variables regarding the outcome of interest), variances of observed variables (11), disturbances of latent variables (3), and covariances between predictor variables that are hypothesized to not be accounted for in the latent factors (4).

Figure 2
Initial HIV Model



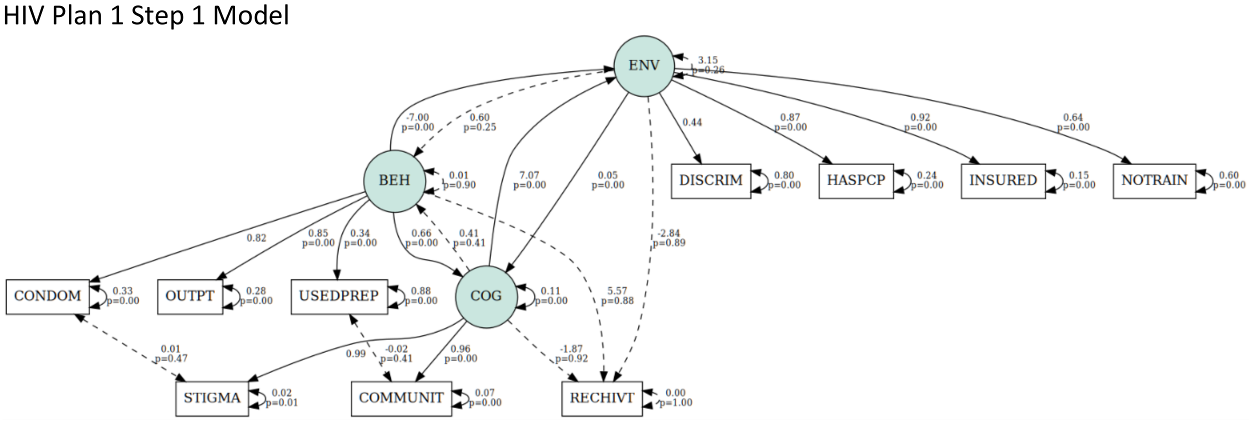
Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 3
Initial STI Model



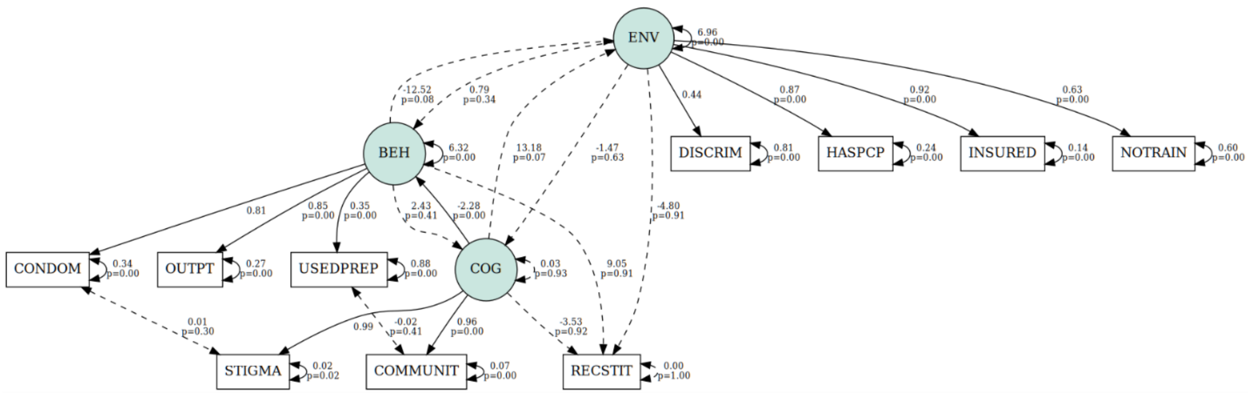
Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 4
HIV Plan 1 Step 1 Model



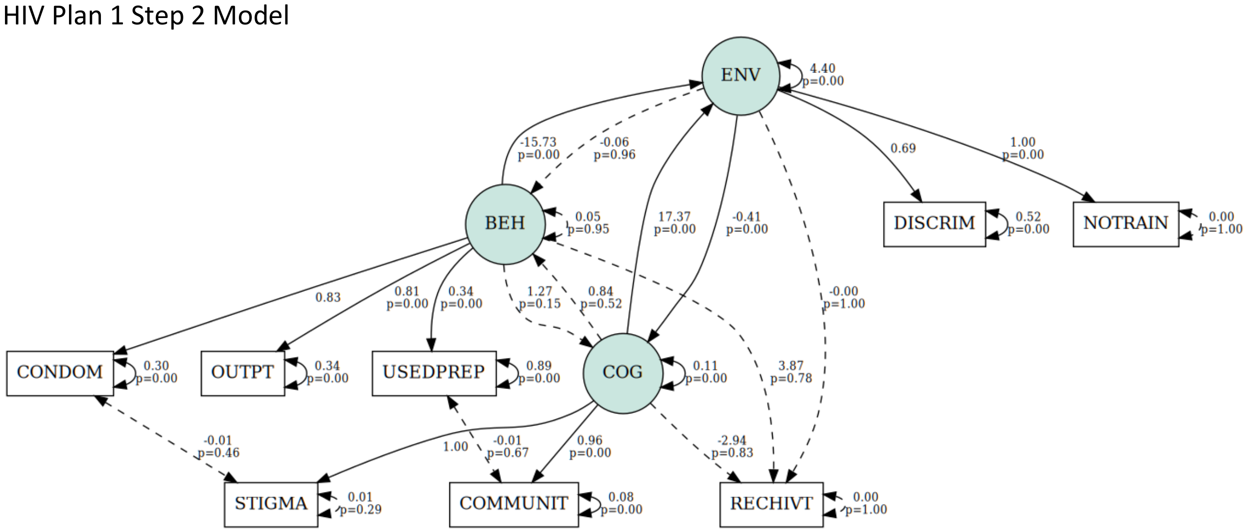
Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 5
STI Plan 1 Step 1 Model



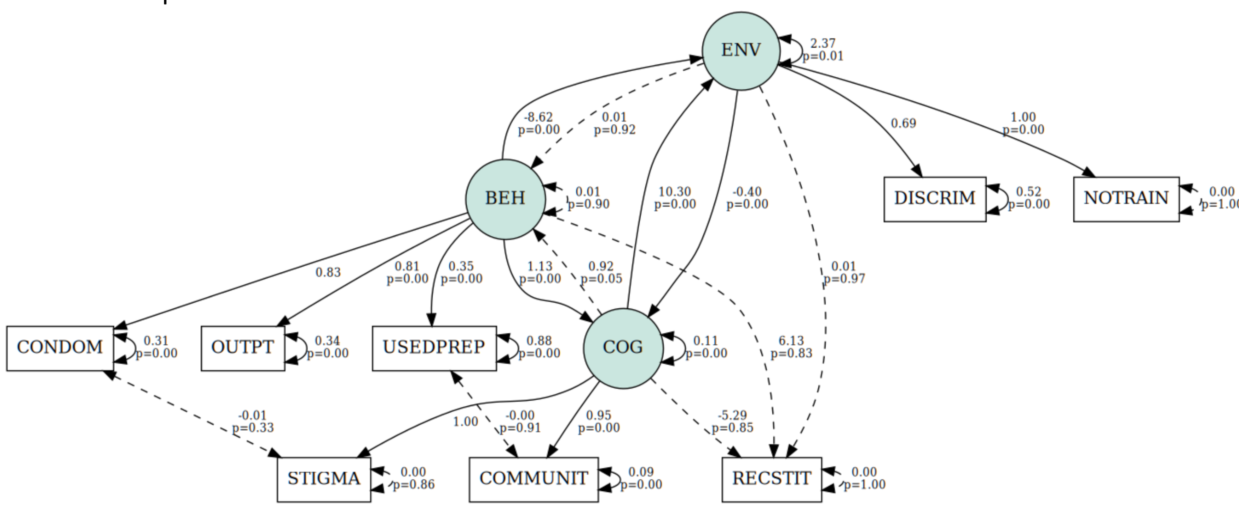
Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 6
HIV Plan 1 Step 2 Model



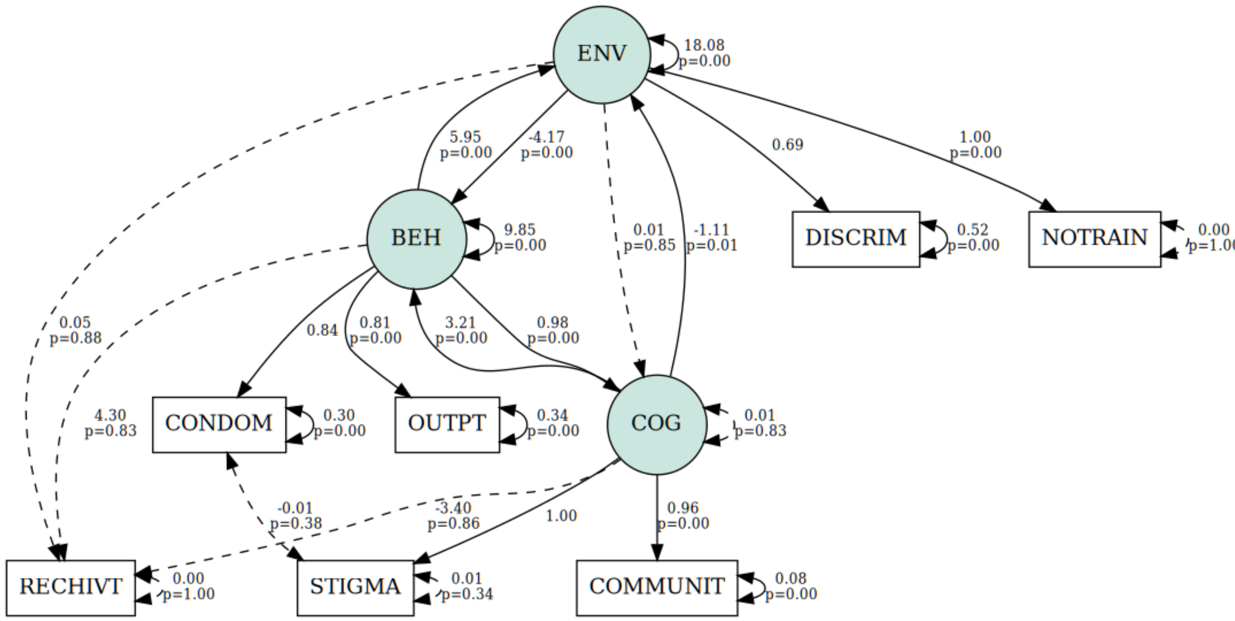
Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 7
STI Plan 1 Step 2 Model



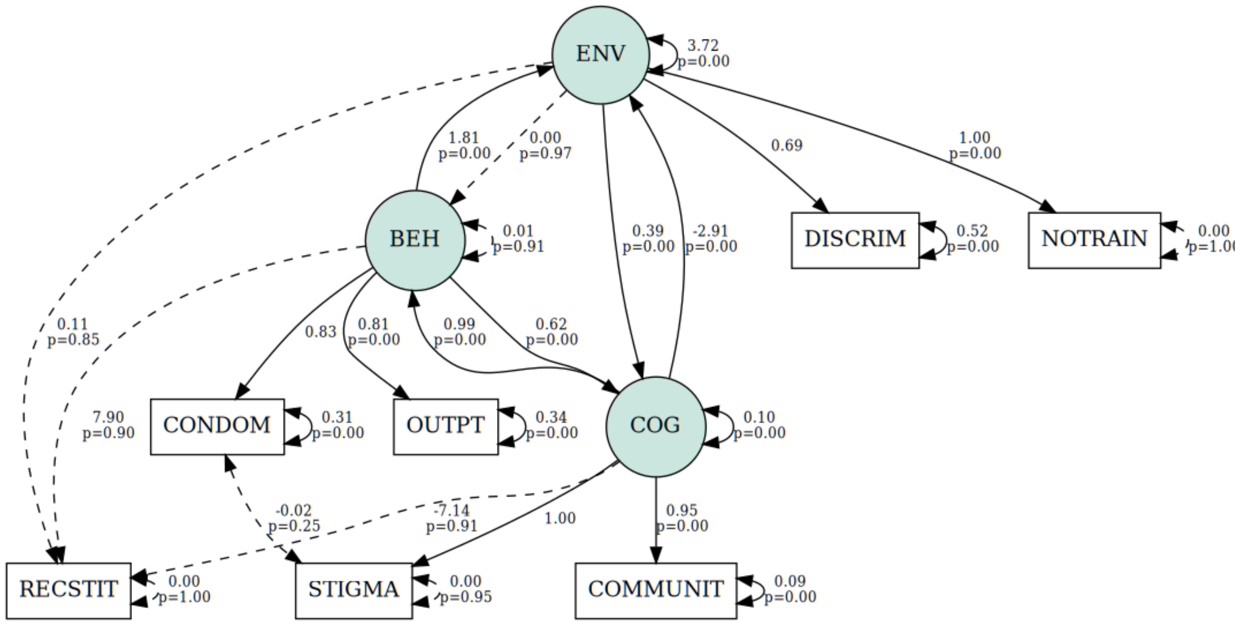
Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 8
HIV Plan 1 Step 3 Model



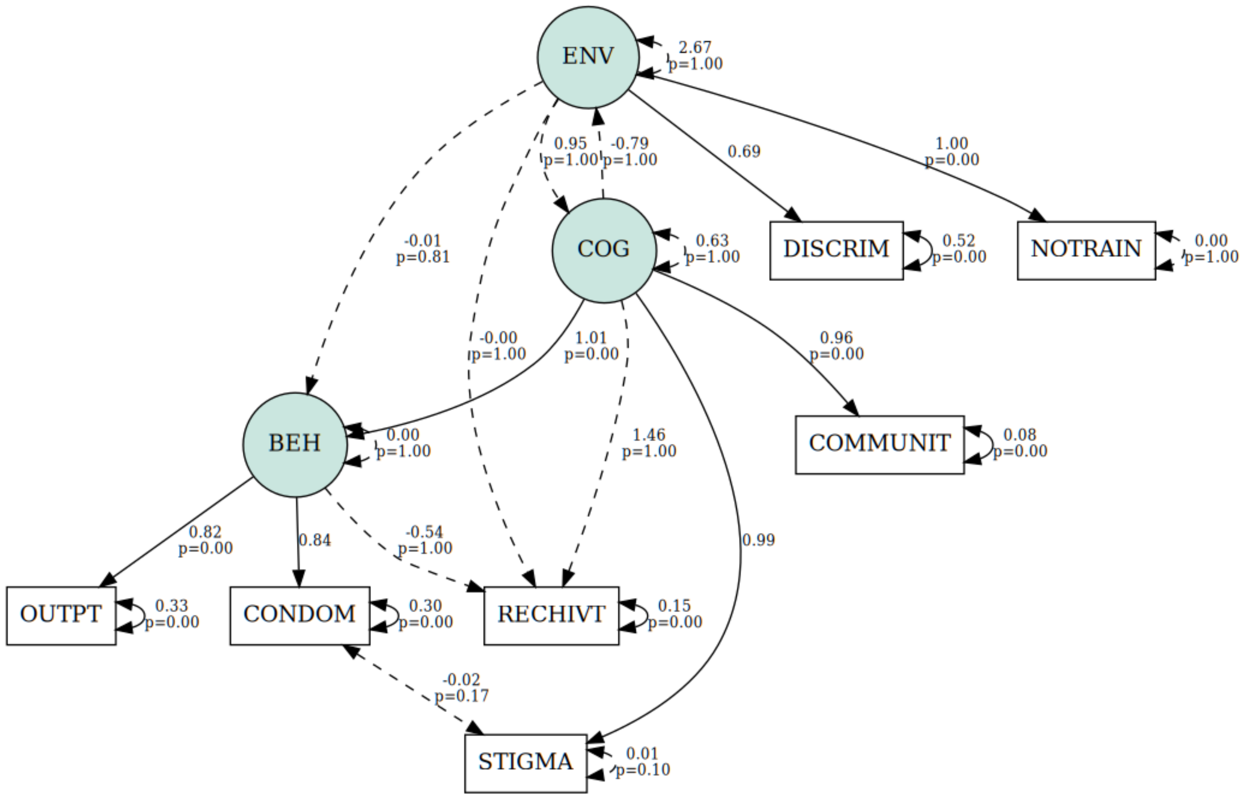
Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 9
STI Plan 1 Step 3 Model



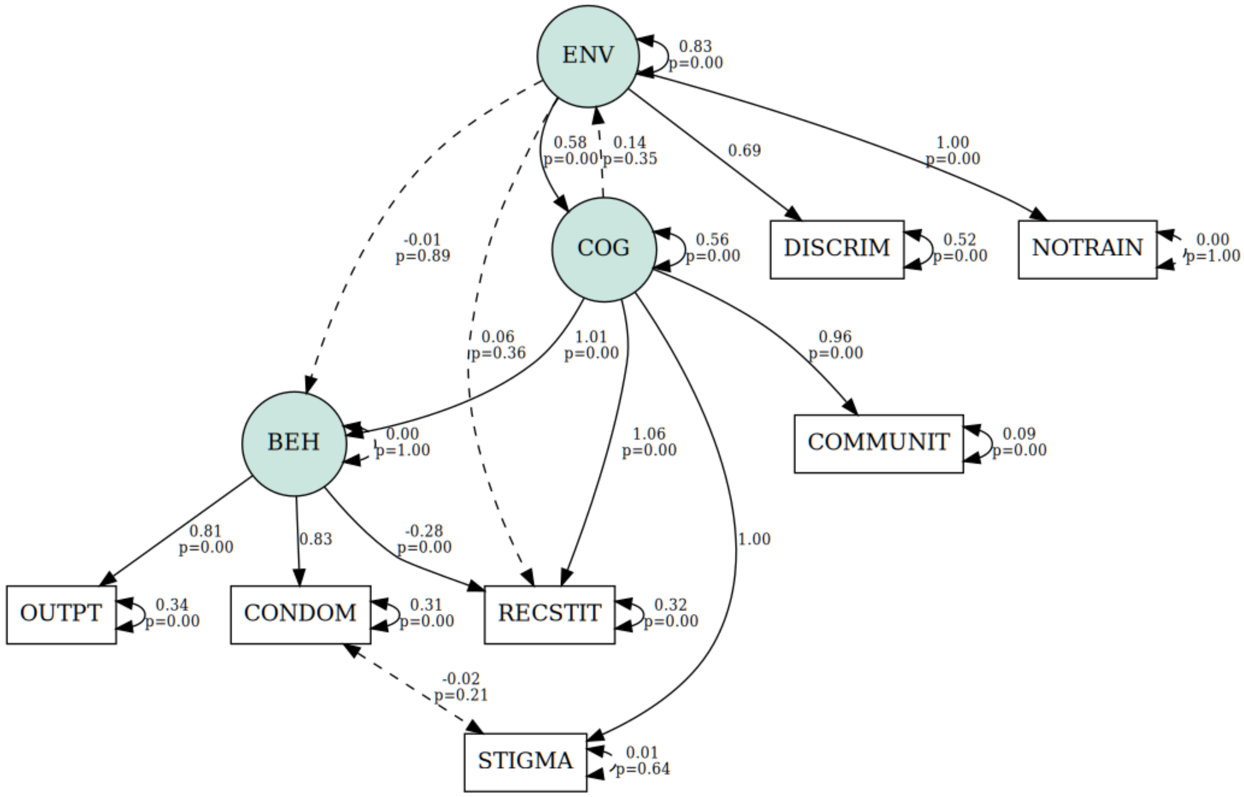
Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 10
HIV Plan 1 Step 4 Model



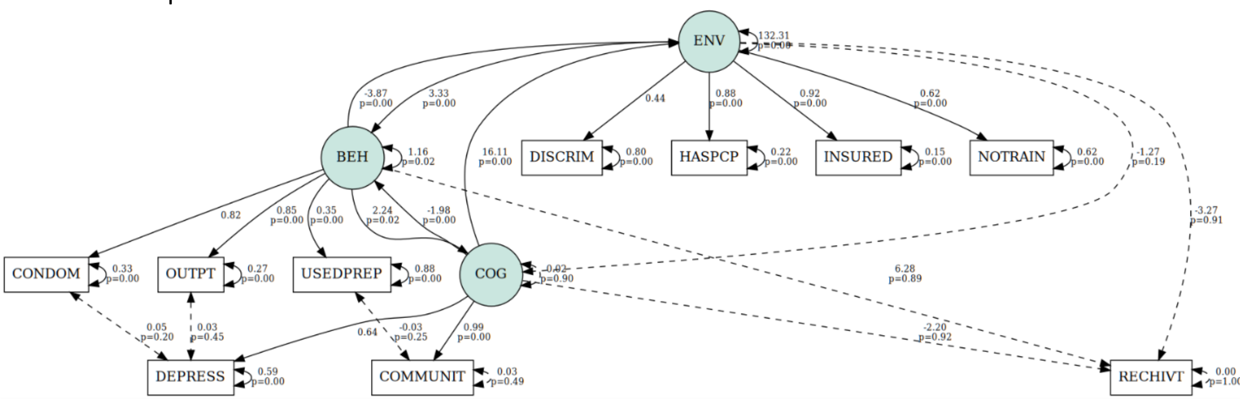
Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 11
STI Plan 1 Step 4 Model



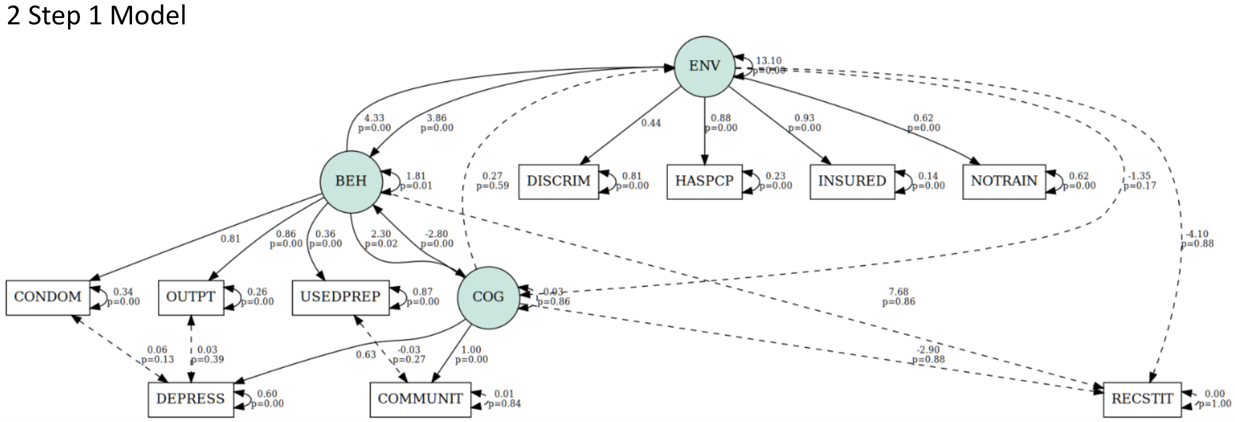
Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 12
HIV Plan 2 Step 1 Model



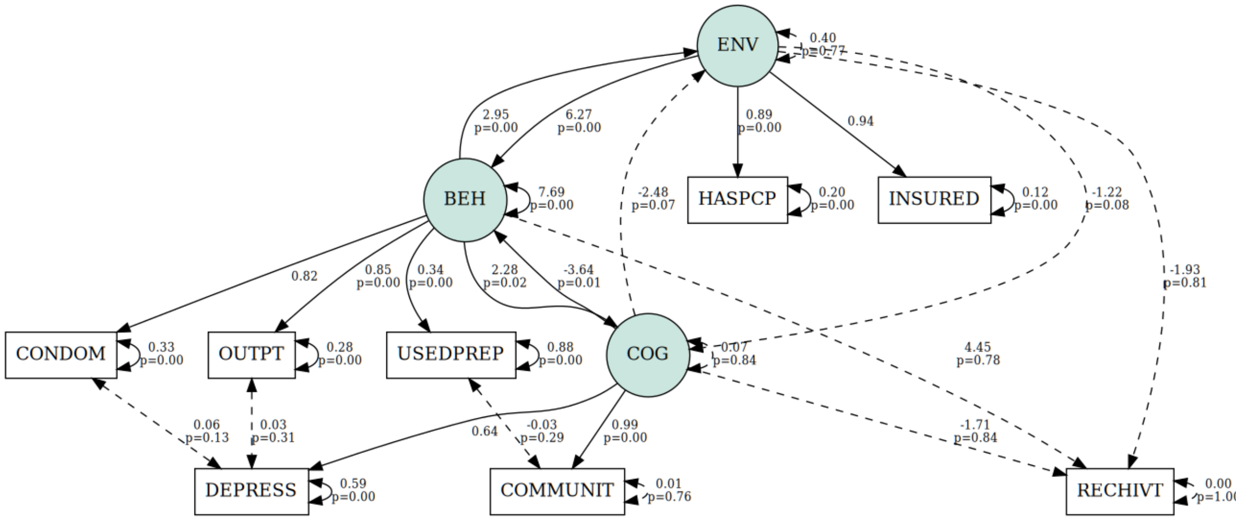
Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 13
STI Plan 2 Step 1 Model



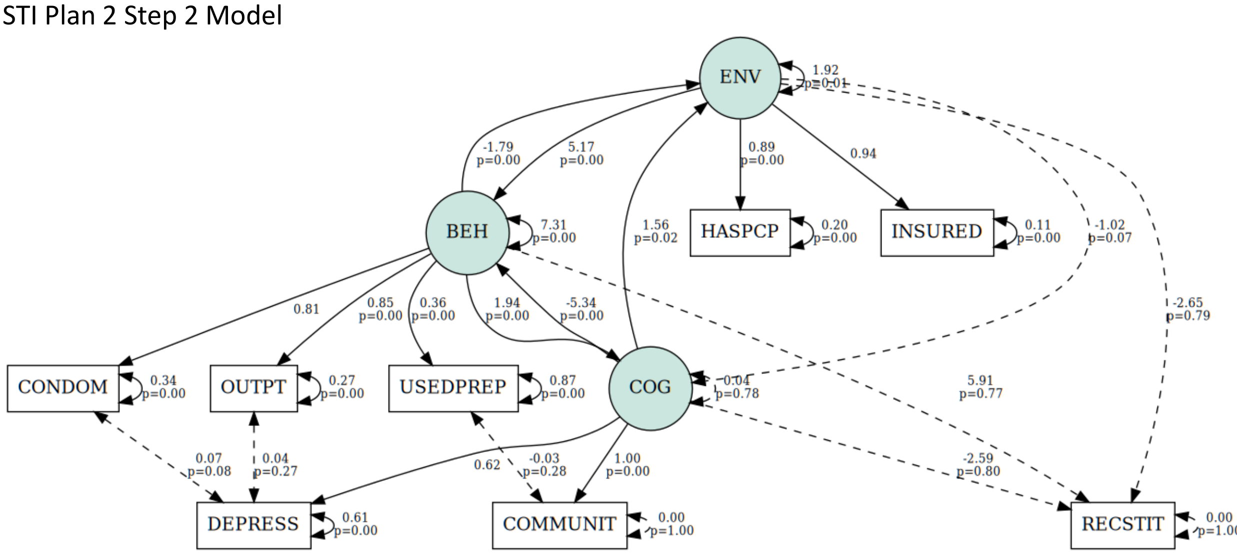
Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 14
HIV Plan 2 Step 2 Model



Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

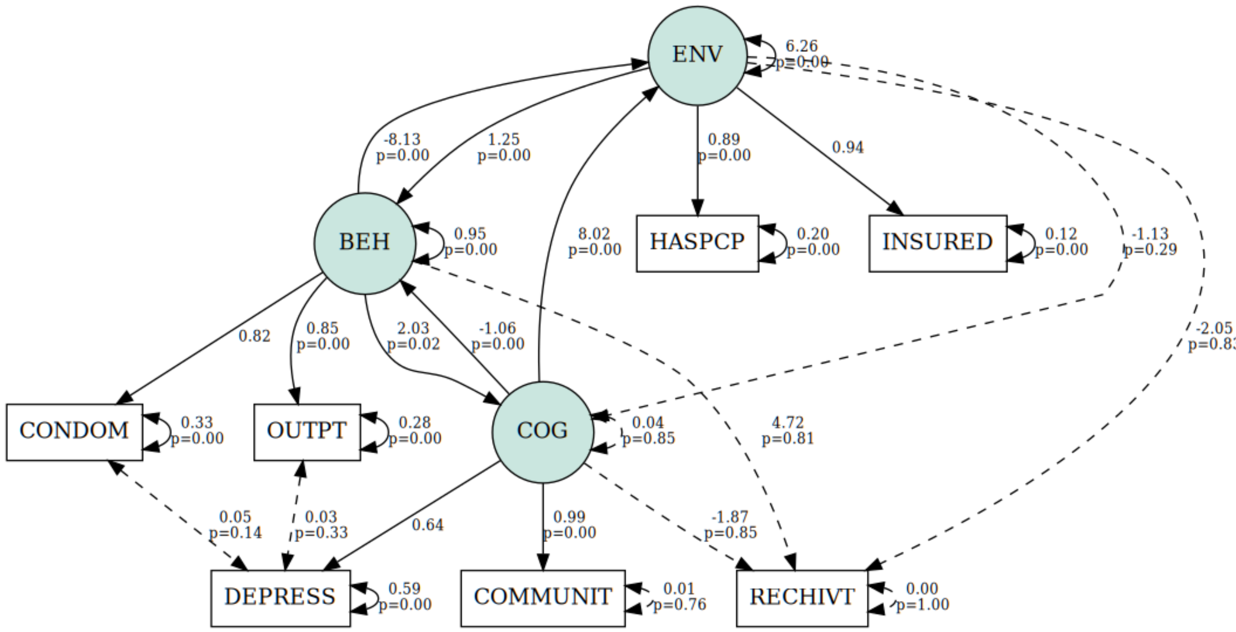
Figure 15
STI Plan 2 Step 2 Model



Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

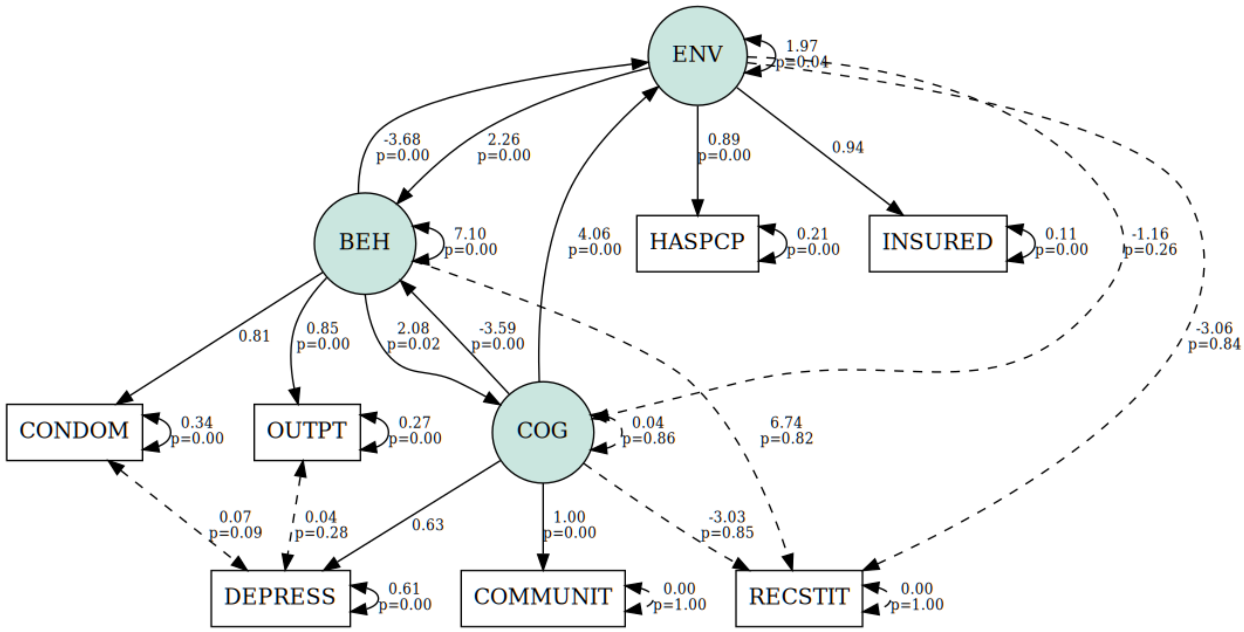
Figure 16

HIV Plan 2 Step 3 Model



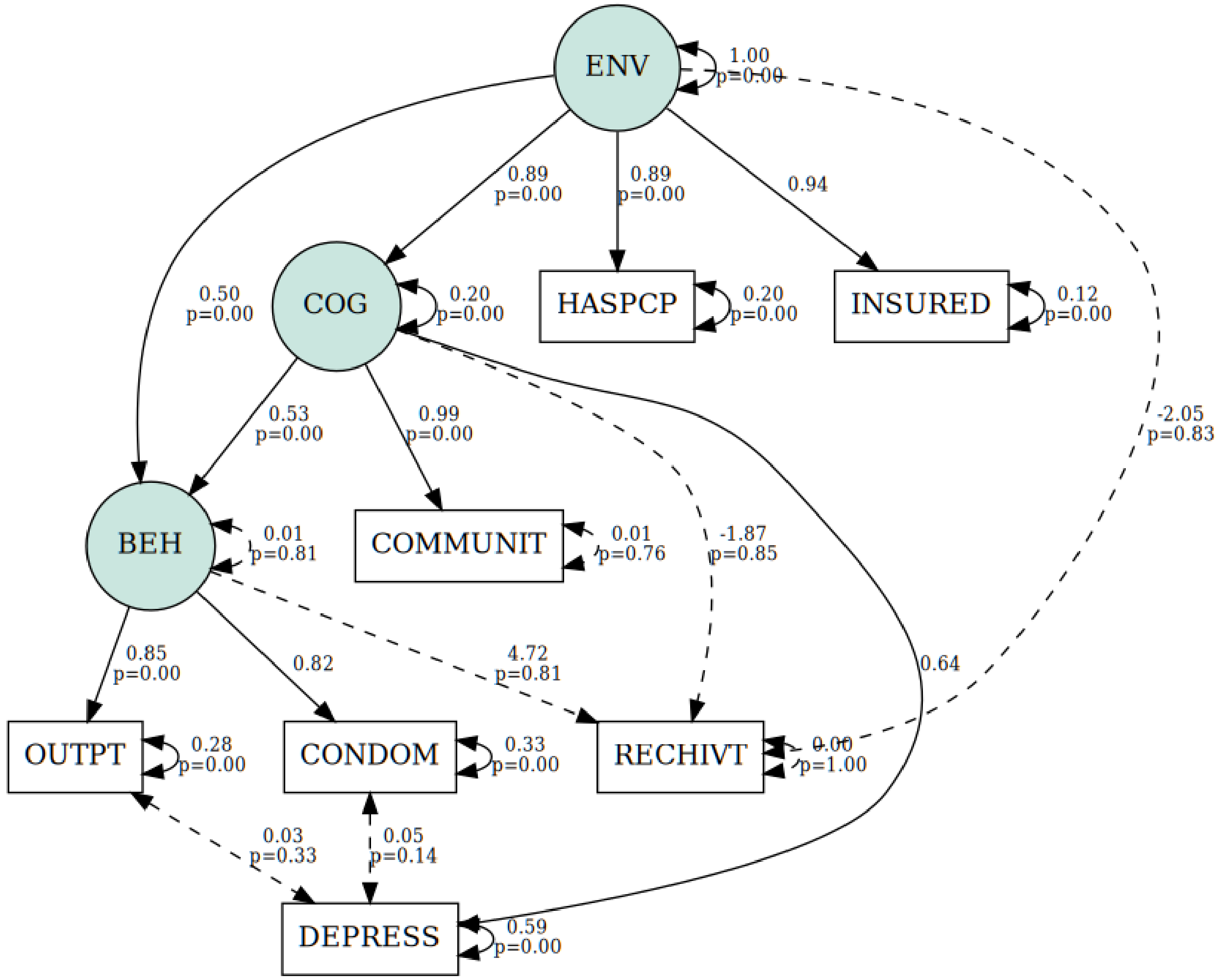
Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 17
STI Plan 2 Step 3 Model



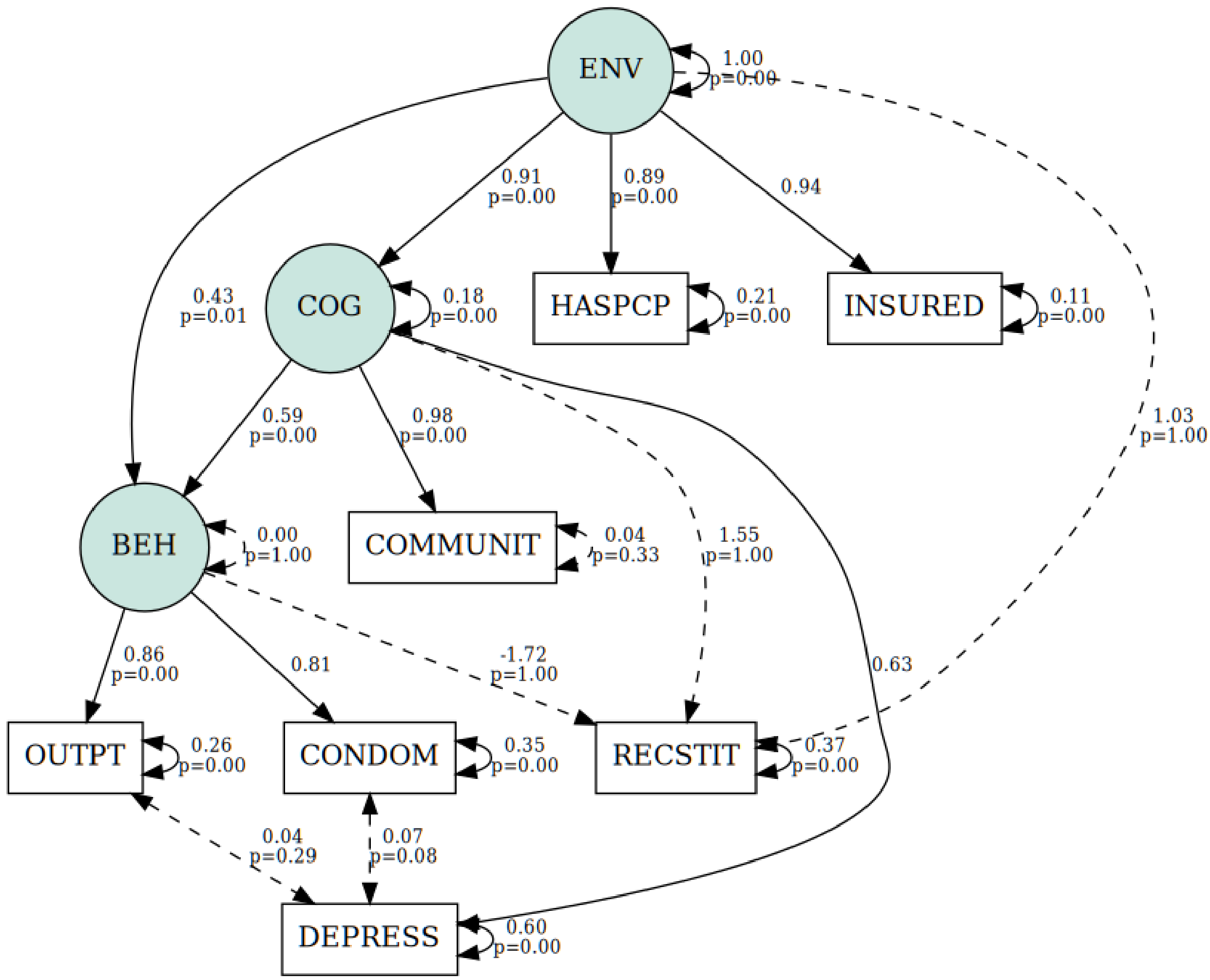
Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 18
HIV Plan 2 Step 4 Model



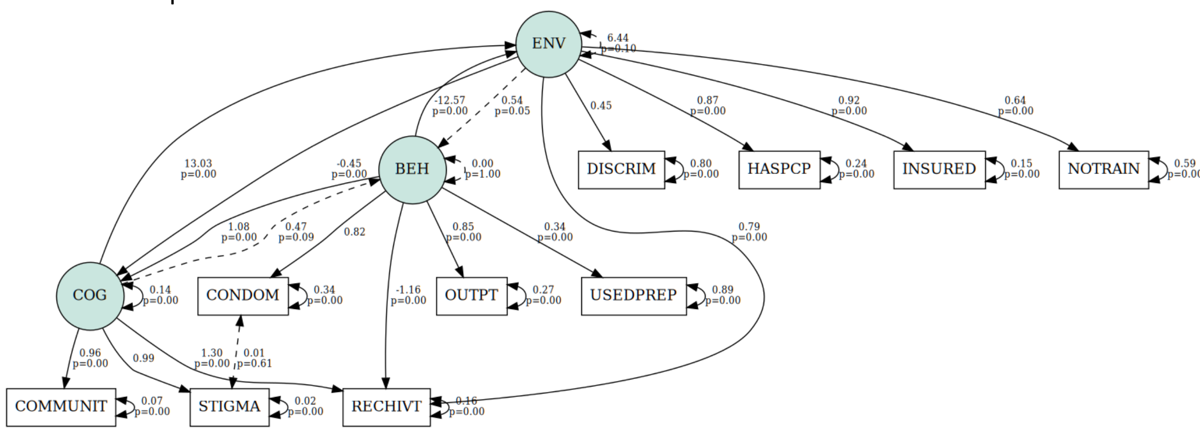
Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, *p* < 0.05. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 19
STI Plan 2 Step 4 Model



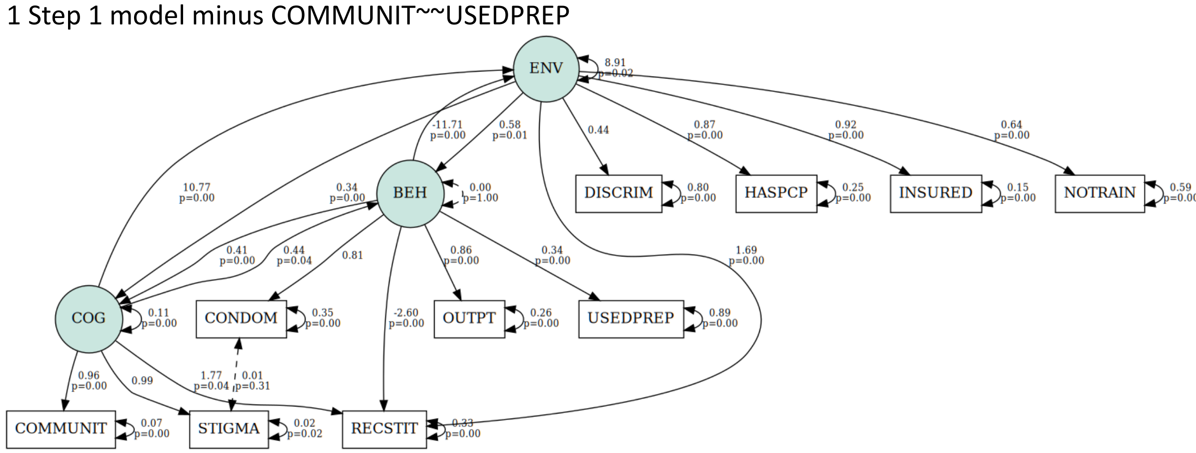
Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, *p* < 0.05. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 20
HIV Plan 1 Step 1 minus COMMUNIT~~USEDPREP



Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 21
STI Plan 1 Step 1 model minus COMMUNIT~~USEDPREP



Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 22
HIV Plan 1 Step 1 minus USEDPREP

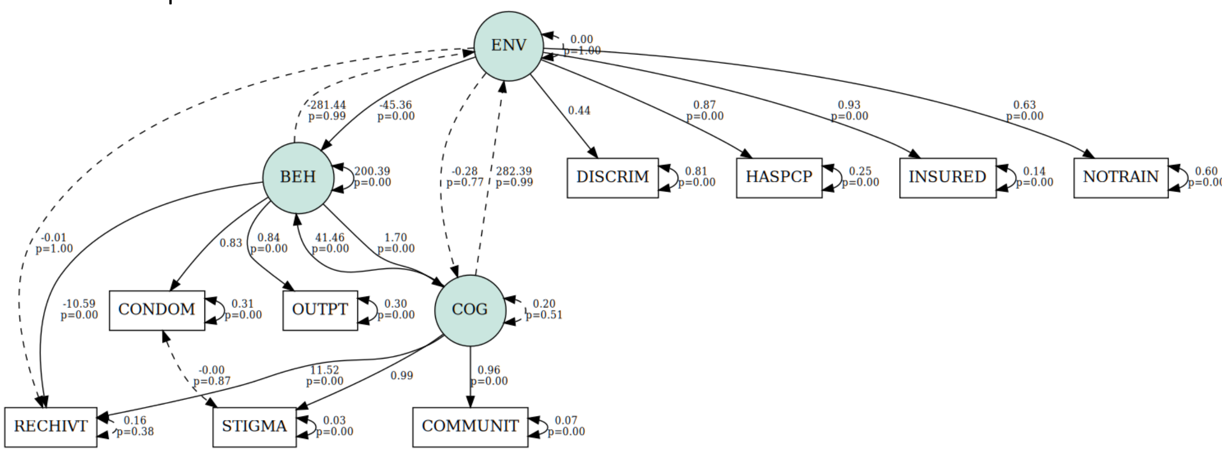


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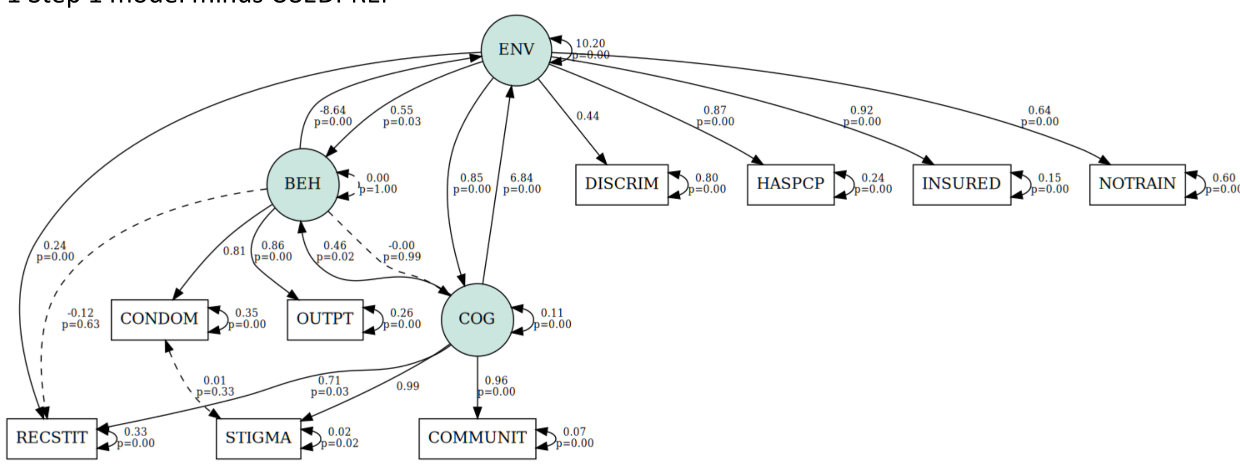
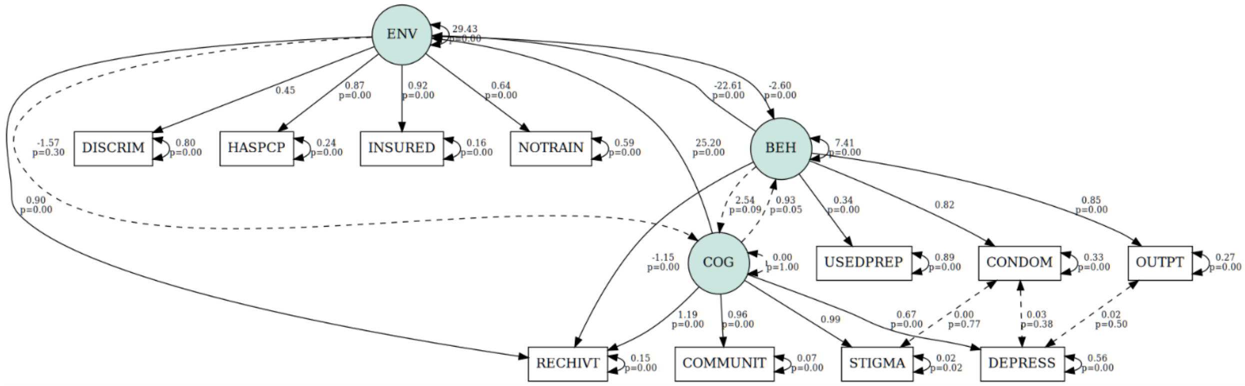
Figure 23
STI Plan 1 Step 1 model minus USEDPREP



Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 24

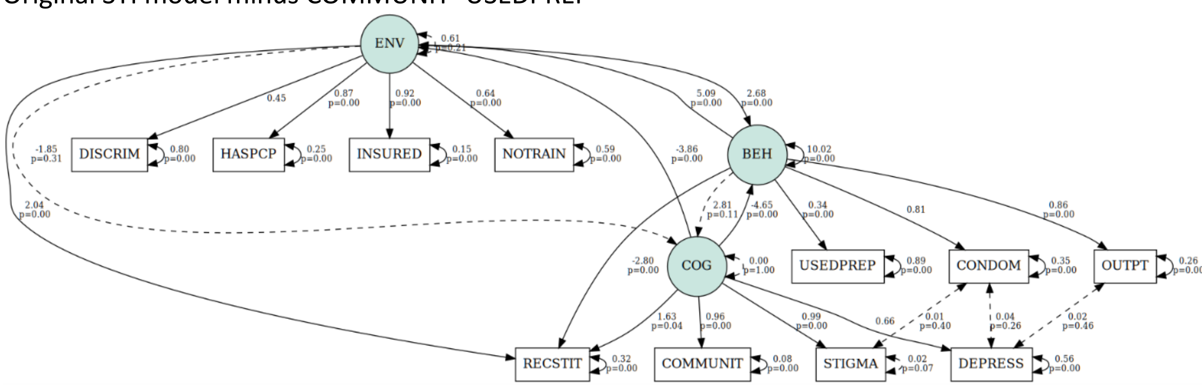
Original HIV model minus COMMUNIT~~USEDPREP



Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

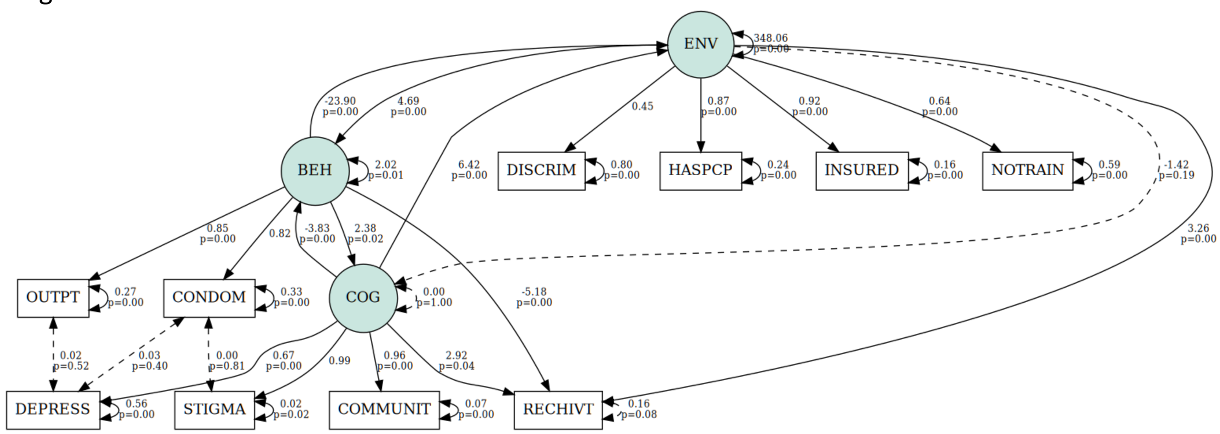
Figure 25

Original STI model minus COMMUNIT~USEDPREP



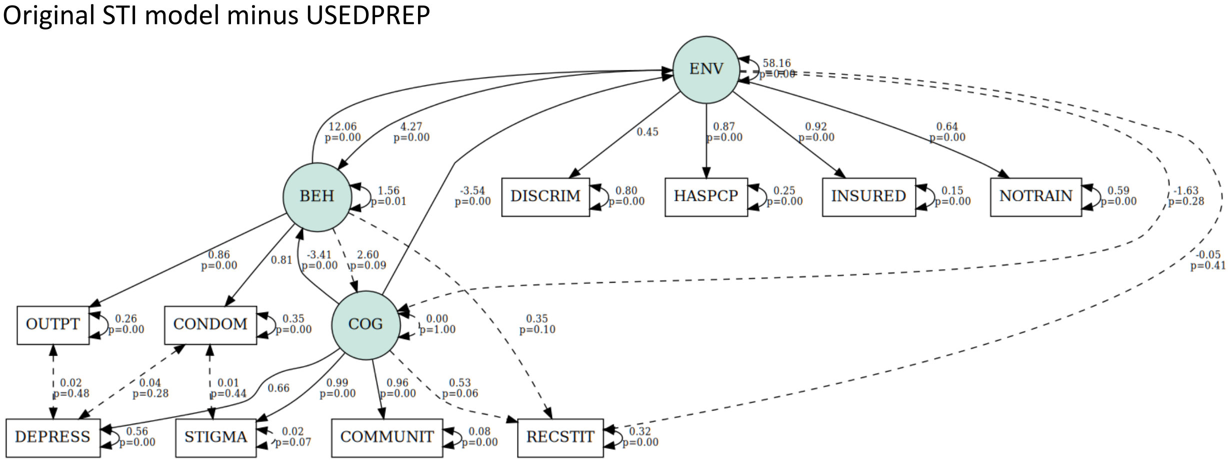
Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 26
Original HIV model minus USEDPREP



Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

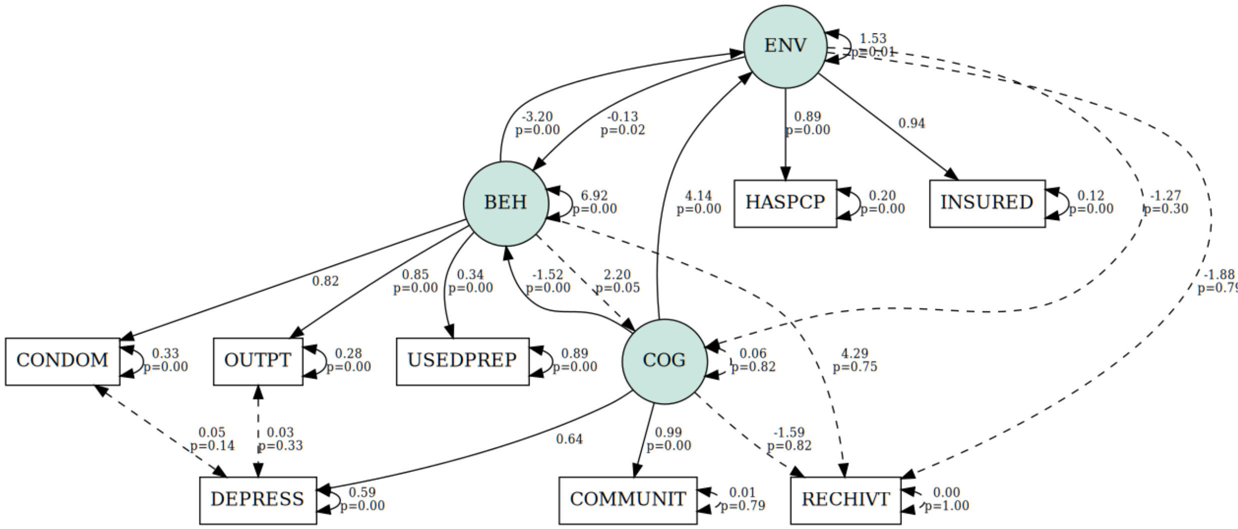
Figure 27
Original STI model minus USEDPREP



Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 28

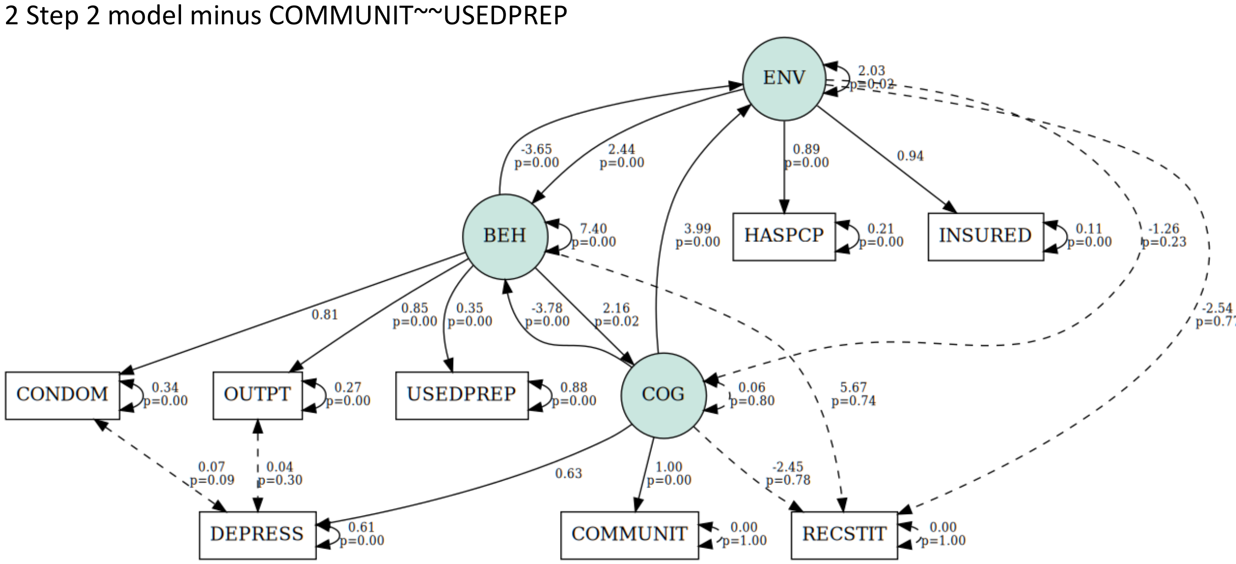
HIV Model 2 Step 2 minus COMMUNIT~~USEDPREP



Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

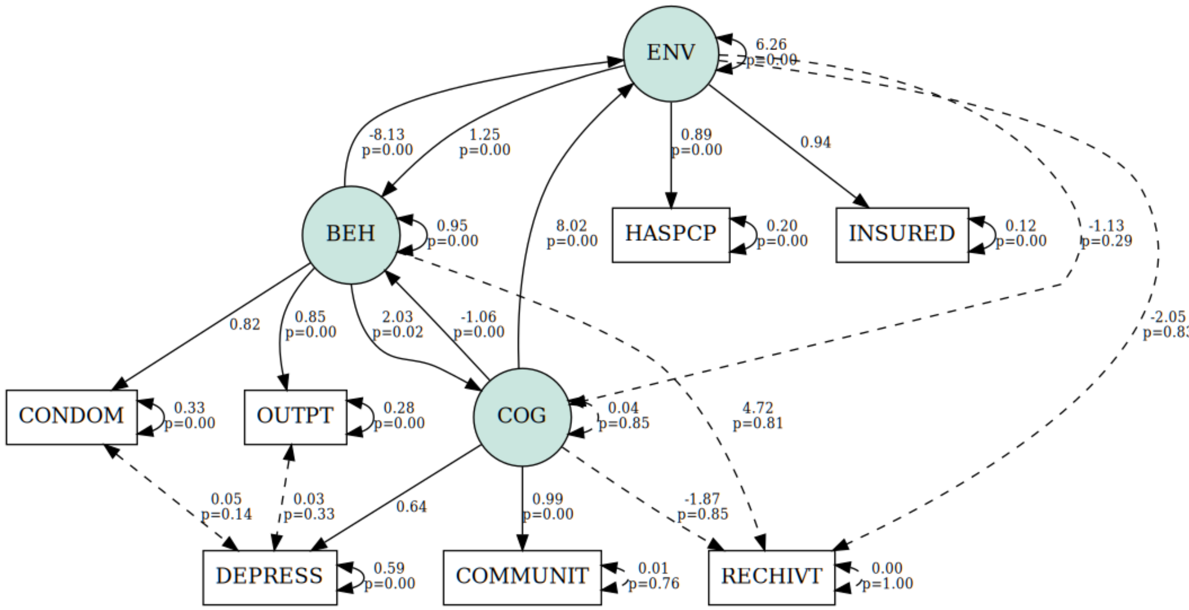
Figure 29

STI Plan 2 Step 2 model minus COMMUNIT~~USEDPREP



Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

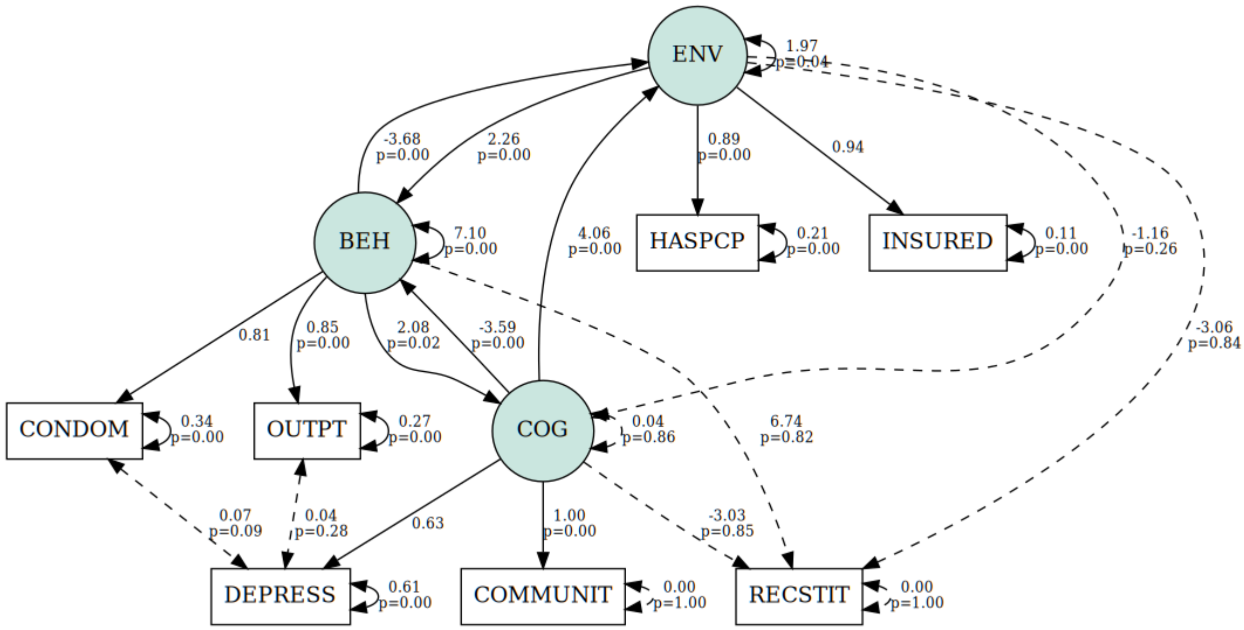
Figure 30
HIV Plan 2 Step 2 model minus USEDPREP



Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 31

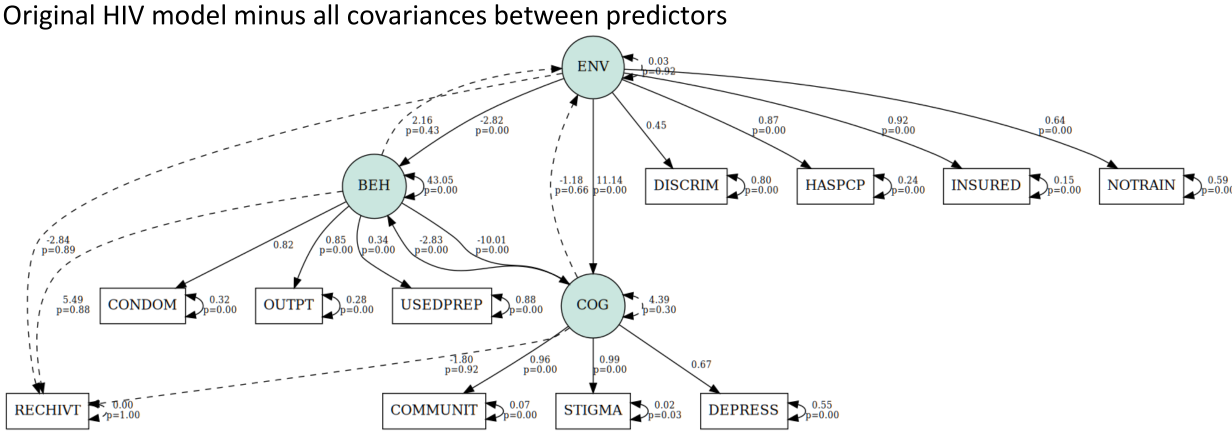
STI Plan 2 Step 2 model minus USEDPREP



Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

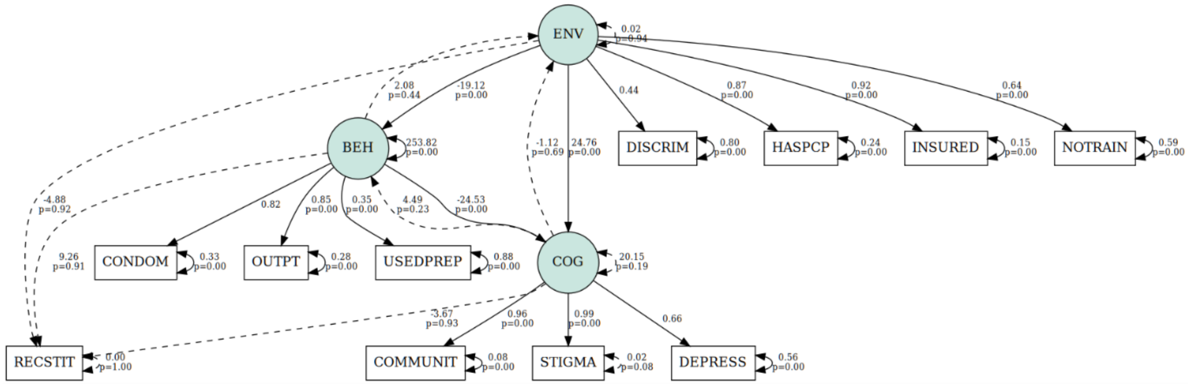
Figure 32

Original HIV model minus all covariances between predictors



Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Figure 33
Original STI model minus all covariances between predictors



Note. Parameter estimates shown are standardized estimates. Solid lines indicate paths representing statistically significant relationships, $p < 0.05$. Dotted lines indicate paths representing relationships which are not statistically significant. One-headed arrows indicate regression relationships. Double-headed arrows indicate variance (when both heads point to same variable) or covariance between variables.

Tables

Table 1

Literature on the Factors that Influence HIV and STI Testing

Paper	Population	Sample Size *or* Studies Reviewed	Sampling Method *or* Focus of Review	Region	Factors HIV	Factors STI	Model HIV	Model STI	Comp.
DeWit & Adam 2008*	General, At-Risk	50	Barriers	English speaking; Mostly US	**BEH**				
Lorenc et al. 2011*	MSM	19	Qualitative	High Income Economies	**BEH**				
Reilly et al. 2014	MSM	448	Venue	New York City, US	**BEH**				
Ayodele 2017	Students	273	Undergraduate	Nigeria	**INT**		**TPB**		
Mirkuzie et al. 2011	Women	3833	Antenatal Care	Ethiopia	**BEH**		**TPB**		
Mo et al. 2018	Sex Workers	183	Online, referral, snowball	Hong Kong	**INT**		**TPB**		
Salud et al. 2014	Asian Americans	299	Undergraduate	California, US	**INT**		**TPB**		
DeVisser & O'Neill 2013	Students	275	Online, opportunity	UK		**BEH**			
Grey 2013	MSM	1254	Online advertising	US		**BEH**			
Booth et al. 2014	Young People	278	Vocational students	Deprived areas, UK city		**INT**		**TPB**	
Dillow & Labelle 2014	Students	193	Undergraduate	Mid-Atlantic, US		**INF**		**MIM**	
Powell et al. 2016	General	118	Google Adwords	Online, Mostly UK		**INT**		**TPB**	
Wombacher et al. 2018	Students	265	Undergraduate	Southeastern US		**BEH**		**MBP**	
Adam et al. 2014	MSM	580	Facebook	Australia	**BEH**	**BEH**			**YES**
Wilkerson et al. 2014	MSM	930	Facebook	US	**BEH**	**BEH**	**SCT**	**SCT**	
Present Study	MSM, Trans F	164	Venue, snowball	Southeastern US	**BEH**	**BEH**	**SCT**	**SCT**	**YES**

Note. Articles marked with an asterisk (*) are review articles. Factors columns indicates paper addressed factors influencing HIV or STI testing. BEH = Behavioral outcomes were assessed. INT = Intentions were assessed. INF = Information seeking/disclosure assessed. Model columns indicates paper discussed a theoretical model of HIV or STI testing. TPB = Theory of Planned Behavior. ARRM = AIDS Risk Reduction Model. MIM = Theory of Motivated Information Management. MBP = Integrated Model of Behavioral Prediction. SCT = Social Cognitive Theory. A YES in the final column indicates paper compared factors influencing HIV behavior and STI testing behavior.

Table 2

Basic demographics of sample

Characteristic	*n*	%
Age Group		
18-36	110	67.07%
37-56	40	24.39%
57-76	14	8.54%
Race		
White/Caucasian	112	68.30%
Black/African American	31	18.90%
Hispanic	8	4.90%
Multiracial	4	2.40%
Asian	1	0.60%
Native Hawaiian/Other Pacific Islander	1	0.60%
American Indian/Alaska Native	2	1.20%
Other	1	0.60%
Prefer not to answer	4	2.40%
Gender Identity		
Male	137	83.50%
Transgender Female	17	10.40%
Genderqueer	4	2.40%
Female	2	1.20%
Transgender Male	1	0.60%
Other	3	0.60%
Identify as transgender or gender non-conforming		
No	138	84.10%
Yes	26	15.90%
Sexual Orientation		
Gay	115	70.10%
Bisexual	22	13.40%
Pansexual	9	5.50%
Straight/Heterosexual	5	3.00%
Queer	3	1.80%
Lesbian	3	1.80%
Questioning	1	0.60%
Other	4	2.40%
Missing	2	1.20%
In a relationship		
No	90	54.90%
Yes	64	39.00%
Missing	10	6.10%

Table 3

Socioeconomic demographics of sample

Characteristic	*n*	%
Income		
Up to $9.999	16	9.80%
$10,000-$14,999	8	4.90%
$15,000-$19,999	5	3.00%
$20,000-$29,999	15	9.10%
$30,000-$39,999	19	11.60%
$40,000-$49,999[a]	23	14.00%
$50,000-$74,999	17	10.40%
$75,000-$99,999	10	6.10%
$100,000 and over	19	11.60%
Prefer not to answer	27	16.50%
Missing	5	3.00%
Education		
Less than high school	3	1.80%
High school diploma or GED	21	12.80%
Some college	50	30.50%
Associates degree or vocational education[a]	19	11.60%
Bachelors degree	30	18.30%
Some graduate/professional school	11	6.70%
Graduate degree	16	9.80%
Doctoral/Professional degree	9	5.50%
Prefer not to answer	2	1.20%
Missing	3	1.80%
Housing		
Own house/apartment	63	38.40%
Rent house/apartment	46	28.00%
Living in home/apartment of someone else	42	25.60%
Homeless	1	0.60%
Other type of occupancy	7	4.30%
Prefer not to answer	2	1.20%
Missing	3	1.80%

Note. [a]sample medians

Table 4

Summary of continuous model predictors in sample studied

Variable	*Mean*	SD	*n*	Missing
Depression	1.63	1.17	161	3
Internalized Stigma	4.01	0.70	139	25
Sense of Community	3.23	0.97	139	25

Table 5

Summary of ordinal model predictors in sample studied

Variable	*n*	%
Condom use during anal sex		
Never	45	27.40%
Sometimes	70	42.70%
Always	36	22.00%
Missing	13	7.90%
Ever used PrEP		
No	105	64.00%
Yes	12	7.30%
Missing	47	28.70%
Uses outpatient healthcare clinics		
No	57	34.80%
Yes	104	63.40%
Missing	3	1.80%
Has health insurance coverage		
No	42	25.60%
Yes	122	74.40%
Missing	0	0.00%
Has Primary Care Provider		
No	59	36.00%
Yes	105	64.00%
Missing	0	0.00%
Endorses discrimination among providers		
Not a problem at all	120	73.20%
Very slight problem	25	15.20%
Somewhat a problem	6	3.70%
Major problem	10	6.10%
Missing	3	1.80%
Endorses problem with providers' training		
Not a problem at all	81	49.40%
Very slight problem	27	16.50%
Somewhat a problem	32	19.50%
Major problem	23	14.00%
Missing	1	0.60%

Table 6

Summary of outcome variables in sample studied

Variable	*n*	%
Recency of HIV Test		
Never	18	10.98%
Over 2 Years Ago	15	9.15%
1-2 Years Ago	27	16.46%
Less than 12 months ago	92	56.10%
Missing	12	7.32%
HIV Test in Last 12 months		
No	60	36.59%
Yes	92	56.10%
Missing	12	7.32%
Recency of STI Test		
Never	38	23.17%
Over 2 Years Ago	26	15.85%
1-2 Years Ago	22	13.41%
Less than 12 months ago	60	36.59%
Missing	18	10.98%
STI Test in Last 12 Months		
No	86	52.43%
Yes	60	36.59%
Missing	18	10.98%

Table 7

Bivariate correlations between demographics, predictors, and outcome variables

Variable	1	2[a]	3[a]	4[a]	5	6[ab]	7	8	9[c]	10[c]	11[c]	12[a]	13[a]	14[c]	15[a]	16[a]
1. Age	-															
2. Race[a]	0.159*	-														
3. Income[a]	0.117†	-0.016	-													
4. Education[a]	0.271**	0.143††	0.266**	-												
5. Depression	-0.103	0.209*	-0.174*	-0.291**	-											
6. Condom Use[ab]	0.001	-0.165*	-0.081	0.031	-0.028	-										
7. Internal Stigma	-0.012	0.114	-0.111	0.011	-0.046	-0.035	-									
8. Community Identity	-0.030	0.017	0.038	0.019	-0.103	0.014	0.228**	-								
9. Insured[c]	0.138††	0.058	0.068	0.339**	-0.344**	-0.017	0.060	0.047	-							
10. Has PCP[c]	0.164*	0.029	0.075	0.132††	-0.222**	-0.035	-0.068	0.112	0.492**	-						
11. Used PrEP[c]	-0.065	-0.138	0.090	0.028	-0.147†	0.021	0.113	0.036	0.066	0.109	-					
12. Providers Discrim.[a]	0.040	0.066	-0.143††	-0.113	0.158*	0.010	0.016	0.024	-0.093	-0.089	0.061	-				
13. Providers Not Trained[a]	0.017	0.115	-0.131†	0.050	0.167*	-0.058	0.153††	-0.214*	-0.097	-0.126†	0.148†	0.590**	-			
14. Uses Outpatient Clinics	0.129†	0.147††	0.061	0.108	-0.025	0.042	0.137†	0.257**	0.296**	0.418**	0.052	0.091	0.089	-		
15. Recency of HIV test[a]	-0.032	-0.125†	-0.165*	-0.086	-0.036	0.245**	0.190*	0.048	0.073	0.093	0.211*	0.116	0.070	0.121†	-	
16. Recency of STI test[a]	-0.081	-0.132†	-0.047	-0.011	0.049	0.188*	0.249**	-0.041	0.102	-0.011	0.320**	0.138††	0.125†	0.095	0.597**	-

Note. Correlations are Pearson's *r*. Ordinal variables are treated as continuous as in other analyses herein (Johnson & Creech, 1983). [a] *ordinal variable* [b] *higher values indicate less frequent condom use* [c] *binary variable, 0=no, 1=yes ** $p < 0.01$ * $p < 0.05$ †† $p < 0.10$ † $p < 0.15$*

Table 8

Model fit indices for original HIV model and Plan 1 modifications

	HIV	HIV Plan 1			
Model	Original[a]	1[a]	2[a]	3[a]	4[a]
df	32	25	10	5	7
χ^2	181601.556**	125427.548**	148429.520**	175439.507**	176028.283**
CFI	0.586	0.659	0.555	0.510	0.509
TLI	0.289	0.386	-0.245	-1.056	-0.474
RMSEA	5.900	5.547	9.542	14.672	12.421

Note. [a]one or more covariance parameter estimates are negative; ** $p < 0.01$

Table 9

Model fit indices for original HIV model and Plan 2 modifications

	HIV	HIV Plan 2			
Model	Original[a]	1[a]	2[a]	3	4
df	32	24	9	4	7
χ^2	181601.556**	159968.149**	105503.034**	132595.616**	132595.619**
CFI	0.586	0.545	0.625	0.566	0.566
TLI	0.289	0.148	-0.167	-1.276	-0.301
RMSEA	5.900	6.394	8.480	14.260	10.780

Note. [a]one or more covariance parameter estimates are negative; ** $p < 0.01$

Table 10

Model fit indices for original STI model and Plan 1 modifications

	STI	STI Plan 1			
Model	Original[a]	1[a]	2[a]	3[a]	4[a]
df	32	25	10	5	7
χ^2	188560.518**	131635.890**	154447.943**	181520.466**	181896.128**
CFI	0.559	0.631	0.522	0.478	0.477
TLI	0.243	0.336	-0.339	-1.194	-0.570
RMSEA	6.012	5.683	9.734	14.924	12.626

Note. [a]one or more covariance parameter estimates are negative; ** $p < 0.01$

Table 11

Model fit indices for original STI model and Plan 2 modifications

	STI	STI Plan 2			
Model	Original[a]	1[a]	2[a]	3	4
df	32	24	9	4	7
χ^2	188560.518**	165009.748**	110298.445**	137561.270**	138213.888**
CFI	0.559	0.516	0.592	0.534	0.532
TLI	0.243	0.093	-0.268	-1.448	-0.405
RMSEA	6.012	6.494	8.671	14.525	11.006

Note. [a]one or more covariance parameter estimates are negative; ** $p < 0.01$

Table 12

Model fit indices for original HIV model and post-hoc modifications

	HIV	without		
Model	Original[a]	PrEP cov	PrEP var	All cov
df	32	33	24	36
χ^2	181601.556**	182094.024**	209068.065**	181827.440**
CFI	0.586	0.585	0.549	0.586
TLI	0.289	0.308	0.154	0.367
RMSEA	5.900	5.818	7.310	5.566

Note. [a]one or more covariance parameter estimates are negative; ** $p < 0.01$

Table 13

Model fit indices for original STI model and post-hoc modifications

	STI	without		
Model	Original[a]	PrEP cov	PrEP var	All cov
df	32	33	24	36
χ^2	188560.518**	188612.228**	215605.715**	188575.061**
CFI	0.559	0.559	0.523	0.559
TLI	0.243	0.265	0.107	0.327
RMSEA	6.012	5.921	7.423	5.668

Note. [a]one or more covariance parameter estimates are negative; ** $p < 0.01$

Table 14

Model fit indices for HIV Plan 1 Step 1 model and post-hoc modifications

	HIV	without	
Model	Plan 1 Step 1[a]	PrEP cov	PrEP var[a]
df	25	26	18
χ^2	125427.548**	125923.994**	153979.350**
CFI	0.659	0.658	0.607
TLI	0.386	0.407	0.215
RMSEA	5.547	5.450	7.244

Note. [a]one or more covariance parameter estimates are negative; ** $p < 0.01$

Table 15

Model fit indices for HIV Plan 2 Step 2 model and post-hoc modifications

	HIV	without	
Model	Plan 2 Step 2[a]	PrEP cov	PrEP var
df	9	10	4
χ^2	105503.034**	105617.509**	132595.616**
CFI	0.625	0.625	0.566
TLI	-0.167	-0.051	-1.276
RMSEA	8.480	8.049	14.260

Note. [a]one or more covariance parameter estimates are negative; ** $p < 0.01$

Table 16

Model fit indices for STI Plan 1 Step 1 model and post-hoc modifications

	STI	without	
Model	Plan 1 Step 1[a]	PrEP cov	PrEP var
df	25	26	18
χ^2	131635.890**	132070.411**	159059.752**
CFI	0.631	0.630	0.583
TLI	0.336	0.360	0.166
RMSEA	5.683	5.582	7.363

Note. [a]one or more covariance parameter estimates are negative; ** $p < 0.01$

Table 17

Model fit indices for STI Plan 2 Step 2 model and post-hoc modifications

	STI	without	
Model	Plan 2 Step 2[a]	PrEP cov	PreP var
df	9	10	4
χ^2	110298.445**	110420.958**	137561.270**
CFI	0.592	0.592	0.534
TLI	-0.268	-0.143	-1.448
RMSEA	8.671	8.230	14.525

Note. [a]one or more covariance parameter estimates are negative; ** $p < 0.01$

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