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What's Impulsivity Got to Do with It? Exploring the Association Between Delay Discounting and Risky Sexual Behavior in Men Who Have Sex with Men

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MS, University of Florida, 2009
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An abstract of
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Abstract

What's Impulsivity Got to Do with It? Exploring the Association Between Delay Discounting and Risky Sexual Behavior in Men Who Have Sex with Men

By Jeb Jones

Men who have sex with men (MSM) experience the highest number of new diagnoses of human immunodeficiency virus (HIV) each year in the United States despite comprising approximately 2% of the population. Additional interventions are needed to increase condom use to reduce HIV transmission in this key group. Delay discounting is a measure of impulsivity that might be related to sexual risk-taking. Delay discounting has the potential to serve as an indicator of risk and as a target for behavioral HIV risk-reduction interventions. We conducted three studies to illustrate the possible role of delay discounting in HIV risk among MSM.

In the first study, we examined the association between monetary and sexual discounting in an online sample of MSM in the United States. Monetary discounting suffers from less social desirability bias compared to measures of sexual delay discounting and, therefore, might provide a more reliable proxy measure of sexual risk. Among 1,012 MSM we did not observe an association between sexual and monetary discounting.

In the second study, we used the same online sample of MSM to examine the association between sexual and monetary discounting and condomless anal intercourse (CAI) in the past 12 months. We did not observe an association between monetary discounting and CAI; however, we did observe a robust association between sexual discounting and CAI. This suggests that men who discount condom-protected sex are more likely to engage in sex without a condom and that monetary discounting would not be a good proxy measure for sexual risk-taking.

In the third study, we used an agent-based model to estimate the potential impact of a delay-discounting intervention on population-level incidence of HIV. Depending on the assumptions that were used in the model, we show that 4-14% of infections could be averted over a ten-year period.

These findings suggest that sexual, but not monetary, delay discounting is associated with sexual risk-taking among MSM and that an intervention targeting delay discounting could result in meaningful decreases in HIV incidence. Future cohort studies should assess the longitudinal relationship between delay discounting and CAI and explore strategies for discounting-based risk-reduction interventions.

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Chapter 1: Background and Significance

Epidemiology of HIV

Men who have sex with men are disproportionately affected by HIV in the United States. The HIV epidemic continues to be a major cause of morbidity and mortality worldwide, with an estimated 2 million new infections globally each year[1]. Although patterns of incidence vary globally, in the United States HIV has had a disparate impact on men who have sex with men (MSM) since the beginning of the epidemic. In 2010, MSM accounted for 63% of all new infections in the US[2], even though MSM are estimated to comprise less than 2% of the population of the US.[3] The disparity in rates of HIV infection is even greater among young MSM aged 13-29 years, specifically young MSM of color: from 2006-2009 there was a 47% increase in HIV diagnoses among young, black MSM compared to a 18% increase among young, white MSM.[4] Overall, the rate of HIV diagnosis among black MSM was 6.0 times higher than white MSM in 2008.[3]

Behavioral HIV Prevention Interventions

There is increasing recognition that HIV prevention interventions will be most effective when used in combination.[5-8] HIV prevention interventions include behavioral interventions targeting reductions in risk behavior, biomedical interventions aimed at reducing exposure to HIV or the likelihood of seroconversion in the event of exposure, and structural interventions designed to change the context in which individuals make behavioral and healthcare decisions.

Behavioral interventions have not been sufficiently effective in ending the transmission of HIV among MSM. To date, behavioral interventions have been modestly

efficacious in reducing the frequency of condomless anal intercourse (CAI)[9], but not in reducing HIV incidence.[6] In addition to the lack of effectiveness of available behavioral interventions, the number of available interventions targeted to MSM is not proportional to the burden of disease experienced by this group. The Centers for Disease Control and Prevention (CDC) maintains a list of behavioral HIV prevention interventions that have been deemed to be effective. As of 2016, a total of 93 effective behavioral interventions (EBIs) are disseminated or supported by CDC. Of these, 13 (14%) are targeted toward MSM and only 4 (4%) are individual-level interventions for MSM.[10] Most of the interventions available have been validated in racially homogenous groups; thus, it is unclear to what degree the observed effectiveness of each intervention will generalize to other racial subgroups.

Overall, there is a dearth of behavioral HIV prevention interventions available to reduce HIV sexual risk-taking among MSM. This can also cause problems with regard to programmatic funding to implement HIV prevention interventions. In order to obtain funding for program implementation from the US CDC, HIV prevention organizations are required to use interventions that have been deemed effective[11]. If these interventions do not exist then this poses a clear challenge to funding HIV prevention for MSM. Biomedical HIV prevention interventions have also been developed, but behavioral interventions will continue to be necessary in order to reduce sexual risk-taking to reduce the spread of HIV and other sexually transmitted infections.

Biomedical HIV Prevention Interventions

Biomedical HIV prevention is accomplished through primary prevention among HIV-uninfected individuals and secondary prevention via treatment of HIV-infected

individuals. Treatment-as-prevention (TasP) is a prevention strategy that involves initiating treatment for HIV-infected individuals in order to reduce their viral load and the probability of HIV transmission to an HIV-uninfected partner. TasP has been shown to be up to 96% effective[12]; however, most of the evidence for TasP has been accumulated in studies of heterosexual couples. It is unclear how effective TasP is in MSM.[13]

Pre-exposure prophylaxis (PrEP) is another promising biomedical prevention intervention. PrEP involves administering antiretroviral medication that is used to treat HIV to HIV-uninfected individuals before exposure in order to prevent infection in the event of HIV exposure. PrEP has been shown to confer strong protection against HIV infection with strict adherence.[14] However, PrEP will be most effective as a public health strategy when targeted to the highest risk individuals.[15] Tools are needed to facilitate such targeting.

Methods for Targeting HIV Prevention Interventions

Risk scores have been developed over the past decade to identify individuals at highest risk of HIV for the purposes of targeting HIV prevention interventions such as increased HIV testing and PrEP: the HIV Incidence Risk Index for MSM (HIRI-MSM)[16], the Menza score[17], and the San Diego Early Test Score (SDET)[18]. However, each of these risk scores has deficiencies that prevent them from performing adequately in the current epidemic.

HIRI-MSM was developed using data from a vaccine trial, VAXGEN 004[19,20], and a randomized-controlled trial of a behavioral HIV prevention intervention, Project EXPLORE.[21] The study populations for each of these trials was overwhelmingly white. In VAXGEN 004, 86% of the men were non-Hispanic white; only 4% were non-Hispanic

black. In Project EXPLORE, 73% were non-Hispanic white and only 7% were non-Hispanic black. Thus, the group that is currently the most disproportionately affected by HIV is drastically underrepresented in each of these study populations.

The Menza score was developed using data from STD Clinics operated by the Seattle-King County Public Health Department. This population was 77% non-Hispanic white. All remaining racial/ethnic groups were reported in aggregate, so it is unclear what proportion were non-Hispanic black. The Menza score was validated using the same Project EXPLORE data that was used for HIRI-MSM.

The SDET score was developed using data collected as part of a study investigating acute HIV infection. The available cohort was dichotomized into a derivation and validation cohort. The overall study population was 67% non-Hispanic white; only 6% were non-Hispanic black.

The underrepresentation of black men in the study populations used to derive and validate the available risk scores calls into question the utility of these scores to identify black MSM at high risk of HIV. In fact, when tested in the Involve[men]t cohort, a cohort of non-Hispanic black and white MSM in Atlanta, Georgia, each score had low sensitivity to predict later seroconversion among black MSM. The sensitivity of HIRI-MSM, Menza, and SDET to predict seroconversion over the two-year follow-up period was 63%, 63%, and 25% respectively. However, the scores performed better among white compared to black MSM. HIRI-MSM had 75% sensitivity for white men compared to 58% for black men, Menza had 88% sensitivity for white men compared to 54% for black men, and SDET had 50% sensitivity for white men compared to 17% sensitivity for black men.[22]

The low sensitivity to predict seroconversion among black MSM for each of these scores indicates that different scores and criteria are needed and that additional inputs might help to increase the sensitivity of the scores. Improved tools are needed to aid in the efficient allocation of HIV prevention intervention resources. To be economically sustainable and to have the greatest impact, HIV prevention interventions should be delivered to those individuals or groups that are at greatest risk of acquiring and/or transmitting HIV.

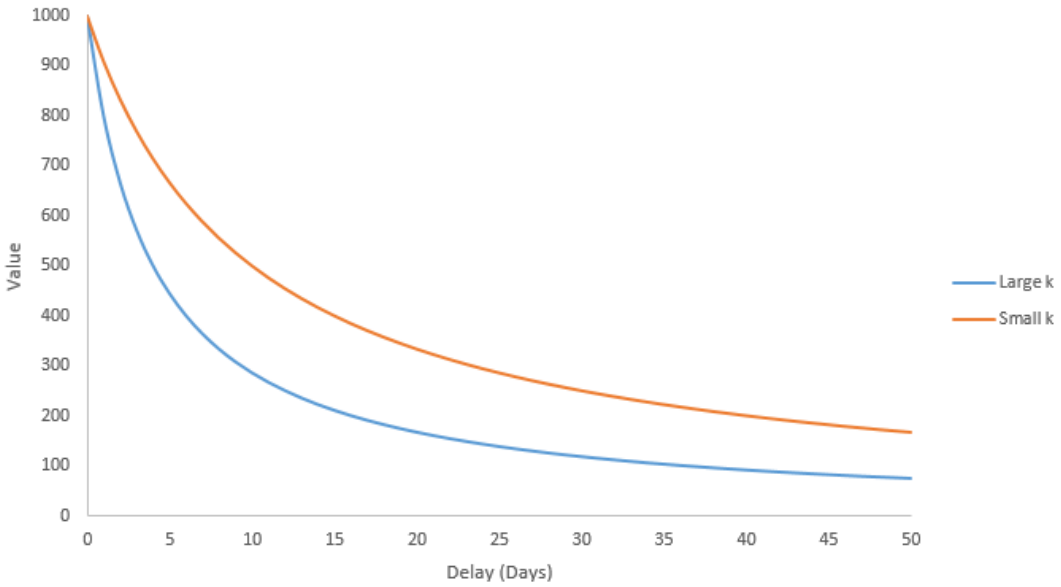
Delay Discounting

Outside of the setting of HIV preventions, delay discounting has been shown to be associated with a number of behaviors related to impulsive decision-making and might be a useful tool to help identify individuals at highest risk of HIV. Delay discounting is a measure of impulsivity describing an individual's tendency to select smaller rewards available immediately or at a short delay over larger rewards available after a longer delay. The decay in value of a delayed reward has been shown to be hyperbolic in nature, reflecting a tendency for individuals to shift preferences from the larger later reward to the smaller sooner reward as the delay to the latter decreases[23]. The hyperbolic form of the discounting function is described by Equation 1

(1) $$V = \frac{A}{1+kD}$$

where V is present value, A is an amount of money, D is the delay until that money is available, and k is a free parameter that is estimated and describes a given individual's monetary discount rate.[23] Assessments are available to derive an individual's k value. Based on Equation 1, larger values of k result in greater reductions in the present value of delayed rewards, indicating steeper delay discounting (Figure 1.1).

Figure 1.1. Differences in delayed value of $1000 for different values of the monetary delay discounting parameter *k*.



Measuring Monetary Delay Discounting

Delay discounting is most commonly measured with respect to monetary outcomes. In a monetary delay discounting task, an individual is presented with a series of dichotomous choices between a certain amount of money available immediately or at a short delay versus a larger amount of money available at a longer delay. In the classic procedure, the delays and monetary amounts are varied until an indifference point is determined.[24] The indifference point specifies the present subjective value of money available in the future. For instance, an individual might be indifferent between receiving $10 today versus $11 one week from today. This titrating procedure can be time consuming, sometimes requiring hundreds of individual choice trials.[24] A shorter monetary delay discounting assessment, the Monetary Choice Questionnaire (MCQ) has been developed.[25] The MCQ is a 27-item questionnaire that can be used to assign an individual's discount rate (*k*). The MCQ can be completed much faster than a traditional

monetary delay discounting task and correlates well with the results obtained from those tasks.[26]

Delay Discounting and Health Outcomes

In a delay discounting framework, the choice to use a drug rather than abstain is viewed as an impulsive choice of a smaller sooner reward over the larger later reward of better health, sustained employment, and more rewarding interpersonal relationships. Delay discounting has been found to be associated with abuse of various substances including alcohol[27,28], cocaine[29], heroin[25,30,31], methamphetamine[32], and nicotine.[33-38] That is, individuals who discount money more steeply are also more likely to be substance abusers. Substance users have also been found to discount their substance of choice more steeply than money.[28,31] Heroin users who are willing to share needles discount money more steeply than those who are not willing to share needles.[31]

Cigarette smokers[39] and heroin and cocaine abusers[40] have been found to discount delayed health outcomes at higher rates than non-substance using controls. In these studies, long-term illnesses to be experienced in the future were discounted more by substance users than by non-users. For example, a 10-year long extended illness beginning one year from now was equivalent to a 5 year illness starting immediately for smokers. For non-smokers the same 10-year illness to begin in the future was the same as an 8.5 year long illness starting now.[39] This indicates that the severity of the future disease was discounted among smokers, indicating that it might have less control over current behavior.

Delay discounting has also been found to be associated with eating behaviors and obesity[41], and individuals more focused on immediate consequences tend to make less

healthy food choices compared to individuals focused on delayed consequences.[42] For example, monetary delay discounting has been shown to be positively correlated with high body mass index (BMI). However, the reported Spearman correlation coefficient is 0.30, which, although statistically significant, indicates that there is a large amount of variation unaccounted for.[41]

Although most studies investigating delay discounting with respect to health behaviors have been cross-sectional, longitudinal studies have demonstrated that discounting of delayed rewards is predictive of future health-related behavior. Adolescents who discount delayed rewards more steeply than their peers are more likely to initiate cigarette smoking.[33] Delay discounting is predictive of treatment effectiveness for some health behaviors: individuals who discount delayed rewards more steeply are more likely to relapse sooner.[43-46] This has been shown in adolescents[45] and adults who smoke and drink[44] who participated in smoking cessation interventions. Delay discounting also predicts postpartum smoking among women who stopped smoking while pregnant.[46] In a laboratory model, individuals with higher monetary discount rates were more likely to smoke during an abstinence reinforcement procedure.[35]

Measuring Sexual Delay Discounting

Under the delay discounting paradigm, delay discounting might be expected to be associated with risky sexual behavior. For instance, the choice to have sex without a condom when one is not available can be conceptualized as a smaller sooner reward compared to the choice to wait until a condom is available and have the larger later reward of potential sexually transmitted disease avoidance. A Sexual Discounting Task (SDT) has been developed[47] in which participants choose between sex with a partner

immediately without a condom or at various delays with a condom. To complete the SDT, participants view an array of images of potential sexual partners and are asked to identify the ones they find sexually attractive. The SDT typically includes images of men and women; however, in the current studies only images of men were used. Next, of the selected images, participants identify the men they would most and least like to have sex with and the men they believe are most and least likely to have a sexually transmitted infection (STI). For each of the selected men, participants use a visual analog scale to indicate their preference between immediate sex without a condom and sex with a condom at seven different delays (1 hour, 3 hours, 6 hours, 1 day, 1 week, 1 month, and 3 months). A no-delay condition, in which the choice is between immediate sex with a condom and immediate sex without a condom, is used in order to control for individual differences in condom use preferences.

Using the SDT, sexual discounting has been shown to be hyperbolic in nature in multiple populations, similar to monetary discounting.[47-50]

Delay Discounting and Sexual Behavior

Preliminary evidence suggests that delay discounting is associated with risky sexual behavior. Studies of undergraduate populations have found the duration of hypothetical sexual activity is discounted hyperbolically[51] similar to monetary outcomes and that discount rates of hypothetical money and hypothetical sexual activity are correlated.[52] Alcohol-dependent individuals have been shown to discount the number of hypothetical sexual acts at a higher rate than non-alcohol-dependent controls.[53] Monetary delay discounting has been shown to be associated with condomless sex in the context of

co-occurring alcohol use, suggesting that substance use might modify the effect of delay discounting on risky sex.[54]

I have previously conducted a study investigating the association between monetary delay discounting and risky sexual behavior in an online sample of MSM.[55] In that study, in a survey of 1,402 MSM, the prevalence odds ratio for reporting multiple (>2) CAI partners in the previous 12 months was higher for MSM who discounted delayed rewards at the highest level. In subsequent analysis of these data, the effect of age on the association between delay discounting and CAI was examined.[56] This analysis revealed an interaction of age in which monetary delay discounting is associated with CAI in MSM age 18-24 years, but not associated with CAI in MSM age 25 years and above (Table 1.1). Based on these preliminary data, we focused our recruitment efforts on young MSM. Young MSM have the highest age-specific HIV incidence in the United States, and are the only age-specific group for whom HIV incidence has increased in the past decade.[57]

Table 1.1. Adjusted prevalence ratios (PR) and confidence intervals for condomless anal intercourse with any and multiple partners in the past 12 months.

	<25 years old		≥25 years old	
Variable	PR (95% CI)	p	PR (95% CI)	p
Any Condomless Anal Intercourse				
Delay Discounting*				
Low	Ref		Ref	
High	1.18 (1.05, 1.32)	<0.01	0.95 (0.84, 1.08)	0.46
Condomless Anal Intercourse with 3 or More Partners				
Delay Discounting*				
Low	Ref		Ref	
High	2.37 (1.62, 3.46)	<0.01	1.06 (0.76, 1.48)	0.74

*Adjusted for education and income.

Johnson et al. found that higher rates of discounting on the SDT, but not monetary discounting, were associated with risky sexual behavior in a group of cocaine-dependent individuals. The populations in these studies have been predominantly heterosexual and comprised of both men and women. All published studies assessing delay discounting and risky sex have been cross-sectional in design and most have not controlled for potential confounding variables.

Neuroscientific Basis for Potential Age Effects in Delay Discounting Studies

There is neurodevelopmental evidence that supports a possible age effect in the association between monetary delay discounting and risky sexual behavior. Steinberg[58] notes two primary reasons that risk-taking tends to decline as individuals transition from adolescence into adulthood. First, the prefrontal cortex continues to develop leading to greater planning ability and reduced impulsivity. Second, increased connectivity of different brain structures allows for enhanced integration of cognitive and emotional reasoning which results in less impulsive or risky behavior. There is evidence that delay discounting declines with age and reaches stable levels around age 30.[59,60]

Based on evidence that different neural systems are involved in decision-making regarding immediate versus delayed rewards[61], Bickel et al[62] have suggested a model in which neural systems compete to affect the selection of smaller, sooner versus larger, later consequences. Specifically, they propose that the limbic system, which plays an important role in affect and emotion, contributes to decisions in favor of smaller, sooner rewards (i.e, impulsive choices), whereas the executive functioning of the prefrontal cortex contributes to decisions in favor of larger, later rewards. An imbalance in these neural systems in which the limbic system is overactive relative to the prefrontal cortex

would result in increased impulsivity. That these systems continue to develop throughout adolescence and young adulthood[58] indicates that this could lead to age-based differences in delay discounting.

Delay Discounting: Trait or State?

Whether delay discounting functions as a state variable or a trait variable will inform the utility that it might have with respect to sexual risk-taking and HIV prevention. A state variable is a modifiable psychological condition.[63] It is something that is transient and can be affected by external manipulations. State variables can be psychological in nature, such as the anxiety one experiences at a traffic stop; physiological in nature, such as the effects of alcohol that caused the traffic stop; or environmental, such as the appearance of the police officer that causes an individual to act with more deference than usual[64]. Trait variables, in contrast, are differences that vary across individuals and are considered to be less modifiable than states and tend to remain stable over extended periods of time.

If delay discounting is a state variable – one that is modifiable by external stimuli – then delay discounting could serve as a target for behavioral interventions designed to reduce delay discounting. If, however, delay discounting is a trait variable – one that is relatively stable and less subject to external modification – then delay discounting per se might not be as easily amenable to intervention. Rather, as a trait variable, delay discounting could serve as a useful indicator of an individual's tolerance for sexual risk. Odum[65] conducted a secondary analysis of multiple studies of delay discounting and found concordance in the degree of delay discounting across multiple domains (e.g., money, food, substance of choice), suggesting that delay discounting is a relatively

consistent characteristic within an individual. This also suggests that interventions that target delay discounting in one domain might influence discounting in other domains.

If delay discounting is more trait-like than state-like, interventions could still be developed to target other psychological or behavioral characteristics related to delay discounting; such interventions have been developed targeting non-sexual outcomes. For example, an intervention that used working memory training has been shown to decrease the degree of delay discounting among individuals seeking treatment for substance use.[66] In another study, a money-management intervention was found to decrease delay discounting and subsequent cocaine use in individuals undergoing treatment for cocaine use.[67] These studies provide evidence that delay discounting is modifiable and, in particular, the latter study provides evidence that interventions targeting delay discounting in one domain (i.e., money) can have effects on other problematic behaviors (i.e., substance use).

An individual's degree of discounting could also be used to inform they type of intervention that might be most beneficial. That is, an individual that steeply discounts delayed consequences might be best served by risk reduction interventions that focus on immediate consequences.[63] Continued research is needed to characterize delay discounting as a trait or a state variable. In a review of the literature, Odum[63] argues that delay discounting has characteristics of both state and trait variables. Regardless, evidence exists that suggests that delay discounting or related processes can serve as the basis for behavioral interventions.

Potential Utility of Delay Discounting in HIV Prevention

Delay discounting provides a potential target for behavioral interventions to reduce sexual risk-taking and HIV risk behavior. As discussed above, interventions targeting delay discounting have been developed.[66,68] To the extent that delay discounting is causally related to risky sexual behavior, interventions targeting a reduction in delay discounting might also reduce the occurrence of risky sexual behavior. There is evidence that delay discounting is a trait variable[65,69], suggesting that interventions designed to address delay discounting in one domain (e.g., monetary) would possibly generalize to delay discounting related to other domains (e.g., sexual).

Delay discounting might also be useful as a screening device to suggest which individuals might need further evaluation for HIV prevention services. If delay discounting can be used to identify individuals more likely to engage in risky sexual behaviors, it could be an additional tool to aid in the targeting of limited public health resources to those individuals at highest risk of seroconversion. Further, a delay discounting task has the added benefit of being less susceptible to social desirability bias than self-reports of specific behaviors.[70] Specifically, to complete the MCQ a participant indicates a preference between two amounts of money at two different times. There is no clear 'right' or 'wrong' answer. The SDT might suffer from more social desirability bias because the participant indicates a preference between condomless sex immediately and condom-protected sex at a delay. However, it is reasonable to expect that the responses to either of these questionnaires will be more reliable than assessments of self-reported sexual behavior.

Further evidence of the concordance of delay discounting across domains – and the effect of interventions targeting each domain – is needed. A syndemic of health problems has been identified among MSM in the United States[71], including risky sexual behavior and substance use, and the need for interventions targeting multiple health behaviors in this population has been noted.[72] Delay discounting has the potential to serve as a unifying target underlying these frequently co-occurring behaviors, but existing research has rarely focused on delay discounting among MSM.

Agent-based Modeling in Infectious Disease Epidemiology

Epidemic modeling provides a method for estimating and evaluating situations that are counterfactual to observation and have been used extensively to evaluate mechanisms of disease spread[73]. Such models can be used to evaluate hypotheses regarding disease transmission and to estimate the effects of increasing coverage of interventions on disease incidence. Broadly, there are two types of models that are typically used: deterministic compartmental models and stochastic agent-based models.[74]

Compartmental models employ a series of differential equations to describe the processes of disease susceptibility, transmission, infection, recovery, and death. Such models are deterministic because they are described by equations with closed-form solutions and provide consistent results based on a given set of inputs. The results of a compartmental model reflect the average (i.e., expectation) state of a population given the input parameters.

Agent-based models, on the other hand, are models that describe virtual populations of individuals (i.e., nodes) which form and break relationships (i.e., edges) over time. Dynamic agent-based models are based on separable, temporal, exponential-

family random graph models (STERGMs).[75] Exponential-family random graph models (ERGMs) describe network connections at a given point in time.[76] STERGMs extend ERGMs by describing changes in edges over time, effectively generating a temporal sequence of cross-sectional networks in which edges can form, break, and be maintained over time.[75] The nodes in an agent-based model have attributes which stochastically govern edge formation, disease susceptibility, and behaviors associated with disease transmission (e.g., condom use). Unlike deterministic models, agent-based models do not have closed-form solutions and are therefore solved via simulation.[77] Agent-based models allow for the examination of much more complex processes than deterministic models. For example, agent-based models help to quantify the role of chance in disease outcomes and allow the outcomes of each individual in the population to be tracked[77].

Agent-based models are a valuable tool for estimating potential impact of public health programs at the population level. For example, agent-based models have been used to demonstrate the expected population level impact on HIV incidence of various combinations of HIV prevention interventions at different levels of coverage[6,78] and to estimate the impact of different prescribing guidelines for PrEP.[79] Thus, these models provide a method for developing estimates of the potential impact of a delay-discounting intervention on HIV incidence.

Dissertation Aims

The purpose of this dissertation is to further explore the relationship between monetary and sexual discounting and risky sexual behavior among MSM. In Aim 1, I will examine the concordance between monetary and sexual discounting to assess whether

discounting in one domain is associated with discounting in the other domain in an online sample of MSM.

In Aim 2, I will examine whether monetary and/or sexual delay discounting are associated with risky sexual behavior in the same online sample of MSM. Specifically, I will examine whether increases in delay discounting are associated with reporting condomless anal intercourse in the past 12 months. Based on the age-dependent effects I previously observed, I will examine whether these associations are modified by age.

In Aim 3, I will use a network model of MSM based on empirical data collected in Atlanta, GA to estimate the potential impact of a behavioral HIV prevention intervention designed to reduce delay discounting. Using estimates of CAI among men who discount delayed condom-protected sex and men who do not, I will examine changes in HIV incidence and prevalence over a ten year period in which a behavioral intervention is implemented. Network simulations with varying intervention effectiveness and coverage will be conducted in order to estimate the potential impact of an intervention under various scenarios. The use of such modeling exercises to guide research priorities will be discussed.

Chapter 2: Assessing the concordance between monetary and sexual delay discounting in an online study of men who have sex with men

Introduction

Men who have sex with men (MSM) have the highest group-specific rate of HIV in the United States. MSM are 57.5 times more likely to be diagnosed with HIV compared to other men.[80] Although the rate of hew HIV diagnoses has been declining in most subgroups in the United States, including heterosexual women and injection drug users, the rate of diagnoses among MSM has been increasing over the past several years.[57] Diagnoses have been increasing even more rapidly among young MSM and MSM of color.[3,57] Combination HIV prevention programs that rely on multiple modes of prevention, including increased access to and use of condoms, are the most promising public health strategy to reduce HIV transmission.[6] Impulsivity may play an important role in condom use, and therefore in sexual risk-taking that can lead to HIV transmission.

Impulsivity is a concept that has been defined in multiple ways by different researchers[81], but one frequently used definition is the preference for a smaller reward or consequence available sooner over a more preferred reward available after a longer delay.[82] Broadly, impulsivity can be measured using domain general or domain specific assessments.[83] Domain general assessments focus on impulsivity as a trait of the individual that is present across situations. Domain specific assessments allow that situational and stimulus-specific factors may contribute to impulsive behavior. For example, an individual may exhibit self-control and a lack of impulsivity in their management style at work but make financially impulsive decisions when away from the office. Empirical evidence suggests that domain specific measurements of impulsivity are

more valid and allow for within-individual variations in behavior compared to domain general measurements.[83] That is, individual differences in impulsivity across domains cannot be detected by domain general measures and it is unclear how much concordance should be expected between domain general and domain specific measures.

Delay discounting is a behavioral economic measure of impulsivity that has been shown to be associated with a number of health-related behaviors and conditions including substance abuse[26,29-31,39,84] and obesity.[41,85] There is growing evidence that delay discounting may be associated with sexual risk-taking.[47,52,86,87] Commonly, delay discounting has been measured using a monetary choice task in which respondents select between a given amount of money available immediately or in the near future and a larger amount of money available after a longer delay. Monetary delay discounting tasks, although specific to financial impulsivity, have become a de facto domain general measurement of impulsivity in the delay discounting paradigm. The frequency with which monetary discounting has been found to be associated with impulsivity in domains other than financial decision-making supports this use of monetary tasks. Domain-specific delay discounting tasks have also been developed. For example, discounting of substance of choice has been measured for specific substances such as heroin[88,89] and alcohol[28]; other tasks have been developed to measure discounting of health outcomes.[39,40] Understanding the relationship between delay discounting and health-related problems may contribute to development of novel public health strategies to reduce morbidity and mortality associated with impulsive behavior. Indeed, interventions have been developed that reduce delay discounting and substance use[66,67]; similar interventions might be effective in reducing sexual risk taking.

Domain-specific methods to assess delay discounting of sexual behavior have also been developed. Tasks measuring delay discounting of access to erotic stimuli,[87] the quantity/duration of sexual behavior,[51,52] and the attractiveness of a potential sexual partner[90] have found systematic patterns of responding across a range of delay values. The Sexual Delay Discounting Task[47] (SDT) is a domain-specific delay discounting task that measures discounting of condom-protected sex, a behavioral outcome with direct relevance to HIV and sexually transmitted infection (STI) transmission. Using the SDT, condom-protected sex has been shown to be described by a two-parameter hyperboloid function[47,49,50] similar to other forms of discounting. This function describes the decay in value of a reward as the delay to the reward increases. In the context of the SDT, the reward is the protection conferred by a condom. Systematic discounting data have been obtained from multiple populations including young adults,[50] men who have sex with men,[49] and opioid-dependent women.[48] Opioid-dependent women were found to discount condom-protected sex more steeply than non-opioid-using controls.[48]

Monetary discounting has previously been found to be associated with condomless anal intercourse (CAI) in an online sample of MSM.[55] Given that sexual delay discounting has also been shown to be associated with sexual risk-taking,[47,52,86,87] monetary and sexual discounting might be measuring a general tendency to discount across multiple domains. That is, the tendency for monetary discounting tasks to predict impulsivity in domains beyond financial behavior may translate to sexual discounting as well.

The concordance between monetary and sexual discounting is interesting for a couple of reasons. First, it will be important to recognize from a behavioral perspective

whether people who tend to discount delayed money also tend to discount delayed access to condoms or sexual activity. If discounting in the two domains tends to be concordant within individuals then this will provide an indication of the generalizability of domain-specific delay discounting to other domains. Second, to the extent that it is associated with sexual risk-taking, delay discounting might play an important role in reducing risky sexual behavior and HIV/STI transmission. Delay discounting might be useful as screening tool to identify individuals who are more likely to engage in risky sex and, to the extent that delay discounting is modifiable, might serve as a target for behavioral interventions. If delay discounting is generalizable across domains then information about an individual's tendency to discount in one domain (e.g., money) could provide information about their discount rate for other domains (e.g., sexual). The ease of implementation of some monetary discounting tasks compared to sexual discounting tasks and the reduced social desirability bias associated with monetary discounting tasks[70] might make monetary discounting a more desirable screening tool.

It is unclear if monetary and sexual delay discounting are related phenomena or if the processes operate independently. There are limited published studies in which both delay discounting and monetary discounting have been measured.[47,52,91,92] In these studies, the concordance between monetary and sexual delay discounting has been unclear: Correlations between the two types of discounting have been inconsistent. When statistically significant the correlations tend to be small.[47,52,92] However, the reported studies tend to have small numbers of participants and were not conducted specifically to assess the association between monetary and sexual discounting. Additionally, many

studies comprise undergraduate populations,[52,91] raising questions about the generalizability of the results.

The aim of the current study was to assess the concordance between monetary and sexual delay discounting. To address some of the shortcomings of previous studies, we recruited a large population from a widely used social network and focused recruitment on MSM, the group with the highest rate of HIV diagnoses in the United States.

Methods

Recruitment

Participants were recruited via Facebook advertisements targeted to men who indicated that they were interested in men in their profile or who 'liked' pages that indicated that they might be MSM. Men who clicked through to the survey were provided with information about the study and completed an eligibility screener. Men were eligible for the study if they were 18 years of age or older, born male, and had sex with a man in the previous 6 months. Participants completed the survey anonymously and were uncompensated for participating. This study was determined to be exempt from review by the Emory University IRB.

Delay Discounting Measures

Monetary delay discounting was measured using the Monetary Choice Questionnaire (MCQ)[25] and sexual delay discounting was measured using the Sexual Discounting Task (SDT)[47]. To control for potential order effects of the delay discounting tasks, the order of the MCQ and SDT was randomized across participants.

Monetary Delay Discounting. The MCQ consists of 27 dichotomous questions of the form, "Would you prefer $54 today or $55 in 117 days?" The pattern of responding across the 27 items is used to assign a value of *k* that describes the rate of monetary discounting in the hyperbolic discounting equation $V = 1/(1+kD)$, where V is the present subjective value of a monetary outcome, D is the delay, and *k* is a free parameter that describes the rate of discounting[23]. Higher values of *k* indicate steeper discounting of delayed monetary outcomes.

Sexual Delay Discounting. The SDT measures the extent to which delayed condom-protected sex is discounted compared to immediately available condomless sex. Prior to completing the task, participants were presented with an array of 41 headshots of different men and instructed to select the men with whom, assuming they liked his personality, they would be interested in having sex. Using language adapted from Johnson et al[47], participants were instructed to assume that they were not in a relationship and no one else would be affected if they were to have sex with one of the selected men.

Participants were shown all of the selected photos and asked to identify the man they would most like to have sex with (MOSTSEX). That image was then removed and the participant was asked to identify the man he would least like to have sex with (LEASTSEX). All of the originally selected images were then presented again and the same procedure was used to identify the man he thought was most likely to have a STI (MOSTSTI) and least likely to have a STI (LEASTSTI). Thus, up to four different images could be selected to satisfy these four conditions and the discounting task was completed for each. If an image was selected for more than one condition then the discounting task was only completed once for that image. The four different conditions of the SDT represent four different decision-making contexts. This allows for the assessment of condom preferences in different situations, such as with a partner who is perceived to be very attractive or a partner who is perceived to have a high likelihood of having a STI.

For the discounting task, participants indicated on a visual analog scale (VAS) their preference for sex without a condom immediately versus sex with a condom at 7 different delays: 1 hour, 3 hours, 6 hours, 1 day, 1 week, 1 month, and 3 months. The left

side of the VAS was always “I will definitely have sex now without a condom.” The right anchor of the VAS was always “I will definitely wait <delay> to have sex with a condom.” An additional condition in which there was no delay for condom-protected sex was used to assess individual condom use preferences.

Analytic Methods

The monetary discounting parameter, *k*, was determined using the method proposed by Kirby et al.[93] based on the pattern of responding across the 27 items. Briefly, a participant’s pattern of responding was compared to 10 potential response patterns, each of which is associated with a given value of *k*. A value of *k* was assigned based on the standard pattern that the participant’s responses most closely matched. Participants who matched two patterns equally well were assigned the geometric mean between the two values of *k* associated with those patterns. Responses that did not meet 80% agreement with at least one value of *k* were marked invalid. The distribution of *k* was skewed, so it was log-transformed for analyses.

The selection on the VAS for the SDT was treated as the indifference point between condomless and condom-protected sex. To account for differences in condom preference, the seven delay conditions of the SDT were standardized to the 0-delay condition by dividing the former by the latter, restricting the range of the standardized area under the curve (AUC) to [0,1]. Thus, standardized values were not calculated for participants who selected immediate condomless sex (i.e., 0 on the VAS) in the 0-delay condition. These standardized values used to determine the AUC for each participant for each condition of the SDT using the method proposed by Myerson et al[94]. Lower AUCs indicate steeper discounting of condom-protected sex.

Orderliness of the SDT data was assessed using a method adapted from Johnson & Bickel[95]. Specifically, a participant's data were excluded on a given condition if either of the following two criteria were met: the indifference point for a given delay was >20% higher than the indifference point for the preceding delay or the AUC was > 1 (i.e., preference for condoms increased as the delay to condoms increased). Group median AUCs were fit to the hyperboloid function $V = 1/(1+kD)^s$ that has previously been found to describe sexual discounting data[47-50]. In this function, *V* is the present subjective value of condom-protected sex, *D* is the delay to condom-protected sex, and *k* and *s* are free parameters.

SDT data were heavily skewed. A rank transformation was employed as in previous studies.[48,49] Rank transformed variables can take the place of a skewed variable in large-sample statistical methods.[96] However, the rank-transformed AUC was still considerably skewed due to a substantial number of ties, particularly at the ends of the distribution. Therefore, the AUCs were also categorized in the following manner: $0.00 \leq AUC \leq 0.25$, $0.25 < AUC \leq 0.50$, $0.50 < AUC \leq 0.75$, $0.75 < AUC < 1.00$, $AUC = 1.00$. The same categorization was used for each SDT condition. Discounting of each condition likely represents somewhat different processes (e.g., sex with most preferred man vs. with man most likely to have a STI). Using the same cutpoints in each condition allows for the assessment of a given amount of discounting across conditions.

Concordance of monetary and sexual discounting was assessed using linear regression models in which the outcome was the log-transformed *k* from monetary discounting and the predictor variables were either the rank-transformed AUC or categorized AUC from SDT.

Because of the high prevalence of men who did not discount condom-protected sex, chi-square tests, stratified by age, were conducted to assess whether men who do not discount condom-protected sex also tend to not discount money (i.e., always choose the larger, later amount).

All analyses were conducted in SAS 9.4 (Cary, NC).

Results

Demographics

Of 217,287 Facebook impressions, there were 4,265 click-throughs to the survey for a click-through rate of 2.0%. Of those who clicked through to the survey, 2,684 (62.9%) initiated the survey; 790 (29.4%) of those who initiated the survey did not meet the eligibility criteria. A total of 1,012 men provided systematic responses for at least one of the MCQ and/or SDT.

Demographics of the study population are presented in Table 2.1. Because the prevalence of no discounting of condom-protected sex was so high, demographic characteristics are dichotomized as no vs. any sexual discounting in the MOSTSEX condition. Approximately half (45.3%) of the participants were under 25 years old and most were white (66.7%) or other/multiracial (17.7%). Overall, the study population was well-educated with 79.3% reporting at least some college. 29.0% of participants reported an income below the poverty line, defined as <$15,000 per year. Close to half (43.5%) of participants reported a main partner, defined as someone they were committed to above all others. No differences were observed on any of the demographic variables based on discounting (no vs. any) status.

Table 2.1. Demographic characteristics of the study population overall and dichotomized by sexual discounting status.

	Total		Any Sexual Discounting[1]		No Sexual Discounting[1]		Chi-square p-value[2]
	N	%	N	%	N	%	
Age							
18-24	458	45.3	251	47.1	98	44.1	0.46
25+	554	54.7	282	52.9	124	55.9	
Race/Ethnicity							
Black	76	7.5	27	5.1	21	9.5	0.13
Hispanic	82	8.1	43	8.1	19	8.6	
White	675	66.7	363	68.1	147	66.2	
Other/Multiracial	179	17.7	100	18.8	35	15.8	
Education							
High school or less	209	20.7	118	22.2	38	17.1	0.12
At least some college	802	79.3	414	77.8	184	82.9	
Income							
<$15,000/year	260	29.0	143	30.4	53	27.2	0.41
≥$15,000/year	637	71.0	328	69.6	142	72.8	
Marital Status							
Married/domestic partner	120	11.9	60	11.3	28	12.6	0.75
Widowed/Divorced/Separated	19	1.9	9	1.7	5	2.3	
Never married	872	86.3	463	87.0	189	85.1	
Main partner							
Yes	386	43.5	209	44.4	79	40.9	0.46
No	468	52.8	244	51.8	109	56.5	
Don't know	33	3.7	18	3.8	5	2.6	

[1]On the MOSTSEX condition; [2]Comparing any vs. no sexual delay discounting

Orderliness and Distribution of Discounting Data

Patterns of responding that indicate that a participant did not understand or did not attend to the delay discounting task are typically discarded prior to analysis. For example, random response patterns or non-monotonic discounting functions indicate that a participant is not responding systematically. Non-systematic responding on the SDT was

high and is reported for each condition in Table 2.2. There was non-systematic responding in 29.6%, 21.2%, 17.4%, and 23.4% of MOSTSEX, LEASTSEX, MOSTSTI, and LEASTSTI conditions, respectively. Across conditions, 9.0%, 5.7%, 4.6%, and 11.6% of participants indicated a definite preference for immediate condomless sex in the MOSTSEX, LEASTSEX, MOSTSTI, and LEASTSTI conditions, respectively, and thus did not contribute to analyses involving standardized AUC.

Table 2.2. Reasons that no standardized AUC value was obtained for each SDT condition.

	MostSex		LeastSex		MostSTI		LeastSTI	
	N	%	N	%	N	%	N	%
20% Criterion	262	25.9	160	15.8	108	10.7	199	19.7
AUC > 1	110	10.9	126	12.5	111	11.0	95	9.4
Total Non-systematic	299	29.6	214	21.2	176	17.4	237	23.4
Missing Data	56	5.5	108	10.7	96	9.5	90	8.9
Zero-Delay Condition = 0	91	9.0	58	5.7	46	4.6	117	11.6

There was a large proportion of participants in each SDT condition that did not discount condom-protected sex. That is, they selected a complete preference for condom-protected sex at each of the delays. The distribution of the log-transformed *k* and AUCs from each SDT condition are presented in Table 2.3. The values for *k* were approximately normal following the log-transformation; however, the standardized AUC values were skewed due to the clustering of values at the extremes of the distribution. The median standardized AUC values were 0.83, 1.0, 1.0, and 0.99 for MOSTSEX, LEASTSEX, MOSTSTI, and LEASTSTI, respectively. Thus, more than half of participants did not discount condom-protected sex in the LEASTSEX and MOSTSTI conditions.

Table 2.3. Mean, median, minimum, and maximum values for the log-transformed *k* and AUC for each SDT condition. AUCs are presented for the fully study population, including participants who did not discount condom-protected sex, and for the subset of participants who did discount condom-protected sex.

	Mean	Median	Min	Max	Proportion not discounting
lnk	-4.53	-4.63	-8.74	-1.39	4.4
MostSex AUC	0.66	0.83	2.31E-04	1.00	29.4
MostSex AUC[a]	0.44	0.45	2.31E-04	1.00[b]	--
LeastSex AUC	0.84	1.00	2.31E-04	1.00	48.1
LeastSex AUC[a]	0.63	0.70	2.31E-04	1.00 [b]	--
MostSTI AUC	0.89	1.00	2.31E-04	1.00	56.4
MostSTI AUC[a]	0.69	0.79	2.31E-04	1.00 [b]	--
LeastSTI AUC	0.75	0.99	2.31E-04	1.00	37.8
LeastSTI AUC[a]	0.52	0.55	2.31E-04	1.00 [b]	--

[a]Excluding participants who did not discount condom-protected sex, [b]Rounds to 1.00.

SDT data were well described by the two-parameter hyperboloid function when non-discounters were excluded from model fitting ($R^2 > .97$ for all SDT conditions). When non-discounters were included, there was no least squares solution obtained for the LEASTSEX and MOSTSTI conditions; however, the model fit was good for MOSTSEX ($R^2 = .99$) and LEASTSTI ($R^2 = 1.0$).

Concordance of Monetary and Sexual Discounting

Results from the linear regression models are presented in Table 2.4. Overall, there were no significant associations between monetary and sexual delay discounting in either young or older MSM. One category of MOSTSEX ($25.0 < AUC \leq 50.0$) had a statistically significant association with monetary discounting. Given the multiple comparisons present in the current analysis, the statistical significance of this association

should be interpreted with caution. Following a Bonferroni correction, none of the results would be statistically significant.

Table 2.4. Change in mean ln*k* associated with increases in sexual discounting for each condition of the SDT for categorized and rank-transformed AUC.

	MOSTSEX		LEASTSEX		MOSTSTI		LEASTSTI	
Categorized AUC	Δlnk (95% CI)	p-value	Δlnk (95% CI)	p-value	Δlnk (95% CI)	p-value	Δlnk (95% CI)	p-value
$0.0 \leq AUC \leq 25.0$	0.29 (-0.11, 0.69)	0.15	0.49 (-0.07, 1.04)	0.09	0.10 (-0.54, 0.75)	0.76	0.16 (-0.29, 0.61)	0.49
$25.0 < AUC \leq 50.0$	0.56 (0.02, 1.09)	0.04	0.11 (-0.53, 0.76)	0.73	0.65 (-0.11, 1.40)	0.09	0.50 (-0.03, 1.03)	0.06
$50.0 < AUC \leq 75.0$	0.45 (-0.02, 0.93)	0.06	0.15 (-0.33, 0.63)	0.54	0.04 (-0.48, 0.55)	0.89	-0.23 (-0.72, 0.26)	0.35
$75.0 < AUC < 1.0$	0.10 (-0.34, 0.54)	0.64	0.16 (-0.20, 0.52)	0.38	-0.04 (-0.37, 0.29)	0.81	0.15 (-0.24, 0.54)	0.44
$AUC = 1.0$	ref		ref		ref		ref	
Rank-Transformed AUC	Δlnk (95% CI)	p-value	Δlnk (95% CI)	p-value	Δlnk (95% CI)	p-value	Δlnk (95% CI)	p-value
100-Unit Decrease in Rank*	0.09 (0.00, 0.18)	0.05	0.06 (-0.02, 0.14)	0.16	0.01 (-0.06, 0.09)	0.73	0.03 (-0.05, 0.12)	0.43

*decrease in rank indicates an increase in sexual delay discounting

Although non-significant, the effects were in the expected direction. As sexual discounting increased, the mean ln*k* value also increased; however, these increases tended to be small. For example, a 100-unit decrease in rank in MOSTSEX standardized AUC (i.e., steeper delay discounting) was associated with a 0.09 increase in the log-transformed *k*. Similarly, men with a MOSTSEX standardized AUC between 0.0 and 0.25 had a mean ln*k* that was 0.29 units higher than men with a standardized AUC = 1.0. These trends were generally consistent across the SDT conditions.

The results of the chi-square tests assessing the concordance of any- vs. no-monetary and sexual discounting are presented in Table 2.5. Only one of the tests was significant, indicating that any monetary discounting is associated with any discounting of condom-protected sex in the MOSTSEX condition. As above, this result would not be statistically significant following corrections for multiple comparisons.

Table 2.5. Chi square tests examining the concordance between no vs. any delay discounting on the MCQ and SDT.

	Monetary Discounting		
SDT Condition	No DD	Any DD	p
MOSTSEX			
No DD	14	191	0.03
Any DD	10	338	
LEASTSEX			
No DD	16	304	0.38
Any DD	10	273	
MOSTSTI			
No DD	21	386	0.26
Any DD	9	261	
LEASTSTI			
No DD	14	241	0.09
Any DD	9	318	

Discussion

In an online sample of MSM we found no association between monetary and sexual delay discounting. The results of previous studies in which both monetary and sexual discounting have been assessed have been inconsistent. However, none of the four conditions in the SDT was found to be associated with monetary delay discounting, as measured by the MCQ.

The lack of concordance between these two measures suggests that the two delay discounting tasks are measuring separate behavioral processes or that delay discounting in one domain (e.g., economic) does not indicate delay discounting in other domains (e.g., sexual). These results suggest that monetary delay discounting tasks are unlikely to be useful tools to identify individuals most likely to engage in risky sexual behavior who are, therefore, most in need of prevention interventions to reduce HIV/STI transmission. Monetary discounting tasks have the benefit of reduced social desirability bias compared to sexual discounting tasks and could provide a method for identifying people who tend to be impulsive in economic decision-making as well as other decision-making contexts. However, these results suggest that with regard to the discounting of condom-protected sex, monetary discounting is uninformative.

Previous research has demonstrated that there may be an association between monetary discounting and impulsive behavior in other domains. Numerous studies have demonstrated an association between substance use and abuse and monetary delay discounting.[28,29,34,35,37,40] Further, interventions have been developed that have been demonstrated to reduce monetary delay discounting as well as subsequent substance use.[66,67] Monetary delay discounting has also been demonstrated to be associated with

eating behaviors and body mass.[41,42,85,97] Thus, the lack of concordance between monetary and sexual discounting appears to represent a divergence in the trend for economic impulsivity to generalize to impulsivity in other domains. However, in a previous study Jones and Sullivan[55] did observe an association between monetary discounting and reporting multiple CAI partners.

One possibility for the lack of concordance between sexual and monetary discounting is that social desirability bias may affect the current results. The SDT specifically asks participants to indicate a preference between condom-protected and condomless sex. Unlike the MCQ in which participants are merely expressing a preference between amounts of money at various delays, there is a clear 'right' answer in the SDT: Wait for a condom to be available. In the current study, a substantial proportion of men selected that they would always prefer to wait for a condom regardless of the delay for each of the four SDT conditions. That is, they did not discount condom-protected sex. Whether this reflects a true preference that is indicative of his behavior or an unwillingness to express a preference for condomless sex in some situations is unclear. The lack of concordance between monetary and sexual discounting persisted in analyses in which men who did not discount condomless sex were excluded (data not shown).

The SDT also represents a more complex decision-making scenario than does the MCQ. The MCQ presents a series of dichotomous choices between different amounts of money available at different delays. The only difference in the outcomes is quantitative – the amount of money and the delay to receipt. The SDT, on the other hand, requires participants to indicate a preference between two outcomes that are *qualitatively* different: sex with or without a condom. In addition to the qualitative difference in the

two outcomes, the SDT might also rely on decision-making with regard to likelihood of HIV/STI acquisition. Although the SDT includes conditions specific to perceived STI risk (MOSTSTI and LEASTSTI), it is likely that HIV/STI risk plays a role in a man's preference in the other conditions as well. This is likely especially true in a MSM population for whom condoms exclusively serve the purpose of preventing transmission of HIV/STIs given that pregnancy is not a concern.

Other sexual discounting tasks have been developed in which the delayed outcome is sex with a more attractive partner[90], a greater quantity (i.e., longer duration) of sex[52], or access to erotic stimuli.[87] These tasks, particularly those with more quantitative outcomes, might be more highly correlated with monetary discounting.

There was a high rate of non-systematic responding on the SDT in the present study, up to 39% in the MOSTSEX condition including those who had a value of zero in the zero-delay condition and thus could not contribute to analyses with standardized AUC. Previous studies have reported non-systematic responding, but at a lower rate. For example, Herrmann et al.[49] conducted a survey of MSM recruited through Amazon's Mechanical Turk service. In that study, 89% of respondents' data were systematic; however, the authors did not report how many participants were excluded from analyses involving standardized AUC due to definite preference for immediate CAI in the 0-delay condition. Further, previous studies do not report excluding participants with AUC > 1.0.[47-49] Thus, it is not clear how much more non-systematic responding was present in the current study compared to others. It is possible that the sequential administration of two relatively complex delay discounting tasks was an excessive participant burden.

This study has a number of strengths. We were able to recruit a large sample of MSM to complete both the SDT and MCQ, obtaining a larger sample size than most studies of delay discounting. The study population was diverse with respect to race, age, educational attainment, and income. Using Facebook advertisements to recruit men to participate in research studies has been demonstrated to result in a minimally-biased study population that is similar to participants obtained via venue-based time-space recruitment.[98] Participants completed the survey anonymously, which should reduce any social desirability bias associated with reporting sexual history and completing the SDT.[99]

This study also has limitations. The SDT uses a response modality (i.e., VAS) that may not be as familiar to participants as other question types (e.g., radio button, checkbox). It is unclear whether the high proportion of non-systematic responding on the SDT was due in part to participants' lack of familiarity with this type of question. However, only 3% of the responses on the MCQ were invalid indicating that participants were capable of providing systematic discounting data. Participants completed the survey anonymously, so we are unable to use IP addresses to check for duplicate responses. Because participants were not compensated for participating it is unlikely that one would take the survey multiple times.

In conclusion, in a large, online study of MSM we found no concordance between monetary and sexual delay discounting. This indicates that monetary delay discounting is unlikely to be a reliable indicator of sexual risk and that interventions centered on monetary delay discounting may be less likely to have an effect on sexual risk-taking. Further, the present study indicates that impulsive sexual behavior may be qualitatively

different from other impulsive behaviors that have previously been found to be associated with monetary discounting. Future studies should continue to investigate whether other measures of sexual discounting are associated with monetary discounting, and how multiple measures of discounting relate to various risk behaviors.

Chapter 3: Assessing the association between monetary and sexual delay discounting and risky sexual behavior in an online sample of men who have sex with men

Introduction

The HIV epidemic in the United States has had a disproportionate impact on men who have sex with men (MSM). Since the beginning of the epidemic, male-to-male sexual transmission has accounted for more diagnoses than any other mode of transmission[100]. Diagnoses of HIV have been declining among other groups, such as heterosexual women and people who inject drugs, in recent years[57]. During this same time period, however, diagnoses of HIV have been increasing among MSM, especially among young MSM and MSM of color[3,57]. The primary mode of transmission of HIV among MSM is condomless anal intercourse (CAI)[101]; often in the context of a main partnership[102-104].

There are multiple modalities of HIV prevention interventions available to prevent sexual transmission of HIV, including condoms, which decrease the probability of transmission by 70%[105] to 95%[106]. Pre-exposure prophylaxis (PrEP) is a biomedical intervention that involves administration of antiretroviral drugs to HIV-negative individuals to prevent seroconversion in the event they are exposed to the virus[14]. Increased HIV testing reduces HIV transmission by informing individuals of their HIV status so they can develop a plan to remain HIV-negative or initiate treatment if they are HIV-infected[107,108]. Antiretroviral therapy for HIV-infected persons that reduces HIV viral load to undetectable levels has been shown to provide near complete protection against virus transmission in samples predominantly comprising heterosexual couples[12]. Presumably this same protection will be observed among MSM. However,

epidemiological modeling studies have demonstrated that a combination of these interventions will be necessary to have a meaningful impact on the HIV epidemic in MSM[6]. Further, each of these prevention modalities requires individual action (e.g., adherence to PrEP or antiretroviral therapy, condom usage) in order to be effective. Understanding factors that contribute to the likelihood of a man using a given prevention modality may provide a basis to develop interventions to increase prevention behaviors.

Delay discounting is a behavioral economic measure of impulsivity that may be related to sexual risk-taking. Delay discounting describes the decay in value of a reward or event as the time to the event increases. It has been shown to be associated with a number of health-related behaviors and states including smoking initiation[33], substance use and abuse[25,28,31,89], relapse following substance use cessation[46], and obesity[41,85].

There is growing evidence that delay discounting is related to sexual risk-taking. In an online study, young MSM age 18-24 who reported CAI in the past 12 months had higher monetary discount rates than young men who did not; no effect of monetary discounting was observed among older MSM[56]. It is possible that the neural structures involved in impulse control, which continue to develop into the 20s[109], influence the association between delay discounting and sexual risk-taking. This effect of age may be particularly important given the increasing rates of HIV diagnoses in young MSM[57].

The results above involved a monetary discounting task; delay discounting of sexual behavior itself has also been investigated. Tasks have been developed that assess the discounting of access to erotic stimuli[87], duration of sexual activity[51], attractiveness of sexual partners[90], and delay to condom availability[47]. The Sexual Discounting Task (SDT)[47] is designed to measure discounting of condom-protected sex by assessing

preferences between condomless sex at no delay and condom protected sex at delays ranging from one hour to three months. That is, it assesses a willingness to wait for a condom to be available. Delay discounting of condom-protected sex may be particularly relevant to HIV/sexually transmitted infection (STI) transmission given the importance of condom use in combination prevention strategies.

Herrmann et al.[49] conducted a study of MSM recruited via Amazon Mechanical Turk (MTurk), a microtask site that allows requestors to post jobs that workers can opt to complete for a specified price. In their study, sexual discounting as measured by the SDT was associated with risky sexual behavior. Monetary discounting and the potential effect of age on the association between delay discounting and risky sexual behavior were not assessed. Further, it is unclear to what extent MSM on MTurk represent other Internet-using MSM or MSM in general. Finally, Herrmann et al did not assess PrEP use. Given the protection provided against HIV seroconversion by PrEP, it is possible that men using PrEP might discount condom-protected sex differently compared to men who do not use PrEP (i.e., risk compensation). There is limited evidence of risk compensation associated with PrEP use[110-112]. However, PrEP-using men using mobile dating apps have been found to frequently indicate a preference for CAI[113]. It is possible that PrEP use might modify sexual discounting.

Other studies that have assessed monetary discounting and sexual behavior in heterosexual populations have been inconsistent, with some studies finding an association[47,52,54,86,87,114] and others finding none[48,91]. However, these studies also did not assess modification of the effect by age, which has been shown to modify the association between monetary discounting and sexual risk-taking[56]. Further, the populations

generally comprised undergraduates[52,87,91,114] which would preclude an assessment of the effect of age due to the limited age range of undergraduate populations.

The association between delay discounting and sexual risk-taking is of interest for a couple of reasons. First, additional tools are needed to identify those men most at risk of HIV seroconversion in order to efficiently allocate limited public health resources available for HIV prevention intervention. Specifically, although cost-effective when targeted to high risk individuals[115], PrEP is an expensive prevention intervention that costs $10,000 USD or more per patient per year[116]. Screening tools have been developed to identify men that are candidates for PrEP[16,18,117]; however, these screening tools have been demonstrated to have poor sensitivity, particularly among black MSM[22]. Additional measures, such as individual discount rate, may increase the sensitivity of the existing screening tools.

There is also a need for behavioral interventions to reduce sexual risk-taking. Existing behavioral interventions have been largely unsuccessful in reducing CAI[6] and novel approaches are needed to add to the arsenal of available prevention interventions. Delay discounting has the potential to serve as a target of or indicate the success of risk reduction interventions. That is, interventions could target delay discounting directly or reductions in discounting could serve as an immediately available measure of the success of an intervention, in comparison to the delayed outcome of reported condom use. There is a precedence for basing behavioral interventions on delay discounting. In one study a money management intervention was implemented among a group of substance users[67]. Following the intervention, both substance use and monetary discount rate were

decreased. In another study, working memory training was implemented which resulted in a decrease in monetary discount rate[66].

The purpose of the current study is to examine the relationship between two forms of delay discounting – monetary and sexual – and CAI. Based on previous research, we hypothesized that both types of discounting would be associated with CAI and that the association would be stronger among young compared to older men.

Methods

Recruitment

We conducted an online study of MSM recruited via Facebook advertisements. Advertisements were targeted to Facebook users who identified as male and indicated that they were interested in men in their profile or whose interests indicated that they might be MSM. Men who clicked the advertisement were taken to the survey introduction page. Potential participants were provided a brief description of the survey and completed the eligibility screener. To be eligible for the survey, participants had to identify as male, be at least 18 years old, and report having sex with another man in the previous 6 months. Participants completed the survey anonymously. This research was determined to be exempt from review by the Emory University IRB.

Delay Discounting Measurements

Monetary delay discounting was assessed via the Monetary Choice Questionnaire (MCQ)[25] and sexual delay discounting was assessed via the SDT[47]. Each is described in detail below. The order of the delay discounting tasks was randomized across participants.

The MCQ consists of 27 items of the form "Would you prefer $24 today or $35 in 29 days?" The pattern of responding across the 27 items is used to assign a discounting parameter, *k*, from the hyperbolic discounting equation V = A/(1+kD) [Equation 1], where *V* is the present subjective value of delayed money, *A* is the amount of the delayed value, *D* is the delay, and *k* is a free parameter. Larger values of *k* indicate steeper delay discounting, thus a stronger preference for smaller, sooner rewards. The 27 items are

presented in a fixed order that is independent of the amounts, delays, and discount rates associated with each item.

The value of *k* was determined for each participant using the method described by Kirby et al[25]. Briefly, there are 10 values of *k*, determined using Equation 1, associated with 10 distinct patterns of responding on the MCQ. Each participant's response pattern was compared to these 10 standard patterns and the percentage agreement was determined for each. Participants were assigned the value of *k* that corresponded to the standard pattern with which their responses had the highest agreement. If a participant's highest percent agreement was tied across two different standard patterns then the geometric mean of those two values of *k* was assigned. Participants who did not have 80% agreement with at least one standard pattern were deemed to be nonsystematic and were not assigned a *k* value. Final *k* values were log-transformed to correct for skewness and obtain an approximately normal distribution.

The SDT measures discounting of condom-protected sex. To start the task participants were shown an array of 41 headshots of men and instructed to select the images of the men that they would be interested in having sex with. Participants were instructed to assume that they liked the man's personality and that no one else would be affected if they had sex (e.g., assume neither is in a relationship). Next, of the selected images, participants were asked to select the man they would most like to have sex with (MOSTSEX). That image was then removed and participants were asked to indicate which man they would least like to have sex with (LEASTSEX). Next, all of the selected images were presented again and a similar procedure was used to identify the man

perceived to be most likely to have a STI (MOSTSTI) and least likely to have a STI (LEASTSTI).

A series of tasks designed to assess the participant's sexual discount rate followed. For each of the four conditions (MOSTSEX, LEASTSEX, MOSTSTI, LEASTSTI) the image of the selected man was displayed and the participant used a visual analog scale (VAS) to indicate their preference between immediate sex without a condom and sex with a condom at 7 different delays: 1 hour, 3 hours, 6 hours, 1 day, 1 week, 1 month, and 3 months. The VAS was anchored at 0 (immediate condomless sex) and 100 (condom-protected sex at the given delay). To assess individual condom use preferences, participants also indicated their preference between immediate sex without a condom and immediate condom-protected sex. If the same image was selected for more than one condition (e.g., for MOSTSEX and LEASTSTI) then the discounting task was only completed once for that image.

The value selected on the VAS was considered the indifference point between immediate sex without a condom and condom-protected sex at the given delay. The indifference point represents the point at which both options (i.e., immediate condomless sex, delayed condom-protected sex) are equally valuable. To account for individual condom-use preferences, the indifference points from the 7 delays were standardized against the 0-delay condition by dividing the former value by the latter.

These standardized indifference points were then used to determine the area under the curve (AUC)[94] across the 7 delays. Standardized AUCs range from a minimum of 0.0 to a maximum of 1.0. Higher AUC indicates less discounting of condom-protected sex. SDT data were checked for orderliness using a method proposed by Johnson and

Bickel[95]. First, if the indifference point for a given delay was greater than 20% higher than the indifference point for the preceding delay then data for that condition were considered nonsystematic and were discarded. Second, if the AUC for a given condition was greater than 1.0, indicating stronger preference for condom-protected sex following a delay, then data were considered nonsystematic and were discarded.

AUC values were highly skewed and clustered. Rank transformations[96] and Spearman rank correlations have been used in the past as a means of conducting nonparametric statistical analyses with AUC values obtained using the SDT[47-49]. However, the clustering of responses at the ends of the distribution reduces the utility of a rank transformation. Therefore, AUC values were classified according to the following scheme: $0.0 \leq AUC \leq 0.25$, $0.25 < AUC \leq 0.5$, $0.5 < AUC \leq 0.75$, $0.75 < AUC < 1.0$, $AUC = 1.0$. An AUC value of 1.0 indicates that there is no discounting of condom-protected sex. Because of the large proportion of participants who did not discount condom-protected sex analyses were also conducted with a dichotomized AUC variable comparing those with $AUC < 1.0$ (i.e., any discounting of condom-protected sex) to those with $AUC = 1.0$. In contrast to a data-based criterion such as tertiles or quartiles, using the same categorization for each condition of the SDT permits across-condition comparison of similar levels of discounting.

Outcome Measures

The primary outcome is any condomless anal intercourse in the previous 12 months. Participants completed a sexual behavior questionnaire with specific questions about up to 3 most recent sex partners and aggregate data (e.g., number of partners, number with whom the participant had anal sex) for additional partners. If a participant

reported CAI with a given partner, he was asked to specify whether it was receptive, insertive, or both. For the current analysis, a man was considered to have had any CAI if he reported insertive or receptive CAI with at least one partner in the past 12 months.

Other Measures

Data were collected on a number of additional variables that were hypothesized to confound the association between CAI and delay discounting. Participants reported age, income, and educational status. Based on a previous study that found modification of the association between monetary discounting and CAI by age group[56], age was dichotomized as 18-24 years and 25 years or more. Income was dichotomized as low income (<$15,000/year) versus mid- to high-income (≥$15,000/year). Educational status was dichotomized to compare those with at least some college education to those with a high school diploma or below. Finally, total number of partners reported in the sexual behavior questions was also dichotomized as 1-3 partners versus 4 or more partners in the past 12 months.

Analysis Methods

Demographics. Demographic and sexual behavioral variables were stratified by CAI status (any CAI in past 12 months versus none). Chi square tests were used to assess whether any demographic or sexual behavioral variables differed based on CAI status.

Effect of age group. Adjusted prevalence differences were estimated for the association between delay discounting and CAI, stratified by age group. Binomial regression models were used to estimate prevalence differences for the ln*k* and for the dichotomous sexual delay discounting AUC (any versus no discounting). Binomial regression models did not converge for the categorized AUC, so Poisson regression with

robust variances was used to estimate prevalence differences[118]. Separate models were estimated for each condition of the SDT. All models contained an interaction term to assess the effect of age group.

Effect of current PrEP use. Adjusted prevalence ratios were estimated for the association between sexual delay discounting and CAI, stratified by current PrEP use. Due to the small number of men reporting current PrEP use, neither binomial models nor Poisson models with robust variance could be estimated using the categorized SDT AUC variable. Poisson regression with robust variances was used to estimate prevalence differences for each condition of the SDT using the dichotomous AUC variable. All models contained an interaction term to assess the effect of current PrEP use.

Results

Demographics

Participant demographics and HIV testing history are reported in Table 3.1, stratified by CAI status. Overall the age groups were approximately evenly divided (45.3% age 18-24). Participants were mostly white (66.7%) or other/multiracial (17.7%). Similar to other online studies,[55,119,120] the population was highly educated with 79.3% of participants reporting at least some college education. More than half (52.8%) of participants did not have a main partner. Most participants (73.2%) had ever been tested for HIV, a lower percentage than is typically observed in surveillance systems,[121,122] and 6.5% reported ever receiving a positive test. 60.6% reported 1-3 partners in the previous 12 months. Overall, 7.1% of participants reported ever using PrEP with 4.8% reporting current use. Chi square tests indicated associations between CAI in the past 12 months and marital status ($p = 0.0489$), having a main partner ($p < .0001$), ever testing for HIV ($p < .0001$), number of partners reported ($p < .0001$), ever taking PrEP ($p = .0075$), and current PrEP use ($p = .0386$).

Table 3.1. Sample demographics, relationship characteristics, and HIV testing history overall and stratified by CAI in the past 12 months.

	Total (N=1,012)		CAI Past 12 months (N=691)		No CAI Past 12 months (N=321)		Chi-square p-value[2]
	N	%	N	%	N	%	
Age							
18-24	458	45.3	305	44.1	153	47.7	0.2945
25+	554	54.7	386	55.9	168	52.3	
Race/Ethnicity							
Black	76	7.5	49	7.1	27	8.4	0.6424
Hispanic	82	8.1	52	7.5	30	9.4	
White	675	66.7	467	67.6	208	64.8	
Other/Multiracial	179	17.7	123	17.8	56	17.5	
Education							
High school or less	209	20.7	135	19.5	74	23.1	0.1901
At least some college	802	79.3	556	80.5	246	76.9	
Income							
<$15,000/year	260	29.0	175	27.8	85	31.8	0.2207
≥$15,000/year	637	71.0	455	72.2	182	68.2	
Marital Status*							
Married/domestic partner	120	11.9	93	13.5	27	8.4	0.0489
Widowed/Divorced/Separated	19	1.9	11	1.6	8	2.5	
Never married	872	86.3	587	85.0	285	89.1	
Main partner							
Yes	386	43.5	305	51.2	81	27.8	<.0001
No	468	52.8	271	45.5	197	67.7	
Don't know	33	3.7	20	3.4	13	4.4	
Number of partners reported*							
1-3	607	60.6	374	54.1	233	75.2	<.0001
4+	394	39.4	317	45.9	77	24.8	
Ever tested for HIV*							
Yes	740	73.2	538	78.0	202	62.9	<.0001
No	271	26.8	152	22.0	119	37.1	
Ever tested positive for HIV							
Yes	48	6.5	36	6.7	12	6.0	0.7423
No	688	93.5	501	93.3	187	94.0	
Ever used PrEP							
Yes	61	7.1	51	8.7	10	3.7	0.0075
No	799	92.9	536	91.3	263	96.3	
Currently using PrEP							

Yes	41	4.8	34	5.8	7	2.6	0.0386
No	819	95.2	553	94.2	266	97.4	

*Statistically significant at alpha = .05

Distribution of Delay Discounting Variables

The distribution of the delay discounting variables is presented in Table 3.2. The log-transformed *k* value from the MCQ was approximately normal (mean = -4.63, s.d. = 1.85). The AUC values for each condition in the SDT were highly skewed and clustered. A large proportion of men did not discount condom-protected sex at any delay across each condition. Specifically, 37.2%, 53.3%, 60.1%, and 43.7% of men had an AUC of 1.0 in the MOSTSEX, LEASTSEX, MOSTSTI, and LEASTSTI conditions, respectively, indicating no discounting of condom-protected sex. That is, the reported likelihood of using a condom was not affected by time. For some participants, this was due to reporting 100% probability of using a condom at each delay. Other participants did not indicate a preference for consistent condom use, however, their preference for condoms (e.g., 50% likelihood of condom use) was unaffected by time.

Table 3.2. Distribution of delay discounting variables

	Monetary Delay Discounting							
	Mean	Median	Standard Deviation					
ln*k*	-4.53	-4.63	1.85					
	Sexual Delay Discounting							
	MOSTSEX		LEASTSEX		MOSTSTI		LEASTSTI	
	N	%	N	%	N	%	N	%
$0 < AUC \leq 0.25$	132	22.1	48	7.4	32	4.5	87	14.2
$0.25 < AUC \leq 0.50$	62	10.4	34	5.2	24	3.4	59	9.6
$0.50 < AUC \leq 0.75$	76	12.7	68	10.5	56	7.8	70	11.4
$0.75 < AUC < 1.00$	105	17.6	153	23.6	173	24.2	129	21.0
AUC = 1.00	222	37.2	346	53.3	429	60.1	268	43.7

Effect of Age Group

Adjusted prevalence differences of CAI for each one-unit change in the log-transformed *k* value are presented in Table 3.3. There was no association between increasing monetary delay discounting and prevalence of CAI in the past 12 months for either age group. Having 1-3 sexual partners in the previous 12 months was associated with a 16% lower prevalence of CAI compared to those with 4 or more sexual partners.

Table 3.3. Adjusted prevalence differences for CAI and monetary delay discounting.

	PD	95% CI	p-value
ln*k*, one-unit increase			
Age 18-24	-0.003	(-.030, 0.024)	0.8435
Age 25+	-0.001	(-0.023, 0.021)	0.9312
Poverty			
Yes	-0.02	(-0.09, 0.05)	0.5695
No	Ref		
Education			
At least some college	0.02	(-0.06, 0.11)	0.6244
High School or less	Ref		
Number of Partners			
1-3	-0.16	(-0.22, -.10)	<.0001
4+	Ref		

*Binomial regression

Adjusted prevalence differences for the categorized AUC values stratified by age group are presented in Table 3.4. The interaction between age group and delay discounting was not statistically significant for any of the conditions, but prevalence differences for CAI in the past 12 months were generally higher among men age 18-24 compared to men age 25 and older, particularly in the category corresponding to the steepest discounting of condom-protected sex. In general, CAI prevalence differences

increased as sexual delay discounting increased. For the MOSTSEX condition, among those age 18-24, there was a 39% higher prevalence of CAI in the past 12 months among those with an AUC between 0.00 and 0.25 compared to those with AUC of 1.00; for the same comparison among those age 25 and older the prevalence difference was 25%. Among those 18-24 in the MOSTSEX condition, prevalence differences were 0.28 (0.08-0.49), 0.13 (-0.09, 0.36), and 0.17 (-0.03, 0.36) across categories of increasing AUC (i.e., less discounting). These same prevalence differences were less consistent among those age 25 and older. Across categories of increasing AUC for those age 25 and older in the MOSTSEX condition, prevalence differences were 0.04 (-0.16, 0.23), 0.22 (0.05, 0.38), and 0.04 (-0.12, 0.20). Results for the other three conditions were generally similar with more consistent trends in prevalence differences observed among the younger compared to older age group.

Table 3.4. Adjusted prevalence differences for CAI and each condition of the SDT by category, stratified by age group.

	MOSTSEX		LEASTSEX		MOSTSTI		LEASTSTI	
	PD (95% CI)	p-value	PD (95% CI)	p-value	PD (95% CI)	p-value	PD (95% CI)	p-valu
Age 18-24 AUC								
0.0 ≤ AUC ≤ 25.0	0.39 (0.25, 0.53)	<.0001	0.23 (0.03, 0.43)	0.0252	0.30 (0.09, 0.52)	0.0059	0.35 (0.21, 0.50)	<.00
25.0 < AUC ≤ 50.0	0.28 (0.08, 0.49)	0.0057	0.25 (0.06, 0.45)	0.0114	0.20 (-0.03, 0.43)	0.0874	0.28 (0.09, 0.47)	0.00
50.0 < AUC ≤ 75.0	0.13 (-0.09, 0.36)	0.2495	0.21 (0.03, 0.39)	0.0246	0.18 (-0.02, 0.37)	0.0794	0.14 (-0.10, 0.38)	0.24
75.0 < AUC < 1.0	0.17 (-0.03, 0.36)	0.0936	0.19 (0.05, 0.34)	0.0085	0.19 (0.05, 0.32)	0.0079	0.09 (-0.07, 0.26)	0.27
1.0	Ref		Ref		Ref		Ref	
Age 25+ AUC								
0.0 ≤ AUC ≤ 25.0	0.25 (0.12, 0.37)	0.0001	0.29 (0.14, 0.44)	0.0001	0.22 (0.06, 0.38)	0.0082	0.27 (0.14, 0.39)	<.00
25.0 < AUC ≤ 50.0	0.04 (-0.16, 0.23)	0.7195	0.28 (0.10, 0.46)	0.0025	0.32 (0.23, 0.40)	<.0001	0.12 (-0.06, 0.30)	0.18
50.0 < AUC ≤ 75.0	0.22 (0.05, 0.38)	0.009	0.08 (-0.12, 0.27)	0.448	0.06 (-0.13, 0.25)	0.5369	0.01 (-0.16, 0.18)	0.89
75.0 < AUC < 1.0	0.04 (-0.12, 0.20)	0.6068	0.05 (-0.07, 0.18)	0.3998	0.01 (-0.11, 0.13)	0.8993	0.04 (-0.12, 0.19)	0.64
1.0	Ref		Ref		Ref		Ref	
Poverty								
Yes	-0.07 (-0.17, 0.03)	0.1545	-0.04 (-0.14, 0.05)	0.3395	-0.07 (-0.16, 0.01)	0.101	-0.07 (-0.17, 0.03)	0.17
No	Ref		Ref		Ref		Ref	
Education								
Some college	0.12 (0.00, 0.23)	0.0423	0.04 (-0.07, 0.15)	0.4612	0.04 (-0.07, 0.14)	0.4735	0.06 (-0.05, 0.18)	0.27
High School or less	Ref		Ref		Ref		Ref	
Number of Partners								
1-3	-0.14 (-0.22, -0.05)	0.0015	-0.18 (-0.25, -0.10)	<.0001	-0.2 (-0.27, -0.13)	<.0001	-0.15 (-0.23, -0.07)	0.00
4+	Ref		Ref		Ref		Ref	

*Poisson regression with robust variances

Adjusted prevalence differences for the dichotomized sexual delay discounting variable are presented in Table 3.5. As with the categorized delay discounting there was not a statistically significant interaction of age with delay discounting. However, prevalence differences were stronger for younger compared to older men across all four SDT conditions. Among men age 18-24 in the MOSTSEX condition, there was a 27% higher prevalence of CAI comparing those who discounted condom-protected sex compared to those who did not. Among men age 25 and older, the prevalence of CAI was 15% higher among men discounting condom-protected sex in the MOSTSEX condition compared to those who did not.

Table 3.5. Adjusted prevalence differences for CAI and any discounting on the SDT, stratified by age group.

	MOSTSEX		LEASTSEX		MOSTSTI		LEASTSTI	
	PD (95% CI)	p-value	PD (95% CI)	p-value	PD (95% CI)	p-value	PD (95% CI)	p-valu
Any Discounting								
Age 18-24	0.27 (0.06, 0.47)	0.0112	0.21 (0.01, 0.42)	0.0447	0.20 (-0.01, 0.41)	0.0648	0.21 (0.01, 0.41)	0.041
Age 25+	0.15 (-0.03, 0.34)	0.1024	0.12 (-0.05, 0.30)	0.1677	0.06 (-0.11, 0.24)	0.4857	0.10 (-0.08, 0.29)	0.281
Poverty								
Yes	-0.08 (-0.24, 0.07)	0.3089	-0.05 (-0.20, 0.10)	0.5325	-0.08 (-0.23, 0.06)	0.2614	-0.08 (-0.24, 0.08)	0.326
No	Ref		Ref		Ref		Ref	
Education								
Some college	0.11 (-0.06, 0.29)	0.2090	0.05 (-0.13, 0.23)	0.5938	0.04 (-0.13, 0.21)	0.6473	0.07 (-0.11, 0.25)	0.455
High School or less	Ref		Ref		Ref		Ref	
Number of Partners								
1-3	0.27 (0.13, 0.40)	0.0580	-0.17 (-0.31, -0.03)	0.0161	-0.20 (-0.34, -0.06)	0.0038	-0.16 (-0.30, -0.01)	0.034
4+	Ref		Ref		Ref		Ref	

*Binomial regression

Effect of Current PrEP Use

Adjusted prevalence differences for the dichotomized SDT AUC are presented in Table 3.6. Across all SDT conditions, there was higher prevalence of CAI in the past 12 months among those that exhibited any discounting of condom-protected sex compared to those that did not. The prevalence differences were higher among men who were currently on PrEP compared to those who were not, however the effect of PrEP on prevalence differences was only statistically significant for the MOSTSEX condition. In this condition, the prevalence difference for men currently on PrEP was 0.50 (0.30, 0.70) compared to 0.19 (0.10, 0.29) for men who were not currently on PrEP.

Table 3.6. Adjusted prevalence differences for CAI and each condition of the SDT by category, stratified by current PrEP use.

	MOSTSEX*		LEASTSEX		MOSTSTI		LEASTSTI	
	PD (95% CI)	p-value	PD (95% CI)	p-value	PD (95% CI)	p-value	PD (95% CI)	p-valu
Any Discounting								
Current PrEP Use	0.50 (0.30, 0.70)	<.0001	0.32 (0.05, 0.59)	0.0221	0.23 (0.02, 0.45)	0.0338	0.29 (-0.01, 0.59)	0.0612
Not using PrEP	0.19 (0.10, 0.29)	<.0001	0.15 (0.06, 0.23)	0.0008	0.12 (0.04, 0.21)	0.0041	0.17 (0.08, 0.26)	0.0002
Age								
18-24	-0.06 (-0.16, 0.04)	0.2381	-0.02 (-0.11, 0.07)	0.6330	-0.03 (-0.12, 0.06)	0.5429	-0.07 (-0.17, 0.02)	0.1235
25+	Ref		Ref		Ref		Ref	
Poverty								
Yes	-0.11 (-0.22, 0.00)	0.0542	-0.05 (-0.15, 0.06)	0.3738	-0.08 (-0.18, 0.02)	0.1001	-0.08 (-0.19, 0.03)	0.1582
No	Ref		Ref		Ref		Ref	
Education								
At least some college	0.15 (0.03, 0.27)	0.0119	0.08 (-0.04, 0.20)	0.2110	0.09 (-0.03, 0.20)	0.1471	0.12 (0.00, 0.25)	0.0480
High School or less	Ref		Ref		Ref		Ref	
Number of Partners								
1-3	-0.18 (-0.27, -0.09)	<.0001	-0.18 (-0.26, -0.09)	<.0001	-0.22 (-0.30, -0.14)	<.0001	-0.18 (-0.27, -0.09)	<.0001
4+	Ref		Ref		Ref		Ref	

Poisson regression with robust variances; *Effect of current PrEP use statistically significant

Discussion

We examined the association between monetary and sexual delay discounting and risky sexual behavior in an Internet-based, cross-sectional sample of MSM. We did not observe an association between monetary discounting and CAI; however, all conditions of the SDT were associated with higher prevalence of CAI. There was no statistically significant effect of age on the association between discounting of condom-protected sex and CAI; however, there was an effect of current PrEP use. In the MOSTSEX condition, larger prevalence differences were observed comparing men who discounted condom-protected sex to those who do not among men currently on PrEP compared to men not on PrEP.

In a previous online study of MSM, monetary delay discounting was found to be associated with CAI[55], and this association was found to be age dependent[56]. The results of the current study suggest that monetary discounting is not associated with CAI. This is consistent with previous findings that sexual and monetary discounting are not associated (ref Aim 1 – under review). Multiple studies have previously demonstrated an association between monetary delay discounting and impulsive health-related behaviors (e.g., substance use and abuse)[28,31,34,39,40] and health states that are often the result of impulsive behaviors (e.g., obesity)[41,85]. In this sense, monetary delay discounting tasks have served as general indicators of an individual's tendency to behave impulsively. The current results indicate that impulsivity evident on a monetary task may not translate to sex-specific impulsivity. The lack of association between monetary discounting and sexual behavior may reflect fundamental differences in the decision-making processes that are involved in each behavior. Monetary discounting tasks assess preference for specific

quantities of money available at given delays. In comparison, the SDT measures preferences for condom use, a qualitative outcome, with a variety of short-term (e.g., pleasure) and long-term (e.g., avoidance of STIs) consequences associated with it. Continued investigation is needed in light of the discrepant results across studies.

The effects of age or PrEP administration on the association between sexual delay discounting and CAI have not previously been reported. Although the prevalence differences for CAI were generally stronger among younger MSM, this effect was not statistically significant. In contrast, current PrEP usage had a synergistic effect with sexual discounting in the MOSTSEX condition. No effect of PrEP usage was observed across the other three SDT conditions. It is important to note that PrEP only protects against HIV, not other STIs. Thus, if men who discount condom-protected sex are more likely to engage in CAI when taking PrEP, this may result in increased STI transmission.

Few studies have assessed the effects of delay discounting on sexual risk-taking among MSM, even though this population is disproportionately impacted by the HIV epidemic. Prior to this study, Herrmann et al.[49] conducted the only study to specifically assessing sexual delay discounting in MSM. Although they reported an association between discounting on the SDT and CAI, their study sample was relatively small, almost exclusively Caucasian, and was obtained via MTurk. It is not clear to what degree MSM on MTurk are representative of other Internet-using MSM or MSM in general; participants recruited via Facebook have been shown to be similar to those recruited via venue-based sampling[98]. Further, the authors specified that they were seeking MSM in the recruitment posting on MTurk, potentially incentivizing participants to be dishonest about their sexual history in order to qualify to complete the task. Herrmann et al. did

assess multiple sexual behavior outcomes; however, they did not assess potential modifying effects of age or PrEP usage.

Based on the results of the current study it is unclear whether developmental age modifies the association between sexual delay discounting and CAI. Based on tests of statistical significance, there was no interaction of age with delay discounting to increase the prevalence of CAI. The prevalence differences among young MSM, however, were consistently larger than those among older MSM. Thus, the current study might have been underpowered to observe a statistically significant interaction.

The modifying effect of PrEP usage on the association between sexual delay discounting and CAI may be important. There has been much concern that PrEP implementation will be accompanied with risk compensation in which individuals are willing to engage in riskier behaviors because they feel protected from harm[123,124]. That is, taking PrEP might provide a rationale to engage in CAI even though a combination of PrEP and condom usage is much more effective in preventing HIV transmission[105]. The observation that men on PrEP who discounted condom-protected sex in the MOSTSEX condition had higher CAI prevalence differences compared to men not on PrEP suggests that men might be increasing their risk because they are on PrEP, at least in the context of a man they find very attractive. That is, partner type may affect the extent to which a PrEP-user discounts condom-protected sex. The lack of a statistically significant effect of PrEP on the other SDT conditions might indicate insufficient power to detect an effect or reflect the qualitative differences, such as considerations of STI risk, across the conditions.

CAI is a common outcome and was reported by 68% of the study sample. Although 42% only reported CAI with a main partner, CAI in main partnerships continues to carry risk in the context of concurrency[125] and undiagnosed HIV[108]. The high prevalence of CAI indicates that there is a need for additional prevention interventions to reduce sexual risk-taking and reduce transmission of HIV and other STIs. Future studies should also consider more specific risk behaviors, such as CAI with a serodiscordant partner. Partner- and sex-position-specific characteristics affect the probability of transmission of HIV in a given sexual encounter. It may be the case that men willing to engage in CAI with a serodiscordant or serostatus unknown partner have higher discount rates compared to men who exclusively engage in CAI with seroconcordant partners.

The results of the current study indicate that sexual, but not monetary, delay discounting tasks might serve as an indicator of sexual risk. Further, to the extent that sexual delay discounting is modifiable, discount rates might serve as either a target for HIV prevention interventions or as an immediately measurable indicator of the effectiveness of risk reduction interventions that target decision-making processes. Future studies should continue to explore the nature of the relationship between sexual delay discounting and CAI as well as adapt methods from substance abuse interventions[66,67] to assess the feasibility of developing interventions based on sexual delay discounting to reduce CAI.

Chapter 4: Estimating the Potential Impact of a Delay Discounting Intervention to Reduce HIV Transmission Using Agent-Based Modeling

Introduction

Multiple authors have noted the need for combination HIV prevention, consisting of interventions at the individual and structural levels, to have the greatest impact on HIV incidence in the United States[5,6,126]. Despite the effectiveness of biomedical interventions such as pre-exposure prophylaxis (PrEP)[14] and treatment as prevention (TasP)[12], modeling studies indicate that these interventions alone will not be sufficient to curb the epidemic[6,78]. Behavioral interventions designed to increase condom use, HIV testing, and/or discussions about serostatus may be needed to reduce HIV transmission. Historically, behavioral interventions in isolation have had no or modest effects on condomless anal intercourse (CAI)[6,21,127], highlighting the challenge of developing these types of interventions as sole modalities. However, behavioral interventions may enhance the impact of biomedical interventions[78].

Exploring new behavioral determinants of sexual risk-taking may provide new targets to form the basis for the development of novel behavioral prevention interventions. Delay discounting is a measure of impulsivity that describes the tendency for people to place less value on consequences that occur in the future[82]. Delay discounting has been frequently shown to be associated with substance use and abuse[28,31,34,39,40] and other health-related behaviors[41,85]. Emerging evidence suggests that delay discounting is also associated with sexual behavior[51,52,87], including sexual risk-taking[47-50,55,56]. In terms of sexual risk-taking, delay discounting has most frequently been conceived as the choice to have sex without a condom in lieu of waiting a period of time

until a condom is available[47]. This suggests that to the extent that delay discounting is modifiable, an intervention that targets delay discounting might decrease CAI.

Although interventions targeting delay discounting in relation to sexual behavior have not yet been developed, delay discounting interventions have been developed with other behavioral targets. Delay discounting of monetary outcomes has been shown to be reduced following money management interventions[67]. Episodic future thinking has been shown to reduce delay discounting of money and cigarette smoking in a laboratory model[128]. These results suggest that it might be feasible to develop interventions targeting delay discounting that will have an effect on sexual risk-taking. However, it is unclear what the overall population-level effect of such an intervention may have on sexual risk-taking and the incidence of HIV.

Dynamic network modeling methods are useful for the investigation of the effects of disease- and behavior-related phenomena on infectious disease transmission through a population. Dynamic network models are based on separable temporal exponential-family random graph models (STERGMs).[75] STERGMs extend ERGMs, which form the basis for modeling the connections (i.e., edges) between members of a network, so that network configurations can be simulated over time. Nodes are assigned attributes that affect edge formation and edges are preserved over time. Edge formation and dissolution occur independently of each other within each time-step. These models allow for the behavior and disease status of individual nodes to be tracked over time. Networks can also be constrained, for example by limiting the number of concurrent partnerships, so that the structure reflects network structures observed empirically. The current study uses

a network model to estimate the impact of a hypothetical delay discounting HIV prevention intervention to reduce HIV by increasing condom use.

The current study has two primary goals. First, we aim to estimate the potential impact of an intervention targeting delay discounting on the incidence of HIV within a network of sexually active MSM. Second, we highlight this use of network models to inform decision-making about the potential impact of a research program.

Methods

Base Model

We adapted a previously described[79] stochastic, agent-based network model of HIV transmission in an open population of MSM that builds on models designed to assess racial disparities in HIV incidence among MSM in the United States[103]. These models were developed with the EpiModel software platform (www.epimodel.org), which depends on the statistical framework of temporal exponential random graph models (ERGM)[76] to simulate dynamic networks, here of sexual partnerships over time.

Briefly, the model was initialized with 10,000 nodes age 18-39. Sexual relationships can be formed as main partnerships; casual, ongoing partnerships; or instantaneous (i.e., one-off) partnerships. ERGM model terms controlled the predictors of partnership formation uniquely for each partnership type, with interaction terms controlled the total degree (number of ongoing partnerships across types). Behavior within partnerships, such as coital frequency and condom use, was a function of partnership type and other factors such as disease discordant status. HIV transmission rates within discordant partnerships were heterogeneous by HIV viral load, awareness of infection, treatment status, and sexual position. PrEP as a method of HIV prevention is available in the model; however, PrEP use was not included in the current study in order to isolate the effects of modifications to the delay discounting intervention. Behavioral components of the model were parameterized using data collected in two cohort studies of black and white MSM in Atlanta, GA.[129,130] More details about the model are provided in Appendix B.

Delay Discounting Parameter Estimation

Delay discounting was modeled as a dichotomous no-discounting versus any-discounting individual-level attribute. Based on findings from a recent discounting survey in MSM, delay discounting was hypothesized to affect condom use probability in casual and one-off sexual partnerships but not main partnerships. Consistent with that empirical study, we classified 63% of men in the model as exhibiting delay discounting of condom use. In the prior models[79,103], per-act condom use probabilities were 26% and 27% for casual and one-off partnerships, respectively[129]. In this study, we added heterogeneity in the per-act condom-use probability by delay discounting status. Given the prevalence ratio for CAI of 0.55 for delay discounters versus non-discounters observed in the online survey, and the distribution of delay discounting in the population, delay discounters were modeled as having a 20% and non-discounters a 36% per-act condom use probability across both casual and one-off partner types. Key parameters and sources for the current model are described in greater detail in Appendix C.

In the intervention scenarios, men were modeled as moving from the discounter category to the non-discounter category, thus changing their per-act probability of CAI. Men were eligible for this intervention if they were HIV-negative, were currently a discounter, and if they have had CAI with a casual or one-off partner in the previous six months. The probability of the intervention successfully changing a man's discounting status was varied across three values (20%, 50%, and 90%) to estimate the impact of different levels of effectiveness. The intervention effect was assumed to wane stochastically with a probability of 1/52, resulting in an average duration of intervention effectiveness of one year. Once the intervention effect waned a man was reclassified as

delay discounting condom-protected sex, readopting his previous probability of per-act CAI with non-main partners, and was again eligible for intervention..

Model Simulation

An initial 50-year burn-in model was simulated in order to obtain a steady state network with a target HIV prevalence of 26% in equilibrium, consistent with the estimated HIV prevalence in the source population[130]. The burn-in model served as a starting point for each of the intervention scenarios.

Condom use was a dyad-level characteristic and dyads could consist of zero, one, or two delay discounters. Thus, in discounting-discordant partnerships the decision to use a condom could have been made by the discounter or the non-discounter. As a sensitivity analysis, we ran all simulations assuming that the discounter made the decision and again assuming the non-discounter made the decision.

In the model, 22% and 33% of men were modeled as never having CAI with a casual or one-off partner, respectively[129]. It is unclear whether discounters would ever fall in the category of always using condoms with non-main partners; thus, two different assumptions about how delay discounting might affect these probabilities were investigated. In the first, consistent condom use could be assigned non-differentially to both delay discounters and non-discounters. In the second, consistent condom use with non-main partners was only assigned to non-discounters.

Using the above assumptions, there were four total conditions that were assessed combining the assumptions about preferences for condom use and whether discounters could be assigned to always use condoms with casual and one-off partners (Table 4.1). In Condition 1, a proportion of discounters and non-discounters always used condoms with

non-main partners and discounters decided condom use; Condition 2 was identical except non-discounters decided condom use. In Condition 3, a proportion of non-discounters always used condoms with non-main partners (i.e., all discounters had CAI) and the discounter decided condom use; Condition 4 was identical except the non-discounters decided condom use.

Table 4.1. Assumptions for four different model conditions testing the impact of which partner determines condom-use and whether delay discounters are eligible to be assigned to always use a condom with non-main partners.

	Discounter decides condom use	
Delay discounters eligible to be assigned to always use a condom non-main partners	Yes	No
Yes	Condition 1	Condition 2
No	Condition 3	Condition 4

Separate burn-in models were simulated for each of the four conditions with different rates of sexual activity as the calibration parameter to fit the model to the observed target prevalence statistic. All scenarios were simulated 50 times for 10 years. A simulation with no intervention implementation served as the control condition. Intervention scenarios were simulated for each combination of 20%, 50%, and 90% intervention coverage among eligible men with 20%, 50%, and 90% intervention effectiveness for a total of 9 intervention scenarios (Table 4.2) within each of the four conditions.

Table 4.2. Coverage and effectiveness scenarios considered in a stochastic model of an intervention for delay discounting of condom-protected sex among US MSM.

	Effectiveness			
Coverage	0%	20%	50%	90%

0%	Reference[1]			
20%		Scenario 1	Scenario 2	Scenario 3
50%		Scenario 4	Scenario 5	Scenario 6
90%		Scenario 7	Scenario 8	Scenario 9

[1] A no-intervention model served as the reference for 9 different coverage/effectiveness combinations.

Outcome Measures

The effect of the intervention was estimated at each combination of effectiveness and coverage using multiple epidemiological measures: HIV incidence rate and prevalence averaged over the final year of the time series and cumulative number and percent of infections averted over the ten-year time series relative to the no intervention base model. To calculate the number of infections averted, the mean cumulative incidence in the base, no-interaction scenario was subtracted from the mean cumulative incidence in a given intervention scenario. To calculate the percent of infections averted, the number of infections averted in a given scenario was divided by the mean cumulative incidence in the base scenario. All analyses were conducted in R 3.3.1 using the EpiModelHIV package.

Results

Conditions 1 and 2

The results of the scenarios in which some delay discounters always used condoms with casual or one-off partners (Conditions 1 and 2) are presented in Table 4.3. The reference (i.e., no intervention) models produced similar results in year 10 of the simulations of 3.50 and 3.53 infections per 100 person-years in scenarios where the condom use was decided by the discounter and non-discounter, respectively. These incidence rates are similar to those observed in the source data.[131] Modest reductions in incident infections were observed across the nine intervention coverage and effectiveness scenarios. The percent of infections averted ranged from 1.2% to 5.2% across the combinations of intervention coverage and effectiveness that were assessed. Across all scenarios, there were higher percentages of infections averted when the non-discounting partner decided condom use in discounting-discordant partnerships. When 90% of eligible participants were covered by an intervention assumed to be 90% effective, 4.1% and 4.9% of infections were averted when condom use was decided by the discounting partner and the non-discounting partner, respectively. After ten years of follow-up in intervention scenarios, slight reductions were observed in HIV prevalence and incidence rate for all scenarios. Reflecting the higher percentage of infections averted, larger decreases in prevalence after ten years were observed for the scenarios in which condom use was decided by the non-discounting partner.

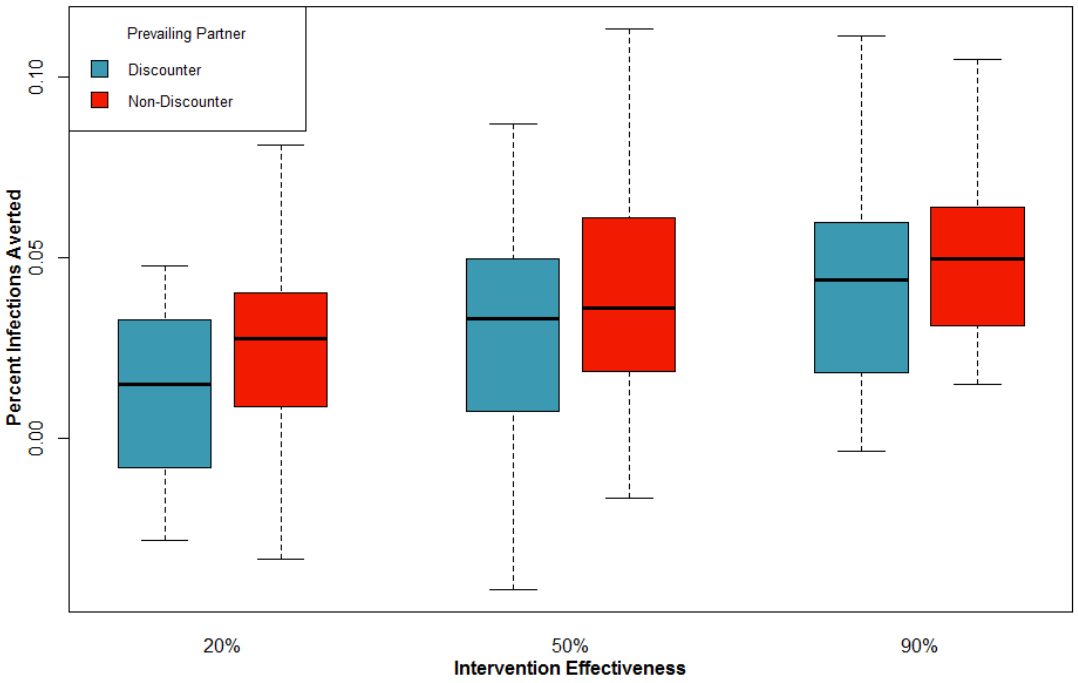
Table 4.3. Prevalence, incidence per 100 person-years, percent of infections averted, and number of infections averted with 95% credibility intervals for each coverage and effectiveness scenario for Conditions 1 and 2.

	Prevalence (%)		Incidence[a]		PIA		NIA[b]	
Scenario	Discounter[c]	Non-Discounter[d]	Discounter[c]	Non-Discounter[d]	Discounter[c]	Non-Discounter[d]	Discounter[c]	Non-Discounter[d]
No Intervention	25.5 (24.8, 26.5)	25.7 (24.5, 27.0)	3.50 (1.33, 6.04)	3.53 (1.33, 6.14)	Ref	Ref	Ref	Ref
Scenario 1	25.3 (24.5, 26.3)	25.1 (23.8, 26.1)	3.41 (1.03, 6.44)	3.43 (1.06, 6.34)	1.2 (-2.6, 4.5)	2.6 (-2.1, 7.9)	40 (-88, 154)	91 (-72, 274)
Scenario 2	25.0 (23.9, 26.3)	24.9 (23.7, 26.0)	3.35 (0.98, 6.33)	3.34 (0.99, 6.27)	3.1 (-2.1, 8.2)	3.9 (-0.4, 9.3)	105 (-73, 280)	134 (-13, 323)
Scenario 3	24.8 (23.8, 25.9)	24.7 (23.5, 25.6)	3.35 (1.0, 6.21)	3.31 (0.87, 6.32)	4.1 (-0.2, 9.3)	5.1 (1.6, 9.9)	142 (-6, 318)	176 (57, 345)
Scenario 4	25.2 (24.0, 26.2)	25.1 (23.8, 26.1)	3.41 (0.99, 6.39)	3.37 (0.98, 6.27)	2.2 (-2.7, 6.9)	3.8 (-0.7, 9.6)	75 (-92, 235)	130 (-24, 334)
Scenario 5	25.1 (23.8, 26.4)	24.8 (23.9, 25.9)	3.38 (0.97, 6.52)	3.29 (0.97, 6.18)	2.6 (-2.3, 8.8)	5.2 (0.5, 9.0)	90 (-80, 300)	182 (17, 311)
Scenario 6	24.8 (23.5, 26.1)	24.7 (23.5, 25.6)	3.34 (0.93, 6.27)	3.37 (0.99, 6.32)	4.4 (-2.1, 9.9)	4.5 (0.3, 9.3)	151 (-72, 337)	157 (11, 321)
Scenario 7	25.1 (24.2, 26.6)	24.9 (23.8, 26.0)	3.38 (0.98, 6.41)	3.33 (0.94, 6.25)	2.7 (-3.4, 6.9)	3.8 (-1.1, 9.20)	92 (-116, 237)	132 (-38, 318)
Scenario 8	24.9 (23.9, 25.8)	24.7 (23.7, 25.8)	3.30 (0.96, 6.25)	3.28 (0.91, 6.26)	3.9 (-0.6, 7.5)	5.2 (0.8, 9.9)	132 (-21, 257)	178 (27, 343)
Scenario 9	24.8 (23.8, 25.8)	24.7 (23.7, 25.9)	3.33 (1.01, 6.27)	3.32 (1.01, 6.28)	4.1 (0.0, 8.6)	4.9 (-0.4, 10.0)	142 (-1, 294)	168 (-13, 347)

[a]Per 100 person-years, [b]Per 100,000 person-years, [c]Condition in which discounters decided condom use, [d]Condition in which non-discounters decided condom use

Boxplots depicting the percentage of infections averted assuming 20% coverage at the three different simulated levels of effectiveness are presented in Figure 4.1. Under each level of effectiveness the impact of the intervention was greatest when non-discounters decided condom use. This follows from the fact that non-discounters had higher per-act condom use probabilities. Thus, when non-discounters decided whether a condom was used there was more condom use overall in the population. The figure also demonstrates that there were a number of simulations in which there was no change from the no-intervention baseline scenario, highlighting the modest effect of the intervention under these assumptions.

Figure 4.1. Percent of infections averted by Effectiveness and Prevailing Condom Use Probability, 20% Intervention Coverage in conditions where some discounters always used condoms.



Percent of infections averted (PIA) at three different levels of effectiveness assuming 20% of eligible men are enrolled in the intervention annually under the assumption that some delay discounters always use condoms with casual and one-off partners. Results are

presented for the condition in which the non-discounter controlled condom use probabilities (blue bars) and the discounter controlled condom-use probabilities (red bars) in delay-discounting discordant partnerships. The lines represent 1.5 times the interquartile range.

Conditions 3 and 4

More robust intervention effects were observed in Conditions 3 and 4 (Table 4.4). In these scenarios, the proportion of the population using condoms 100% of the time increased as the proportion of non-discounting men increased. As above, incidence in the reference conditions was similar to the source data with 3.58 infections per 100 person-years observed discounters determined condom use and 3.45 per 100 person-years when non-discounters determined condom use. The slight differences in these two rates reflect stochasticity and slight differences in initial prevalence in the two separate burn-in models. Consistent with the results discussed above, greater reductions in HIV infections were observed over the ten-year period when condom use was determined by the non-discounting partner. Under the scenario with 90% coverage of eligible men and 90% intervention effectiveness, 12.1% and 14.4% of infections were averted over ten years when the condom use was decided by the discounting and non-discounting partner, respectively. Greater reductions in prevalence and incidence were observed under this assumption as well, with reductions in prevalence of up to 3 percentage points after ten years.

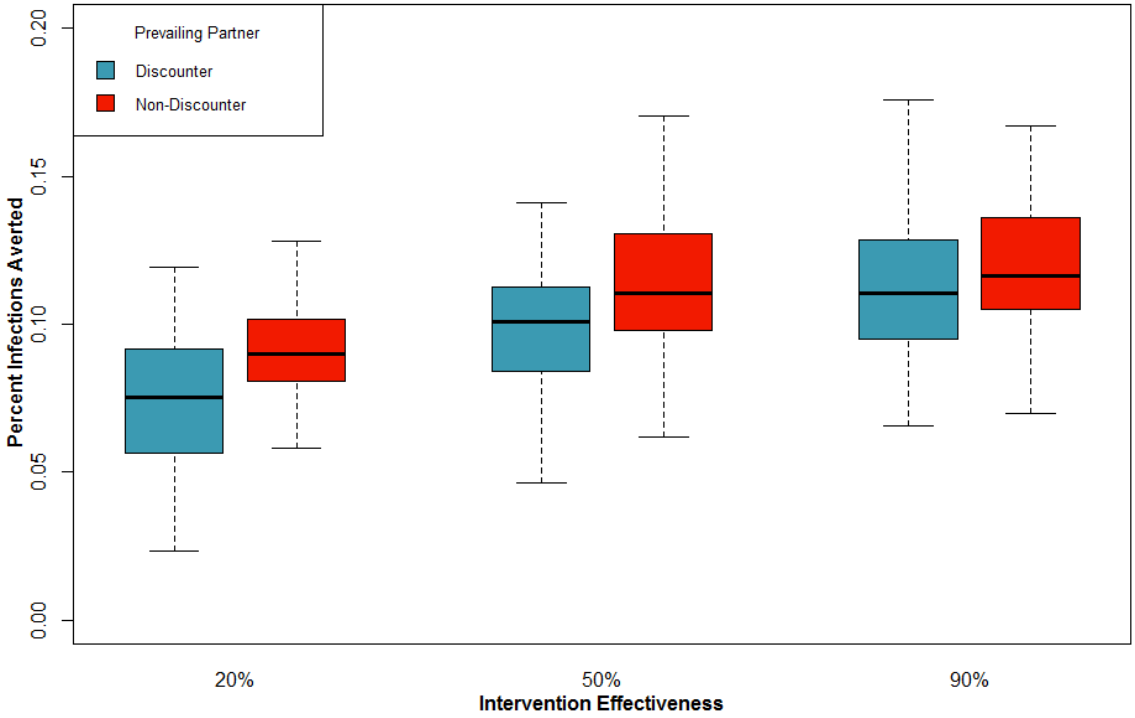
Table 4.4. Prevalence, incidence per 100 person-years, percent of infections averted, and number of infections averted with 95% credibility intervals for each coverage and effectiveness scenario for Conditions 1 and 2.

	Prevalence (%)		Incidence[a]		PIA		NIA[b]	
Scenario	Discounter[c]	Non-Discounter[d]	Discounter[c]	Non-Discounter[d]	Discounter[c]	Non-Discounter[d]	Discounter[c]	Non-Discounter[d]
No Intervention	26.2 (25.1, 27.2)	25.5 (24.3, 26.6)	3.58 (1.36, 6.14)	3.45 (1.25, 6.04)	Ref	Ref	Ref	Ref
Scenario 1	24.7 (23.6, 25.9)	23.8 (22.8, 24.5)	3.28 (0.91, 6.22)	3.07 (0.84, 5.89)	7.5 (2.6, 11.8)	9.1 (6.1, 12.0)	413 (230, 558)	315 (210, 415)
Scenario 2	24.3 (23.4, 25.2)	23.4 (22.4, 24.3)	3.13 (0.83, 5.98)	3.01 (0.79, 5.77)	9.9 (4.7, 13.7)	11.6 (8.4, 15.9)	353 (167, 488)	404 (291, 553)
Scenario 3	24.1 (22.9, 25.2)	23.2 (22.2, 24.5)	3.11 (0.79, 6.00)	2.98 (0.81, 5.77)	11.1 (6.6, 15.3)	12.1 (7.2, 16.7)	398 (237, 546)	418 (248, 581)
Scenario 4	24.4 (23.2, 25.6)	23.5 (22.5, 24.7)	3.20 (0.87, 6.04)	3.03 (0.82, 5.86)	9.5 (5.1, 15.2)	10.8 (6.6, 14.8)	339 (181, 544)	374 (229, 514)
Scenario 5	24.0 (23.0, 25.1)	23.1 (21.9, 24.2)	3.13 (0.90, 5.87)	2.92 (0.71, 5.7)	11.2 (7.3, 15.3)	13.1 (9.0, 18.9)	398 (261, 546)	453 (313, 655)
Scenario 6	23.9 (23.1, 25.0)	22.9 (21.8, 24.1)	3.09 (0.83, 5.93)	2.92 (0.74, 5.70)	11.9 (7.0, 15.4)	14.1 (10.2, 18.3)	424 (250, 549)	488 (352, 635)
Scenario 7	24.0 (23.0, 25.1)	23.2 (22.5, 24.3)	3.15 (0.80, 6.08)	2.94 (0.79, 5.67)	11.6 (6.5, 15.6)	12.4 (8.6, 16.2)	413 (230, 558)	430 (298 ,562)
Scenario 8	23.8 (23.0, 24.9)	22.7 (21.6, 23.7)	3.04 (0.78, 5.92)	2.84 (0.70, 5.56)	12.3 (8.1, 15.7)	14.7 (10.1, 19.5)	439 (290, 560)	510 (350, 676)
Scenario 9	23.9 (22.8, 25.0)	22.8 (21.8, 23.9)	3.07 (0.8, 5.90)	2.90 (0.75, 5.58)	12.1 (7.4, 17.0)	14.4 (10.5, 19.1)	431 (265, 605)	499 (366, 661)

[a]Per 100 person-years, [b]Per 100,000 person-years, [c]Condition in which discounters decided condom use, [d]Condition in which non-discounters decided condom use

Boxplots for these scenarios under the assumption of 20% coverage and the three levels of effectiveness are presented in Figure 4.2. The more robust effects of the intervention in these scenarios compared to Figure 4.1 is evident.

Figure 4.2. Percent of infections averted by effectiveness and prevailing condom use probability assuming 20% efficacy in conditions where no discounters always used condoms.



Percent of infections averted (PIA) at three different levels of effectiveness assuming 20% of eligible men are enrolled in the intervention annually under the assumption that no delay discounters always use condoms with casual and one-off partners. Results are presented for the condition in which the non-discounter controlled condom use probabilities (blue bars) and the discounter controlled condom-use probabilities (red bars) in delay-discounting discordant partnerships. The lines represent 1.5 times the interquartile range.

The reduced incidence in Conditions 3 and 4 compared to Conditions 1 and 2 reflects the fact that the effect of the intervention has a greater impact in the former. This is because

in Conditions 3 and 4 all discounters engage in CAI with non-main partners, whereas in Conditions 1 and 2 some discounters always used condoms with non-main partners. In Conditions 3 and 4, the intervention has the effect of increasing per-act condom use from 20% to 36% for some men and for others condom use is increased to 100%. In Conditions 1 and 2, some discounters always use condoms with non-main partners; thus, the behavior of these men is not changed by the intervention.

Discussion

In this study we found that a stand-alone hypothetical behavioral intervention targeting delay discounting of condom-protected sex among sexually active MSM could avert up to 14% of infections over 10 years. Delay discounting has previously been shown to be associated with CAI in this population[49,55,56]. Currently there are no interventions available to reduce delay discounting of condom-protected sex. However, there are behavioral interventions that have been developed to target delay discounting in other domains (e.g., money[67]). The goal of this study was to demonstrate a range of possible outcomes of such an intervention to reduce CAI and, therefore, HIV transmission in order to inform decisions regarding research priorities.

We explored a variety of assumptions about the impact of delay discounting on condom use under varying levels of intervention coverage and effectiveness. Variations in the conditions and scenarios in our model resulted in differences in the effectiveness of the hypothetical intervention to reduce HIV incidence. Under all assumptions, a high level of coverage and effectiveness resulted in at least 4% of infections averted over a ten year period, with as many as 14.4% of infections averted under the most effective scenario. The magnitude of the intervention effect was largely influenced by the assumption determining whether some delay-discounting men used condoms 100% of the time with non-main partners, with larger proportions of infections averted when the only men who used condoms consistently were non-discounters (Conditions 3 and 4). The somewhat modest impact of the intervention reflects the modest change in per-act condom use probability that was assumed for discounters (20%) compared to non-discounters (36%). Alterations to these estimates based on additional data would result in

greater effects if the discrepancy in condom use were estimated to be larger or lesser effects if the discrepancy were estimated to be smaller.

These results represent a range of possible effects of a behavioral intervention targeting delay discounting. We varied two different characteristics related to condom use. First, delay discounting is an individual characteristic but condom use occurs at the level of the dyad. In partnerships in which one partner discounts delayed condom-use and the other partner does not, it is unclear which partner will decide whether to use a condom. Thus, we simulated the models under the assumption that the discounter decides as well as the assumption that the non-discounter decides. As expected, a greater number of infections were averted in the conditions where the non-discounter decided because these individuals were more likely to use condoms.

Second, based on the sexual behavior data that informed the development of the initial network model[79], 22% of men always use condoms with casual partners and 33% always use condoms with one-off partners. It is unclear what role delay discounting should play with respect to these probabilities. Although men who discount delayed sex are more likely to engage in CAI this does not mean there are not men who are discounters but who nonetheless always use condoms in these situations. Thus, to further assess the range of possible outcomes, we modeled ten-year outcomes assuming that some discounters do use condoms 100% of the time with casual and one-off partners (Conditions 1 and 2) and assuming that only non-discounters do (Conditions 3 and 4). In the latter situation the intervention has a greater impact because some men who stop discounting delayed sex start using condoms 100% of the time with casual and one-off partners.

Additional studies would be beneficial to better parameterize the current model with respect to the effects of delay discounting. Per-act condom use was estimated in the current study based on 12-month prevalence of CAI among discounters and non-discounters. Future studies should investigate whether per-act condom use is similar to the parameters assumed in the current study. Additional studies could investigate mixing patterns to determine if there is random mixing between discounters and non-discounters in sexual partnerships. Further, among those partnerships in which one partner discounts and the other does not, it would be helpful to study if one partner has more influence regarding condom use decisions or if condom use in such partnerships is some average of the two. Finally, additional research would be useful in assessing whether there are discounters who always use condoms with non-main partners.

In order to isolate the effects of a hypothetical intervention, other HIV prevention interventions were not implemented in the scenarios that were assessed. For example, PrEP implementation is available in the model and would be available in any real world scenario in which a behavioral intervention is implemented. Thus, the present results do not specifically indicate the expected decrease in incidence that would occur over and above existing combination HIV prevention. However, condom use promotion is a necessary component of combination prevention interventions[78] and an important next step will be to model the delay discounting intervention in the context of combination prevention. The association between discounting of condom-protected sex and PrEP use will need to be considered. For example, men who discount condom-protected sex may be more likely to initiate PrEP or PrEP use may increase the degree to which men discount.

This study has limitations. The current model assumes random mixing based on delay discounting status. It is unclear whether this is appropriate or if men who discount condom protected sex would be more likely to be in partnerships with each other. For example, if men who are more likely to take sexual risks are also more likely to enter into casual or one-off partnerships then this might affect the impact of the intervention. However, any impact would likely be minimal given that non-random mixing by delay discounting status would be unlikely to be much less extreme than mixing by other characteristics such as race or age. The intervention effects in the context of non-random mixing would likely be between those observed in the conditions in which the discounter decides condom use and those in which the non-discounter decides. This is because the lower rates of condom use in partnerships between delay discounters would be offset by the increased proportion of non-discounter-concordant partnerships when the intervention is implemented.

Other variables, such as substance use, that are associated with both delay discounting[132] and sexual risk-taking[133,134] are not available in the model. Therefore, we are unable to assess effect modification or mediation of effect based on some potentially important variables. Substance use is associated with a greater likelihood of having serodiscordant CAI[135] and is also associated with delay discounting. Targeting an intervention to men who discount condom-protected sex might result in identification of men with more risk behaviors than average. If that is the case then the current results are biased toward the null and the effect of the intervention would be expected to be greater in practice. Future studies should investigate how delay discounting affects other behaviors associated with HIV risk, such as serostatus disclosure and adherence to PrEP. It is possible that

discounting delayed consequences might affect adherence to medications, including preventive regimens such as PrEP. Thus, discounting status might be an important consideration in determining whether a patient needs additional resources to promote adherence.

Finally, many of the sexual behavior parameters in the model were derived from two studies conducted in Atlanta, Georgia and the delay discounting parameters were estimated from a separate study conducted online using a national sample of MSM. Thus, the delay discounting parameters were not derived from the same population as the rest of the model parameters. It is possible that the delay discounting characteristics of the Atlanta study cohorts differed from those of the online survey. Participants in the delay discounting survey were recruited via Facebook advertisements; the generalizability of these results to populations beyond Facebook-using MSM is also questionable.

This study highlights the utility of stochastic network models to inform HIV prevention research priorities. Using cross-sectional data to estimate the association of delay discounting with sexual risk-taking, we were able to estimate the potential effectiveness of an intervention at the population level. Leveraging the existing resource of a network model to answer additional questions provides invaluable insight for planning future research programs. Overall, the results of this study suggest that further research into the association of delay discounting with CAI and a risk-reduction intervention targeting delay discounting may have a meaningful impact on condom use and HIV incidence among MSM. Notably, a modeling study of combination HIV prevention found that a 15% reduction in CAI, comparable to that modeled in the current study, in combination with increases in PrEP use, HIV testing, and treatment of HIV-

infected men would result in a total reduction of 34% of infections over five years[78]. Thus, the current results suggest that an intervention that could reduce delay discounting would be a valuable contribution to combination HIV prevention efforts.

Chapter 5: Conclusions and Public Health Implications

The goal of this dissertation was to assess the role of two types of delay discounting in sexual risk behavior among MSM: monetary delay discounting and sexual delay discounting. Monetary delay discounting, although specific to financial behavior and decision-making, has been used in the literature as a general measure of delay discounting that has been related to impulsive behavior in multiple health domains. Sexual delay discounting assesses impulsive decision-making and behavior specific to sexual behavior. In the current studies, sexual impulsivity is operationalized as the degree to which an individual is willing to wait for a condom to be available.

To the extent that delay discounting was found to be associated with sexual risk-taking, the goal was to further assess the role that delay discounting may play in HIV transmission among MSM in the United States. Behavioral HIV prevention interventions designed to decrease CAI have historically demonstrated limited effectiveness.[6] Biomedical interventions such as TasP and PrEP have been demonstrated to be highly effective; however, they will not be sufficient in isolation to end the epidemic of HIV among MSM.[5,78,126] Behavioral interventions designed to increase condom use are also an important component of combination HIV prevention.[78]

Delay discounting represents a new exposure within HIV epidemiology that may serve as an indicator for propensity to engage in risky sexual behavior and/or as a potential target for novel behavioral prevention interventions. This dissertation, therefore, contributes to the empirical basis for future investigations into the role of delay discounting in risky sexual behavior and HIV transmission. In this chapter, we review the

major contributions of this dissertation followed by a discussion of innovations, public health implications, and future research directions.

Review of Major Findings

In Aim 1, we assessed the concordance between two types of delay discounting – monetary and sexual. Numerous previous studies have assessed monetary delay discounting in isolation and its association with health and behavioral outcomes[28,29,31,34,39,40,88,89,136]; fewer studies have assessed sexual delay discounting[47-53,87,90,92,137], and fewer still have assessed both in the same individuals[47,48,52,91,92]. Further, previous studies tend to be relatively small and many analyzed the discounting data using data transformations that might not be justifiable. Using an Internet-based sample of MSM, we found that there was no association between monetary and sexual delay discounting. This suggests that monetary delay discounting may not be an appropriate measure of propensity to engage in risky sexual behavior. This result stands in contrast to impulsive behavior in other domains, such as substance use and abuse, in which monetary delay discounting is related to non-economic outcomes. Further, we demonstrated that, at least in our study sample, the rank transformations that have been applied to sexual delay discounting data by other authors are inappropriate given the significant amount of clustering that was observed.

In Aim 2, we assessed the association between monetary and sexual delay discounting and risky sexual behavior, operationalized as CAI in the past 12 months. Further, we examined modifications of these association by age group and PrEP use. Adjusting for poverty, education, and number of partners reported, there was no association observed between monetary delay discounting and CAI. An association was

observed between sexual delay discounting and CAI. Although a statistical interaction was not observed, the association tended to be stronger in younger MSM compared to older MSM. Differences were observed based on the condition of the SDT. The four conditions on the SDT were the men the participant would most (MOSTSEX) and least (LEASTSEX) like to have sex with and the men the participant thought was most (MOSTSTI) and least (LEASTSTI) likely to have a STI. The association between sexual discounting and CAI was consistently higher in current PrEP users compared to non-users; however, the interaction was only statistically significant for the MOSTSEX condition. These data are from a cross-sectional survey, so it is not possible to determine whether PrEP use is the cause of higher prevalence of CAI or whether men are on PrEP because they are more likely to engage in sexual risk behavior.

In Aim 3, we assessed the potential impact of a hypothetical delay discounting intervention on HIV incidence in a virtual population. We used dynamic networks to model the expected rates of HIV incidence in a population with delay discounting characteristics derived from the survey data used for Aims 1 and 2. There are currently no interventions available that target sexual delay discounting, although interventions targeting delay discounting in other domains have been demonstrated to be efficacious. Using dynamic network models allowed us to explore the effect of varying levels of intervention coverage and effectiveness to inform the potential for a delay discounting intervention to reduce HIV incidence in an open population of MSM. Overall, the percent of infections averted in a scenario with 90% of eligible participants enrolled to receive an intervention that is 90% effective ranged from 4.1% to 14.4%. This reduction is modest; however, in combination with existing HIV prevention interventions it could lead to a

meaningful decrease in HIV incidence over and above that achieved by current public health efforts. Future modeling studies should explore delay discounting interventions in the context of combination prevention efforts as well as delay discounting interventions that are targeted to the highest risk men.

Finally, the use of network modeling methods in Aim 3 demonstrates a valuable use for these types of models beyond that typically presented in the literature. Network models are commonly used to demonstrate expected outcomes of interventions that are well established or have a large body of literature supporting them. In this dissertation, network modeling methods are being used to analyze the potential impact of a hypothetical intervention to help guide research priorities. These methods allowed us to generate specific estimates of what would be expected based on different scenarios of intervention effectiveness and coverage. These results suggest that, depending on the validity of the prevailing assumptions, relatively high levels of both effectiveness and coverage may be necessary to have a meaningful impact on HIV incidence among MSM.

Innovation

This dissertation represents a number of innovations with respect to delay discounting and HIV prevention among MSM. These three studies represent some of the first studies of monetary and sexual delay discounting among MSM. Previously, one study had investigated monetary discounting among MSM[55] and another had investigated sexual discounting among MSM[49]. This is the first study to investigate both monetary and sexual discounting within the same sample. It is also the first study to assess sexual discounting among MSM in a broadly recruited sample. The previous study that assessed sexual discounting among MSM used Amazon Mechanical Turk (MTurk) to recruit a

sample of 108 MSM. MTurk is a website on which workers can earn money for completing small tasks, including completing surveys. Thus, workers may be incentivized to provide false information in order to qualify for a survey in order to earn money. The study population for this dissertation was recruited via advertisements on Facebook that were targeted to MSM, and participants were not compensated for completing the survey.

The study population in this dissertation is also much larger and more representative of the target population than the samples that are typically recruited for studies of delay discounting. Most studies of delay discounting recruit study populations of fewer than 100 individuals, limiting the ability of researchers to investigate multi-variable relationships between delay discounting and outcomes of interest. Thus, most delay discounting studies present numerous bivariate comparisons but do not have sufficient sample size to investigate potential confounding of these associations. The large sample size employed in this dissertation, in concert with the extensive demographic and behavioral survey that participants completed, allowed for multivariable modeling to control for the effects of extraneous variables on the association between delay discounting and risky sexual behavior.

In addition to control for confounding variables, the analysis methods used to model the effects of sexual delay discounting were also innovative. Sexual delay discounting is measured using a standardized AUC, which is typically rank-transformed for analysis.[47,50] The rank transformation is designed to allow non-parametric statistical testing on the skewed data.[96] However, the standardized AUC values in the current study were highly clustered due to the large proportion of men who did not discount condom-

protected sex and the smaller proportion of men who steeply discounted condom-protected sex. This clustering significantly reduced the utility of a rank transformation due to the substantial number of ties that were observed. It is possible that such clustering was not as evident in previous studies that employed smaller sample sizes. In the current studies, the standardized AUC value was categorized. In future studies, researchers should examine the distribution of the data to determine whether a rank transformation is appropriate.

With regard to HIV prevention, this dissertation provides an innovative means of identifying men at high risk of HIV exposure. Men who discount condom-protected sex are more likely to engage in CAI compared to men who do not. This knowledge may lead to innovative HIV prevention interventions to reduce CAI or expand methods to identify men in need of prevention services. Although improvements in HIV prevention have been realized as a result of advances in biomedical prevention strategies, such as PrEP and TasP, behavioral interventions designed to increase condom use are still needed as part of combination HIV prevention strategies. In this dissertation, we identify delay discounting as a potential theoretical basis for the development of novel behavioral interventions.

We also propose and demonstrate an innovative use for agent-based models of HIV transmission. Agent-based models are often used to observe counterfactual conditions in a population and to estimate the impact of established HIV prevention methods. For example, agent-based models might be used to estimate the impact of increasing levels of coverage of a known intervention, such as PrEP. In contrast, in this dissertation we use agent-based modeling to demonstrate the potential impact of a

hypothetical intervention. Using data from the online survey to estimate the potential increases in condom use that might be observed following a successful delay discounting intervention, we demonstrate the potential effect on HIV incidence in an open population under several different scenarios. This result suggests that continued research with the goal of developing an intervention based on delay discounting of condom-protected sex is warranted.

Relevance and Public Health Impact

This dissertation has direct relevance to prevention of HIV among MSM in the United States. We have demonstrated that delay discounting of condom-protected sex is associated with reduced condom use in a diverse sample of MSM. The potential public health implications for this finding are broad and will depend on the extent to which future research results in interventions that are informed by these findings. These studies lay the groundwork for identifying the role that impulsive behavior, operationalized as delay discounting of condomless sex, might play in decisions about condom use and how alterations to individuals' discount rates might result in meaningful reductions in HIV transmission.

We have demonstrated that sexual, but not monetary, delay discounting is an indicator of sexual risk. In addition to the potential for HIV prevention interventions as described above, delay discounting might also provide a reliable method for assessing individual risk and prioritizing intervention resources to those most at risk of HIV seroconversion. For example, delay discounting tasks might be useful in identifying men most in need of interventions such as PrEP.

Issues surrounding resource allocation are a perennial problem in public health settings. Decisions must be made with regard to programmatic priorities at all levels of public health. Similar decisions must also be made within academic settings and within competitive grant review processes when deciding which projects should be prioritized for further research. We have demonstrated a method for helping to prioritize resource allocations within an academic research setting by using agent-based modeling to estimate the potential benefits of a hypothetical intervention. The differences in condom use between men who discount condom-protected sex and those who do not are relatively modest; therefore, it is not immediately clear how many infections might be averted if fewer men were delay discounters. Network models provide a method for estimating the potential impact. This is a method that other researchers might also use to determine research priorities when existing evidence is limited.

Future Directions

There are a number of research questions that are generated as a result of this dissertation that should be addressed in future research. First, the association between delay discounting and sexual risk behavior should be further explored. The results reported in this dissertation are the result of a cross-sectional survey of MSM. Thus, issues of temporality and causality are difficult to address. An important next step will be to conduct a longitudinal study to assess whether men who discount condom-protected sex are more likely to engage in CAI during follow-up. In a study of HIV-negative black MSM currently being conducted at Emory University, participants are completing monetary and sexual discounting tasks in order to better understand the temporal

relationship between delay discounting, CAI, and HIV seroconversion. This will help to untangle whether delay discounting precedes CAI.

The association between delay discounting and other sexual risk behaviors should also be explored. Other predictors of HIV risk such as failure to discuss serostatus with sexual partners and substance use might be associated with sexual delay discounting. Substance use and abuse is known to be associated with delay discounting in other domains; it is unclear whether it is also associated with sexual delay discounting. In Chapter 3 of this dissertation, number of partners was a statistically significant predictor of CAI. Future research should also investigate whether number of partners is related to delay discounting status.

We have identified delay discounting as a possible tool to aid in the identification of high-risk men who might be good candidates for PrEP. However, delay discounting might also play a role in adherence for those men who initiate PrEP therapy. That is, men who discount delayed outcomes more steeply might be less likely to faithfully adhere to a PrEP regimen. Future studies should investigate whether adherence to PrEP among HIV-negative individuals or adherence to antiretroviral therapy among HIV-infected individuals is associated with delay discounting.

The effect of age on delay discounting status and on the association between delay discounting and CAI should also continue to be explored. In the current studies, there was not a statistically significant interaction based on age group. However, the observed prevalence differences for CAI were stronger across conditions of the SDT in younger compared to older MSM. If the association is indeed stronger among younger MSM, then a delay discounting intervention would be expected to have a greater impact

among younger compared to older MSM. Thus, continued characterization of the association between delay discounting and CAI and potential modifying effects by age is warranted.

Further, analyses should be conducted to assess the extent to which a delay discounting assessment, either alone or in combination with behavioral and sociodemographic information, is able to identify individuals at increased need of HIV prevention interventions, such as PrEP. Additionally, as more data are gathered, it would be beneficial to identify a criterion level of delay discounting that is associated with increased risk so that standardized recommendations could be provided with any screening tools based on a delay discounting task. Additionally, shortened versions of the SDT should be assessed to determine if shorter versions maintain similar sensitivity for identifying individuals at risk for engaging in risky sexual behavior. It is possible that a shorter version that would reduce respondent burden would have similar sensitivity and specificity to the full tool. For example, it may only be necessary to assess one condition of the SDT (e.g., MOSTSEX) in order to obtain a reliable estimate of an individual's discount rate.

Additional agent-based modeling analyses will be useful in determining the role that delay discounting interventions might play in the context of combination prevention. In order to appropriately parameterize these models, future studies should also investigate the extent to which PrEP use affects discounting of condom-protected sex. There have been mixed results with regard to risk compensation among men taking PrEP, and delay discounting tasks provide a method for measuring potential changes in decision-making

and risk perception that result from taking PrEP. Models could also be designed to incorporate substance use and its effects on sexual risk-taking.

More nuanced models of delay discounting could also be explored. In Chapter 4 of this dissertation we dichotomized delay discounting as any discounting versus no discounting in a network model of MSM. This increases the interpretability of the results, but a continuous or categorical scale of delay discounting might also provide more accurate estimates of the potential impact of an intervention.

Finally, research is needed to investigate the feasibility of a risk reduction intervention based on delay discounting. Several intervention strategies, such as episodic future thinking (EFT), have been shown to reduce delay discounting in other domains. These same strategies should be explored in the context of sexual discounting to determine whether they might be efficacious in reducing discounting of condom-protected sex. If so, then this could lead to the development of novel interventions to increase condom use and reduce HIV transmission among MSM.

References

1. UN AIDS. AIDSinfo 2014 [cited 2014 February 20, 2015]. Available from: http://www.unaids.org/en/dataanalysis/datatools/aidsinfo/.

2. Centers for Disease Control and Prevention. CDC - Fact Sheet - Gay and Bisexual Men 2015 [cited 2015 April 27]. Available from: http://www.cdc.gov/hiv/risk/gender/msm/facts/.

3. Purcell DW, Johnson CH, Lansky A, Prejean J, Stein R, Denning P, Gau Z, Weinstock H, Su J, Crepaz N. Estimating the population size of men who have sex with men in the United States to obtain HIV and syphilis rates. The Open AIDS Journal. 2012;6:98-107. Epub 2012/10/11. doi: 10.2174/1874613601206010098. PubMed PMID: 23049658; PMCID: Pmc3462414.

4. Prejean J, Song R, Hernandez A, Ziebell R, Green T, Walker F, Lin LS, An Q, Mermin J, Lansky A, Hall HI, for the HIVISG. Estimated HIV Incidence in the United States, 2006-2009. PLoS One. 2011;6(8):e17502.

5. Beyrer C, Sullivan PS, Sanchez J, Dowdy D, Altman D, Trapence G, Collins C, Katabira E, Kazatchkine M, Sidibe M, Mayer KH. A call to action for comprehensive HIV services for men who have sex with men. Lancet. 2012;380(9839):424-38. Epub 2012/07/24. doi: 10.1016/s0140-6736(12)61022-8. PubMed PMID: 22819663; PMCID: Pmc3805059.

6. Sullivan PS, Carballo-Diéguez A, Coates T, Goodreau SM, McGowan I, Sanders EJ, Smith A, Goswami P, Sanchez J. Successes and challenges of HIV prevention in men who have sex with men. The Lancet. 2012;380(9839):388-99. doi: 10.1016/s0140-6736(12)60955-6.

7. Chang LW, Serwadda D, Quinn TC, Wawer MJ, Gray RH, Reynolds SJ. Combination implementation for HIV prevention: moving from clinical trial evidence to population-level effects. The Lancet Infectious Diseases. 2013;13(1):65-76. doi: 10.1016/s1473-3099(12)70273-6.

8. Grossman CI, Purcell DW, Rotheram-Borus MJ, Veniegas R. Opportunities for HIV combination prevention to reduce racial and ethnic health disparities. Am Psychol. 2013;68(4):237-46. doi: 10.1037/a0032711. PubMed PMID: 23688091; PMCID: 3947902.

9. Herbst JH, Beeker C, Mathew A, McNally T, Passin WF, Kay LS, Crepaz N, Lyles CM, Briss P, Chattopadhyay S, Johnson RL. The effectiveness of individual-, group-, and community-level HIV behavioral risk-reduction interventions for adult men who have sex with men: a systematic review. Am J Prev Med. 2007;32(4 Suppl):S38-67. Epub 2007/03/28. doi: 10.1016/j.amepre.2006.12.006. PubMed PMID: 17386336.

10. Centers for Disease Control and Prevention. Compendium of Evidence-Based Interventions and Best Practices for HIV Prevention 2015 [updated November 2015; cited 2016 February 2016]. Available from: http://www.cdc.gov/hiv/prevention/research/compendium/rr/complete.html.

11. Centers for Disease Control and Prevention. Effective Interventions: HIV Prevention That Works 2015 [cited 2016 10/28/2016]. Available from: https://effectiveinterventions.cdc.gov/.

12. Cohen MS, Chen YQ, McCauley M, Gamble T, Hosseinipour MC, Kumarasamy N, Hakim JG, Kumwenda J, Grinsztejn B, Pilotto JH, Godbole SV, Mehendale S, Chariyalertsak S, Santos BR, Mayer KH, Hoffman IF, Eshleman SH, Piwowar-Manning

E, Wang L, Makhema J, Mills LA, de Bruyn G, Sanne I, Eron J, Gallant J, Havlir D, Swindells S, Ribaudo H, Elharrar V, Burns D, Taha TE, Nielsen-Saines K, Celentano D, Essex M, Fleming TR. Prevention of HIV-1 infection with early antiretroviral therapy. N Engl J Med. 2011;365(6):493-505. Epub 2011/07/20. doi: 10.1056/NEJMoa1105243. PubMed PMID: 21767103; PMCID: Pmc3200068.

13. Wilson DP. HIV treatment as prevention: natural experiments highlight limits of antiretroviral treatment as HIV prevention. PLoS medicine. 2012;9(7):e1001231. doi: 10.1371/journal.pmed.1001231. PubMed PMID: 22807656; PMCID: 3393678.

14. Grant RM, Lama JR, Anderson PL, McMahan V, Liu AY, Vargas L, Goicochea P, Casapia M, Guanira-Carranza JV, Ramirez-Cardich ME, Montoya-Herrera O, Fernandez T, Veloso VG, Buchbinder SP, Chariyalertsak S, Schechter M, Bekker LG, Mayer KH, Kallas EG, Amico KR, Mulligan K, Bushman LR, Hance RJ, Ganoza C, Defechereux P, Postle B, Wang F, McConnell JJ, Zheng JH, Lee J, Rooney JF, Jaffe HS, Martinez AI, Burns DN, Glidden DV. Preexposure chemoprophylaxis for HIV prevention in men who have sex with men. N Engl J Med. 2010;363(27):2587-99. Epub 2010/11/26. doi: 10.1056/NEJMoa1011205. PubMed PMID: 21091279; PMCID: 3079639.

15. Paltiel AD, Freedberg KA, Scott CA, Schackman BR, Losina E, Wang B, Seage GR, 3rd, Sloan CE, Sax PE, Walensky RP. HIV preexposure prophylaxis in the United States: impact on lifetime infection risk, clinical outcomes, and cost-effectiveness. Clin Infect Dis. 2009;48(6):806-15. doi: 10.1086/597095. PubMed PMID: 19193111; PMCID: 2876329.

16. Smith DK, Pals SL, Herbst JH, Shinde S, Carey JW. Development of a clinical screening index predictive of incident HIV infection among men who have sex with men

in the United States. J Acquir Immune Defic Syndr. 2012;60(4):421-7. Epub 2012/04/11. doi: 10.1097/QAI.0b013e318256b2f6. PubMed PMID: 22487585.

17. Menza TW, Hughes JP, Celum CL, Golden MR. Prediction of HIV acquisition among men who have sex with men. Sex Transm Dis. 2009;36(9):547-55. Epub 2009/08/27. doi: 10.1097/OLQ.0b013e3181a9cc41. PubMed PMID: 19707108; PMCID: PMC2753675.

18. Hoenigl M, Weibel N, Mehta SR, Anderson CM, Jenks J, Green N, Gianella S, Smith DM, Little SJ. Development and validation of the San Diego Early Test Score to predict acute and early HIV infection risk in men who have sex with men. Clin Infect Dis. 2015;61(3):468-75. Epub 2015/04/24. doi: 10.1093/cid/civ335. PubMed PMID: 25904374; PMCID: Pmc4542926.

19. Flynn NM, Forthal DN, Harro CD, Judson FN, Mayer KH, Para MF. Placebo-controlled phase 3 trial of a recombinant glycoprotein 120 vaccine to prevent HIV-1 infection. J Infect Dis. 2005;191(5):654-65. Epub 2005/02/03. doi: 10.1086/428404. PubMed PMID: 15688278.

20. Bartholow BN, Buchbinder S, Celum C, Goli V, Koblin B, Para M, Marmor M, Novak RM, Mayer K, Creticos C, Orozco-Cronin P, Popovic V, Mastro TD. HIV sexual risk behavior over 36 months of follow-up in the world's first HIV vaccine efficacy trial. J Acquir Immune Defic Syndr. 2005;39(1):90-101. Epub 2005/04/27. PubMed PMID: 15851919.

21. Koblin B, Chesney M, Coates T. Effects of a behavioural intervention to reduce acquisition of HIV infection among men who have sex with men: the EXPLORE

randomised controlled study. Lancet. 2004;364(9428):41-50. Epub 2004/07/06. doi: 10.1016/s0140-6736(04)16588-4. PubMed PMID: 15234855.

22. Jones J, Hoenigl M, Siegler A, Sullivan PS, Little SJ, Rosenberg E. Assessing the Performance of Three HIV Incidence Risk Scores in a Cohort of Black and White MSM in the South. Sex Transm Dis. Under Review.

23. Mazur JE. An adjusting procedure for studying delayed reinforcement. In: Commons ML, Mazur JE, Nevin JA, Rachlin H, editors. Quantitative analyses of behavior: the effects of delay and of intervening events on reinforcement value. Hillsdale, NJ: Erlbaum; 1987. p. 55–73.

24. Critchfield TS, Kollins SH. Temporal discounting: basic research and the analysis of socially important behavior. J Appl Behav Anal. 2001;34(1):101-22. doi: 10.1901/jaba.2001.34-101. PubMed PMID: 11317983.

25. Kirby KN, Petry NM, Bickel WK. Heroin addicts have higher discount rates for delayed rewards than non-drug-using controls. J Exp Psychol Gen. 1999;128(1):78-87. PubMed PMID: 10100392.

26. Epstein LH, Richards JB, Saad FG, Paluch RA, Roemmich JN, Lerman C. Comparison between two measures of delay discounting in smokers. Experimental and clinical psychopharmacology. 2003;11(2):131-8. PubMed PMID: 12755457.

27. Claus ED, Kiehl KA, Hutchison KE. Neural and behavioral mechanisms of impulsive choice in alcohol use disorder. Alcohol Clin Exp Res. 2011;35(7):1209-19. doi: 10.1111/j.1530-0277.2011.01455.x. PubMed PMID: 21676001; PMCID: 3117198.

28. Petry NM. Delay discounting of money and alcohol in actively using alcoholics, currently abstinent alcoholics, and controls. Psychopharmacology (Berl). 2001;154(3):243-50. doi: 10.1007/s002130000638.

29. Heil SH, Johnson MW, Higgins ST, Bickel WK. Delay discounting in currently using and currently abstinent cocaine-dependent outpatients and non-drug-using matched controls. Addict Behav. 2006;31(7):1290-4.

30. Kirby KN, Petry NM. Heroin and cocaine abusers have higher discount rates for delayed rewards than alcoholics or non-drug-using controls. Addiction. 2004;99(4):461-71. Epub 2004/03/31. doi: 10.1111/j.1360-0443.2003.00669.x. PubMed PMID: 15049746.

31. Odum AL, Madden GJ, Badger GJ, Bickel WK. Needle sharing in opioid-dependent outpatients: psychological processes underlying risk. Drug Alcohol Depend. 2000;60(3):259-66.

32. Semple SJ, Zians J, Grant I, Patterson TL. Impulsivity and methamphetamine use. J Subst Abuse Treat. 2005;29(2):85-93. doi: 10.1016/j.jsat.2005.05.001. PubMed PMID: ISI:000231962600003.

33. Audrain-McGovern J, Rodriguez D, Epstein LH, Cuevas J, Rodgers K, Wileyto EP. Does delay discounting play an etiological role in smoking or is it a consequence of smoking? Drug Alcohol Depend. 2009;103(3):99-106. doi: 10.1016/j.drugalcdep.2008.12.019. PubMed PMID: 19443136.

34. Baker F, Johnson MW, Bickel WK. Delay discounting in current and never-before cigarette smokers: similarities and differences across commodity, sign, and

magnitude. J Abnorm Psychol. 2003;112(3):382-92. Epub 2003/08/29. PubMed PMID: 12943017.

35. Dallery J, Raiff BR. Delay discounting predicts cigarette smoking in a laboratory model of abstinence reinforcement. Psychopharmacology (Berl). 2007;190(4):485-96. doi: 10.1007/s00213-006-0627-5. PubMed PMID: 17205320.

36. Wilson AG, Franck CT, Mueller ET, Landes RD, Kowal BP, Yi R, Bickel WK. Predictors of delay discounting among smokers: Education level and a Utility Measure of Cigarette Reinforcement Efficacy are better predictors than demographics, smoking characteristics, executive functioning, impulsivity, or time perception. Addict Behav. 2015;45C:124-33. doi: 10.1016/j.addbeh.2015.01.027. PubMed PMID: 25661991.

37. Heyman GM, Gibb SP. Delay discounting in college cigarette chippers. Behav Pharmacol. 2006;17(8):669-79. Epub 2006/11/18. doi: 10.1097/FBP.0b013e3280116cfe. PubMed PMID: 17110793.

38. Reynolds B, Richards JB, Horn K, Karraker K. Delay discounting and probability discounting as related to cigarette smoking status in adults. Behavioural processes. 2004;65(1):35-42. doi: 10.1016/s0376-6357(03)00109-8. PubMed PMID: ISI:000188861400005.

39. Odum AL, Madden GJ, Bickel WK. Discounting of delayed health gains and losses by current, never- and ex-smokers of cigarettes. Nicotine Tob Res. 2002;4(3):295-303.

40. Petry NM. Discounting of money, health, and freedom in substance abusers and controls. Drug Alcohol Depend. 2003;71(2):133-41. doi: 10.1016/s0376-8716(03)00090-5. PubMed PMID: ISI:000185224300004.

41. Jarmolowicz DP, Cherry JB, Reed DD, Bruce JM, Crespi JM, Lusk JL, Bruce AS. Robust relation between temporal discounting rates and body mass. Appetite. 2014;78:63-7. Epub 2014/03/22. doi: 10.1016/j.appet.2014.02.013. PubMed PMID: 24650831; PMCID: Pmc4220169.

42. Dassen FC, Houben K, Jansen A. Time orientation and eating behavior. Unhealthy eaters consider immediate consequences, while healthy eaters focus on future health. Appetite. 2015. Epub 2015/03/31. doi: 10.1016/j.appet.2015.03.020. PubMed PMID: 25814191.

43. Washio Y, Higgins ST, Heil SH, McKerchar TL, Badger GJ, Skelly JM, Dantona RL. Delay Discounting is Associated with Treatment Response among Cocaine-Dependent Outpatients. Experimental and clinical psychopharmacology. 2011;19(3):243-8. doi: 10.1037/a0023617. PubMed PMID: PMC3476946.

44. MacKillop J, Kahler CW. Delayed reward discounting predicts treatment response for heavy drinkers receiving smoking cessation treatment. Drug Alcohol Depend. 2009;104(3):197-203. doi: 10.1016/j.drugalcdep.2009.04.020. PubMed PMID: 19570621.

45. Krishnan-Sarin S, Reynolds B, Duhig AM, Smith A, Liss T, McFetridge A, Cavallo DA, Carroll KM, Potenza MN. Behavioral impulsivity predicts treatment outcome in a smoking cessation program for adolescent smokers. Drug Alcohol Depend. 2007;88(1):79-82. Epub 2006/10/20. doi: 10.1016/j.drugalcdep.2006.09.006. PubMed PMID: 17049754; PMCID: 1868698.

46. Yoon JH, Higgins ST, Heil SH, Sugarbaker RJ, Thomas CS, Badger GJ. Delay discounting predicts postpartum relapse to cigarette smoking among pregnant women.

Experimental and clinical psychopharmacology. 2007;15(2):176-86. Epub 2007/05/02. doi: 10.1037/1064-1297.15.2.186. PubMed PMID: 17469941.

47. Johnson MW, Bruner NR. The Sexual Discounting Task: HIV Risk Behavior and the Discounting of Delayed Sexual Rewards in Cocaine Dependence. Drug Alcohol Depend. 2012;123(1-3):15-21. doi: 10.1016/j.drugalcdep.2011.09.032. PubMed PMID: PMC3290676.

48. Herrmann ES, Hand DJ, Johnson MW, Badger GJ, Heil SH. Examining delay discounting of condom-protected sex among opioid-dependent women and non-drug-using control women. Drug Alcohol Depend. 2014;144:53-60. doi: 10.1016/j.drugalcdep.2014.07.026. PubMed PMID: 25190049; PMCID: 4252483.

49. Herrmann ES, Johnson PS, Johnson MW. Examining Delay Discounting of Condom-Protected Sex Among Men Who Have Sex with Men Using Crowdsourcing Technology. AIDS and behavior. 2015. Epub 2015/06/13. doi: 10.1007/s10461-015-1107-x. PubMed PMID: 26066395.

50. Dariotis JK, Johnson MW. Sexual discounting among high-risk youth ages 18-24: implications for sexual and substance use risk behaviors. Experimental and clinical psychopharmacology. 2015;23(1):49-58. Epub 2014/12/30. doi: 10.1037/a0038399. PubMed PMID: 25545764; PMCID: Pmc4350924.

51. Lawyer SR, Williams SA, Prihodova T, Rollins JD, Lester AC. Probability and delay discounting of hypothetical sexual outcomes. Behavioural processes. 2010;84(3):687-92. doi: 10.1016/j.beproc.2010.04.002. PubMed PMID: 20385215.

52. Lawyer SR, Schoepflin FJ. Predicting domain-specific outcomes using delay and probability discounting for sexual versus monetary outcomes. Behavioural processes. 2013;96:71-8. doi: 10.1016/j.beproc.2013.03.001. PubMed PMID: 23500484.

53. Jarmolowicz DP, Bickel WK, Gatchalian KM. Alcohol-dependent individuals discount sex at higher rates than controls. Drug Alcohol Depend. 2013;131(3):320-3. doi: 10.1016/j.drugalcdep.2012.12.014. PubMed PMID: 23312341.

54. MacKillop J, Celio MA, Mastroleo NR, Kahler CW, Operario D, Colby SM, Barnett NP, Monti PM. Behavioral Economic Decision Making and Alcohol-related Sexual Risk Behavior. AIDS and behavior. 2014. Epub 2014/10/01. doi: 10.1007/s10461-014-0909-6. PubMed PMID: 25267115.

55. Jones J, Sullivan PS. Impulsivity as a Risk Factor for HIV Transmission in Men Who Have Sex with Men: A Delay Discounting Approach. J Homosex. 2015;62(5):1-16. Epub 2014/11/18. doi: 10.1080/00918369.2014.987568. PubMed PMID: 25402550.

56. Jones J, Sullivan PS. Age-Dependent Effects in the Association Between Monetary Delay Discounting and Risky Sexual Behavior. SpringerPlus. 2016;5(1):1-8. doi: 10.1186/s40064-016-2570-1.

57. Johnson AS, Hall HI, Hu X, Lansky A, Holtgrave DR, Mermin J. Trends in diagnoses of HIV infection in the United States, 2002-2011. JAMA. 2014;312(4):432-4. Epub 2014/07/20. doi: 10.1001/jama.2014.8534. PubMed PMID: 25038362.

58. Steinberg L. A Social Neuroscience Perspective on Adolescent Risk-Taking. Dev Rev. 2008;28(1):78-106. doi: 10.1016/j.dr.2007.08.002. PubMed PMID: 18509515; PMCID: PMC2396566.

59. Green L, Myerson J, Lichtman D, Rosen S, Fry A. Temporal discounting in choice between delayed rewards: the role of age and income. Psychol Aging. 1996;11(1):79-84. Epub 1996/03/01. PubMed PMID: 8726373.

60. Steinberg L, Graham S, O'Brien L, Woolard J, Cauffman E, Banich M. Age differences in future orientation and delay discounting. Child Dev. 2009;80(1):28-44. Epub 2009/02/25. doi: 10.1111/j.1467-8624.2008.01244.x. PubMed PMID: 19236391.

61. McClure SM, Laibson DI, Loewenstein G, Cohen JD. Separate neural systems value immediate and delayed monetary rewards. Science. 2004;306(5695):503-7. Epub 2004/10/16. doi: 10.1126/science.1100907. PubMed PMID: 15486304.

62. Bickel WK, Miller ML, Yi R, Kowal BP, Lindquist DM, Pitcock JA. Behavioral and neuroeconomics of drug addiction: competing neural systems and temporal discounting processes. Drug Alcohol Depend. 2007;90 Suppl 1:S85-91. doi: 10.1016/j.drugalcdep.2006.09.016. PubMed PMID: 17101239.

63. Odum AL, Baumann AAL. Delay discounting: State and trait variable. In: Bickel GJMWK, editor. Impulsivity: The behavioral and neurological science of discounting. Washington, DC, US: American Psychological Association; 2010. p. 39-65.

64. Hamaker EL, Nesselroade JR, Molenaar PCM. The integrated trait–state model. Journal of Research in Personality. 2007;41(2):295-315. doi: http://dx.doi.org/10.1016/j.jrp.2006.04.003.

65. Odum AL. Delay discounting: trait variable? Behavioural processes. 2011;87(1):1-9. doi: 10.1016/j.beproc.2011.02.007. PubMed PMID: 21385637; PMCID: 3266171.

66. Bickel WK, Yi R, Landes RD, Hill PF, Baxter C. Remember the Future: Working Memory Training Decreases Delay Discounting Among Stimulant Addicts. Biol Psychiatry. 2011;69(3):260-5.

67. Black AC, Rosen MI. A money management-based substance use treatment increases valuation of future rewards. Addict Behav. 2011;36(1-2):125-8.

68. Rung JM, Young ME. Learning to wait for more likely or just more: greater tolerance to delays of reward with increasingly longer delays. J Exp Anal Behav. 2015;103(1):108-24. doi: 10.1002/jeab.132. PubMed PMID: 25641081.

69. Dariotis JK, Johnson MW. Sexual discounting among high-risk youth ages 18-24: Implications for sexual and substance use risk behaviors. Experimental and clinical psychopharmacology. 2015;23(1):49-58. doi: 10.1037/a0038399.

70. Odum AL. Delay discounting: I'm a k, you're a k. J Exp Anal Behav. 2011;96(3):427-39. doi: 10.1901/jeab.2011.96-423. PubMed PMID: 22084499; PMCID: 3213005.

71. Stall R, Friedman M, Catania JA. Interacting Epidemics and Gay Men's Health: A Theory of Syndemic Production among Urban Gay Men. In: Wolitski RJ, Stall R, Valdiserri RO, editors. Unequal Opportunity: Health Disparities Affecting Gay and Bisexual Men in the United States. New York: Oxford University Press; 2008.

72. Grossman CI, Forsyth A, Purcell DW, Allison S, Toledo C, Gordon CM. Advancing novel HIV prevention intervention research with MSM--meeting report. Public Health Rep. 2011;126(4):472-9. Epub 2011/08/02. PubMed PMID: 21800742; PMCID: Pmc3115207.

73. Lessler J, Cummings DA. Mechanistic Models of Infectious Disease and Their Impact on Public Health. Am J Epidemiol. 2016;183(5):415-22. Epub 2016/02/20. doi: 10.1093/aje/kww021. PubMed PMID: 26893297; PMCID: PMC5006438.

74. Mishra S, Fisman DN, Boily MC. The ABC of terms used in mathematical models of infectious diseases. J Epidemiol Community Health. 2011;65(1):87-94. Epub 2010/10/23. doi: 10.1136/jech.2009.097113. PubMed PMID: 20966445.

75. Krivitsky PN, Handcock MS. A Separable Model for Dynamic Networks. Journal of the Royal Statistical Society Series B, Statistical methodology. 2014;76(1):29-46. Epub 2014/01/21. doi: 10.1111/rssb.12014. PubMed PMID: 24443639; PMCID: PMC3891677.

76. Morris M, Handcock MS, Hunter DR. Specification of Exponential-Family Random Graph Models: Terms and Computational Aspects. Journal of statistical software. 2008;24(4):1548-7660. Epub 2008/07/25. PubMed PMID: 18650964; PMCID: PMC2481518.

77. Garnett GP, Cousens S, Hallett TB, Steketee R, Walker N. Mathematical models in the evaluation of health programmes. Lancet. 2011;378(9790):515-25. Epub 2011/04/13. doi: 10.1016/s0140-6736(10)61505-x. PubMed PMID: 21481448.

78. Brookmeyer R, Boren D, Baral SD, Bekker LG, Phaswana-Mafuya N, Beyrer C, Sullivan PS. Combination HIV prevention among MSM in South Africa: results from agent-based modeling. PLoS One. 2014;9(11):e112668. Epub 2014/11/15. doi: 10.1371/journal.pone.0112668. PubMed PMID: 25398143; PMCID: PMC4232469.

79. Jenness SM, Goodreau SM, Rosenberg E, Beylerian EN, Hoover KW, Smith DK, Sullivan P. Impact of the Centers for Disease Control's HIV Preexposure Prophylaxis

Guidelines for Men Who Have Sex With Men in the United States. J Infect Dis. 2016. Epub 2016/07/16. doi: 10.1093/infdis/jiw223. PubMed PMID: 27418048.

80. Rosenberg ES, Grey JA, Sanchez TH, Sullivan PS. Rates of prevalent HIV infection, prevalent diagnoses and new diagnoses among men who have sex with men in US states, metropolitan statistical areas, and counties, 2012-2013. JMIR Public Health and Surveillance. 2016;2(1):e22. doi: 10.2196/publichealth.5684.

81. Duckworth AL, Kern ML. A Meta-Analysis of the Convergent Validity of Self-Control Measures. J Res Pers. 2011;45(3):259-68. Epub 2011/06/07. doi: 10.1016/j.jrp.2011.02.004. PubMed PMID: 21643479; PMCID: PMC3105910.

82. Madden GJ, Johnson PS. A delay-discounting primer. In: Bickel GJMWK, editor. Impulsivity: The behavioral and neurological science of discounting. Washington, DC, US: American Psychological Association; 2010. p. 11-37.

83. Tsukayama E, Duckworth AL, Kim B. Resisting everything except temptation: Evidence and an explanation for domain-specific impulsivity. European Journal of Personality. 2012;26(3):318-34. doi: 10.1002/per.841. PubMed PMID: 2012-10328-015.

84. Bickel WK, Marsch LA. Toward a behavioral economic understanding of drug dependence: delay discounting processes. Addiction. 2001;96(1):73-86. doi: 10.1080/09652140020016978. PubMed PMID: 11177521.

85. Lawyer SR, Boomhower SR, Rasmussen EB. Differential associations between obesity and behavioral measures of impulsivity. Appetite. 2015. doi: 10.1016/j.appet.2015.07.031. PubMed PMID: 26235925.

86. Chesson HW, Leichliter JS, Zimet GD, Rosenthal SL, Bernstein DI, Fife KH. Discount rates and risky sexual behaviors among teenagers and young adults. Journal of Risk and Uncertainty. 2006;32(3):217-30.

87. Lawyer SR. Probability and delay discounting of erotic stimuli. Behavioural processes. 2008;79(1):36-42. doi: 10.1016/j.beproc.2008.04.009. PubMed PMID: ISI:000258058500006.

88. Madden GJ, Bickel WK, Jacobs EA. Discounting of delayed rewards in opioid-dependent outpatients: exponential or hyperbolic discounting functions? Experimental and clinical psychopharmacology. 1999;7(3):284-93. Epub 1999/09/03. PubMed PMID: 10472517.

89. Madden GJ, Petry NM, Badger GJ, Bickel WK. Impulsive and self-control choices in opioid-dependent patients and non-drug-using control participants: drug and monetary rewards. Experimental and clinical psychopharmacology. 1997;5(3):256-62. Epub 1997/08/01. PubMed PMID: 9260073.

90. Jarmolowicz DP, Lemley SM, Asmussen L, Reed DD. Mr. right versus Mr. right now: A discounting-based approach to promiscuity. Behavioural processes. 2015;115:117-22. Epub 2015/03/26. doi: 10.1016/j.beproc.2015.03.005. PubMed PMID: 25804220.

91. Holt DD, Newquist MH, Smits RR, Tiry AM. Discounting of food, sex, and money. Psychonomic bulletin & review. 2014;21(3):794-802. doi: 10.3758/s13423-013-0557-2. PubMed PMID: 24338570.

92. Johnson MW, Johnson PS, Herrmann ES, Sweeney MM. Delay and probability discounting of sexual and monetary outcomes in individuals with cocaine use disorders

and matched controls. PLoS One. 2015;10(5):e0128641. Epub 2015/05/29. doi: 10.1371/journal.pone.0128641. PubMed PMID: 26017273.

93. Kirby KN, Maraković NM. Delay-discounting probabilistic rewards: Rates decrease as amounts increase. Psychonomic bulletin & review. 1996;3(1):100-4.

94. Myerson J, Green L, Warusawitharana M. Area under the curve as a measure of discounting. J Exp Anal Behav. 2001;76(2):235-43. doi: 10.1901/jeab.2001.76-235. PubMed PMID: PMC1284836.

95. Johnson MW, Bickel WK. An algorithm for identifying nonsystematic delay-discounting data. Experimental and clinical psychopharmacology. 2008;16(3):264-74. Epub 2008/06/11. doi: 10.1037/1064-1297.16.3.264. PubMed PMID: 18540786; PMCID: PMC2765051.

96. Conover WJ, Iman RL. Rank Transformations as a Bridge Between Parametric and Nonparametric Statistics. The American Statistician. 1981;35(3):124-9. doi: 10.2307/2683975.

97. Dassen FC, Jansen A, Nederkoorn C, Houben K. Focus on the future: Episodic future thinking reduces discount rate and snacking. Appetite. 2015. Epub 2015/10/04. doi: 10.1016/j.appet.2015.09.032. PubMed PMID: 26431684.

98. Hernandez-Romieu AC, Sullivan PS, Sanchez TH, Kelley CF, Peterson JL, Del Rio C, Salazar LF, Frew PM, Rosenberg ES. The comparability of men who have sex with men recruited from venue-time-space sampling and facebook: a cohort study. JMIR research protocols. 2014;3(3):e37. Epub 2014/07/23. doi: 10.2196/resprot.3342. PubMed PMID: 25048694; PMCID: Pmc4129125.

99. Booth-Kewley S, Edwards JE, Rosenfeld P. Impression management, social desirability, and computer administration of attitude questionnaires: Does the computer make a difference? J Appl Psychol. 1992;77(4):562-6. doi: 10.1037/0021-9010.77.4.562. PubMed PMID: 1992-41453-001.

100. Centers for Disease Control and Prevention. HIV Surveillance Report, 20112013;23. Epub February 2013.

101. Centers for Disease Control and Prevention. HIV Surveillance Report, 2013 2015 [cited 2015 March 11, 2015]; February 2015:[Available from: http://www.cdc.gov/hiv/library/reports/surveillance.

102. Sullivan PS, Salazar L, Buchbinder S, Sanchez TH. Estimating the proportion of HIV transmissions from main sex partners among men who have sex with men in five US cities. AIDS. 2009;23(9):1153-62. Epub 2009/05/07. doi: 10.1097/QAD.0b013e32832baa34. PubMed PMID: 19417579.

103. Goodreau SM, Carnegie NB, Vittinghoff E, Lama JR, Sanchez J, Grinsztejn B, Koblin BA, Mayer KH, Buchbinder SP. What drives the US and Peruvian HIV epidemics in men who have sex with men (MSM)? PLoS One. 2012;7(11):e50522. Epub 2012/12/05. doi: 10.1371/journal.pone.0050522. PubMed PMID: 23209768; PMCID: PMC3510067.

104. Rosenberg E, Grey J, Paz-Bailey G, Hall H, Lansky A, Mermin J, Skarbinski J. Estimating the Number and Characteristics of Male-Male HIV Transmissions in the USA. Conference on Retroviruses and Opportunistic Infections; Seattle, WA2015.

105. Smith DK, Herbst JH, Rose CE. Estimating HIV Protective Effects of Method Adherence With Combinations of Preexposure Prophylaxis and Condom Use Among

African American Men Who Have Sex With Men. Sex Transm Dis. 2015;42(2):88-92. doi: 10.1097/OLQ.0000000000000238. PubMed PMID: 25585067.

106. Varghese B, Maher JE, Peterman TA, Branson BM, Steketee RW. Reducing the risk of sexual HIV transmission: quantifying the per-act risk for HIV on the basis of choice of partner, sex act, and condom use. Sex Transm Dis. 2002;29(1):38-43. Epub 2002/01/05. PubMed PMID: 11773877.

107. Marks G, Crepaz N, Janssen RS. Estimating sexual transmission of HIV from persons aware and unaware that they are infected with the virus in the USA. AIDS. 2006;20(10):1447-50. Epub 2006/06/23. doi: 10.1097/01.aids.0000233579.79714.8d. PubMed PMID: 16791020.

108. Hall HI, Holtgrave DR, Maulsby C. HIV transmission rates from persons living with HIV who are aware and unaware of their infection. AIDS. 2012;26(7):893-6. Epub 2012/02/09. doi: 10.1097/QAD.0b013e328351f73f. PubMed PMID: 22313960.

109. Giedd JN. Structural magnetic resonance imaging of the adolescent brain. Ann N Y Acad Sci. 2004;1021:77-85. Epub 2004/07/15. doi: 10.1196/annals.1308.009. PubMed PMID: 15251877.

110. Grov C, Whitfield TH, Rendina HJ, Ventuneac A, Parsons JT. Willingness to Take PrEP and Potential for Risk Compensation Among Highly Sexually Active Gay and Bisexual Men. AIDS and behavior. 2015;19(12):2234-44. Epub 2015/03/05. doi: 10.1007/s10461-015-1030-1. PubMed PMID: 25735243; PMCID: PMC4560674.

111. Carlo Hojilla J, Koester KA, Cohen SE, Buchbinder S, Ladzekpo D, Matheson T, Liu AY. Sexual Behavior, Risk Compensation, and HIV Prevention Strategies Among Participants in the San Francisco PrEP Demonstration Project: A Qualitative Analysis of

Counseling Notes. AIDS and behavior. 2016;20(7):1461-9. Epub 2015/04/04. doi: 10.1007/s10461-015-1055-5. PubMed PMID: 25835463; PMCID: PMC4592687.

112. Sagaon-Teyssier L, Suzan-Monti M, Demoulin B, Capitant C, Lorente N, Preau M, Mora M, Rojas Castro D, Chidiac C, Chas J, Meyer L, Molina JM, Spire B. Uptake of PrEP and condom and sexual risk behavior among MSM during the ANRS IPERGAY trial. AIDS Care. 2016:1-8. Epub 2016/02/18. doi: 10.1080/09540121.2016.1146653. PubMed PMID: 26883400.

113. Newcomb ME, Mongrella MC, Weis B, McMillen SJ, Mustanski B. Partner Disclosure of PrEP Use and Undetectable Viral Load on Geosocial Networking Apps: Frequency of Disclosure and Decisions About Condomless Sex. J Acquir Immune Defic Syndr. 2016;71(2):200-6. Epub 2016/01/14. doi: 10.1097/qai.0000000000000819. PubMed PMID: 26761520; PMCID: PMC4712713.

114. Wilson M, Daly M. Do pretty women inspire men to discount the future? Proceedings Biological sciences / The Royal Society. 2004;271 Suppl 4:S177-9. Epub 2004/07/16. doi: 10.1098/rsbl.2003.0134. PubMed PMID: 15252976; PMCID: 1810021.

115. Jacobsen MM, Walensky RP. Modeling and Cost-Effectiveness in HIV Prevention. Current HIV/AIDS reports. 2016;13(1):64-75. Epub 2016/02/03. doi: 10.1007/s11904-016-0303-2. PubMed PMID: 26830283; PMCID: PMC4779384.

116. Chen A, Dowdy DW. Clinical Effectiveness and Cost-Effectiveness of HIV Pre-Exposure Prophylaxis in Men Who Have Sex with Men: Risk Calculators for Real-World Decision-Making. PLoS One. 2014;9(10):e108742. doi: 10.1371/journal.pone.0108742. PubMed PMID: 25285793.

117. U.S. Public Health Service. Preexposure prophylaxis for the prevention of HIV infection in the United States - 2014: A clinical practice guideline 2014 [cited 2014 September 1]. Available from: http://www.cdc.gov/hiv/pdf/prepguidelines2014.pdf.

118. Spiegelman D, Hertzmark E. Easy SAS calculations for risk or prevalence ratios and differences. Am J Epidemiol. 2005;162(3):199-200. doi: 10.1093/aje/kwi188. PubMed PMID: 15987728.

119. Vaughan AS, Kramer MR, Cooper HL, Rosenberg ES, Sullivan PS. Completeness and Reliability of Location Data Collected on the Web: Assessing the Quality of Self-Reported Locations in an Internet Sample of Men Who Have Sex With Men. Journal of medical Internet research. 2016;18(6):e142. Epub 2016/06/11. doi: 10.2196/jmir.5701. PubMed PMID: 27283957.

120. Dasgupta S, Vaughan AS, Kramer MR, Sanchez TH, Sullivan PS. Use of a Google Map Tool Embedded in an Internet Survey Instrument: Is it a Valid and Reliable Alternative to Geocoded Address Data? JMIR research protocols. 2014;3(2):e24. doi: 10.2196/resprot.2946. PubMed PMID: 24726954.

121. Sanchez HT, Sineath CR, Kahle ME, Tregear JS, Sullivan SP. The Annual American Men's Internet Survey of Behaviors of Men Who Have Sex With Men in the United States: Protocol and Key Indicators Report 2013. JMIR Public Health Surveill. 2015;1(1):e3. doi: 10.2196/publichealth.4314.

122. Centers for Disease Control and Prevention. HIV Risk, Prevention, and Testing Behaviors - National HIV Behavioral Surveillance System: Men Who Have Sex With Men, 20 U.S. Cities, 2011 2014 [updated September 2014]. Available from: http://www.cdc.gov/hiv/library/reports/surveillance/#special.

123. Underhill K, Operario D, Skeer M, Mimiaga M, Mayer K. Packaging PrEP to Prevent HIV: An Integrated Framework to Plan for Pre-Exposure Prophylaxis Implementation in Clinical Practice. J Acquir Immune Defic Syndr. 2010;55(1):8-13. Epub 2011/03/23. PubMed PMID: 21423876.

124. Golub SA. Tensions between the epidemiology and psychology of HIV risk: implications for pre-exposure prophylaxis. AIDS and behavior. 2014;18(9):1686-93. Epub 2014/04/11. doi: 10.1007/s10461-014-0770-7. PubMed PMID: 24719201; PMCID: Pmc4127100.

125. Rosenberg ES, Rothenberg RB, Kleinbaum DG, Stephenson RB, Sullivan PS. The implications of respondent concurrency on sex partner risk in a national, web-based study of men who have sex with men in the United States. J Acquir Immune Defic Syndr. 2013;63(4):514-21. Epub 2013/04/18. doi: 10.1097/QAI.0b013e318294bcce. PubMed PMID: 23591633; PMCID: Pmc3700588.

126. Boily MC, Shubber Z. Modelling in concentrated epidemics: informing epidemic trajectories and assessing prevention approaches. Current opinion in HIV and AIDS. 2014. doi: 10.1097/COH.0000000000000036. PubMed PMID: 24468893.

127. Johnson WD, Holtgrave DR, McClellan WM, Flanders WD, Hill AN, Goodman M. HIV intervention research for men who have sex with men: a 7-year update. AIDS Educ Prev. 2005;17(6):568-89. Epub 2006/01/10. doi: 10.1521/aeap.2005.17.6.568. PubMed PMID: 16398578.

128. Stein JS, Wilson AG, Koffarnus MN, Daniel TO, Epstein LH, Bickel WK. Unstuck in time: episodic future thinking reduces delay discounting and cigarette

smoking. Psychopharmacology (Berl). 2016. Epub 2016/08/25. doi: 10.1007/s00213-016-4410-y. PubMed PMID: 27553824.

129. Sullivan PS, Peterson J, Rosenberg ES, Kelley CF, Cooper H, Vaughan A, Salazar LF, Frew P, Wingood G, Diclemente R, del Rio C, Mulligan M, Sanchez TH. Understanding racial HIV/STI disparities in black and white men who have sex with men: a multilevel approach. PLoS One. 2014;9(3):e90514. Epub 2014/03/13. doi: 10.1371/journal.pone.0090514. PubMed PMID: 24608176; PMCID: PMC3946498.

130. Hernandez-Romieu AC, Sullivan PS, Rothenberg R, Grey J, Luisi N, Kelley CF, Rosenberg ES. Heterogeneity of HIV Prevalence Among the Sexual Networks of Black and White Men Who Have Sex With Men in Atlanta: Illuminating a Mechanism for Increased HIV Risk for Young Black Men Who Have Sex With Men. Sex Transm Dis. 2015;42(9):505-12. Epub 2015/08/13. doi: 10.1097/olq.0000000000000332. PubMed PMID: 26267877; PMCID: PMC4536576.

131. Sullivan PS, Rosenberg ES, Sanchez TH, Kelley CF, Luisi N, Cooper HL, Diclemente RJ, Wingood GM, Frew PM, Salazar LF, del Rio C, Mulligan MJ, Peterson JL. Explaining racial disparities in HIV incidence in black and white men who have sex with men in Atlanta, GA: a prospective observational cohort study. Ann Epidemiol. 2015;25(6):445-54. doi: http://dx.doi.org/10.1016/j.annepidem.2015.03.006.

132. Yi R, Mitchell SH, Bickel WK. Delay discounting and substance abuse-dependence. Impulsivity: The behavioral and neurological science of discounting. 2010:191-211. doi: 10.1037/12069-007.

133. Vosburgh HW, Mansergh G, Sullivan PS, Purcell DW. A review of the literature on event-level substance use and sexual risk behavior among men who have sex with

men. AIDS and behavior. 2012;16(6):1394-410. Epub 2012/02/11. doi: 10.1007/s10461-011-0131-8. PubMed PMID: 22323004.

134. Maisto SA, Simons JS. Research on the Effects of Alcohol and Sexual Arousal on Sexual Risk in Men who have Sex with Men: Implications for HIV Prevention Interventions. AIDS and behavior. 2016;20 Suppl 1:S158-72. Epub 2015/10/16. doi: 10.1007/s10461-015-1220-x. PubMed PMID: 26459332.

135. Hess KL, Chavez PR, Kanny D, DiNenno E, Lansky A, Paz-Bailey G. Binge drinking and risky sexual behavior among HIV-negative and unknown HIV status men who have sex with men, 20 US cities. Drug Alcohol Depend. 2014. Epub 2015/01/04. doi: 10.1016/j.drugalcdep.2014.12.013. PubMed PMID: 25555622.

136. Impulsivity: The behavioral and neurological science of discounting. Washington, DC, US: American Psychological Association; 2010. Delay discounting as a predictor of drug abuse; p. 243-71.

137. Johnson PS, Sweeney MM, Herrmann ES, Johnson MW. Alcohol Increases Delay and Probability Discounting of Condom-Protected Sex: A Novel Vector for Alcohol-Related HIV Transmission. Alcohol Clin Exp Res. 2016. Epub 2016/05/01. doi: 10.1111/acer.13079. PubMed PMID: 27129419.

Appendix A. Survey

Emory University Men's Health and Behavior Survey

Eligibility Questions

VALIDATION

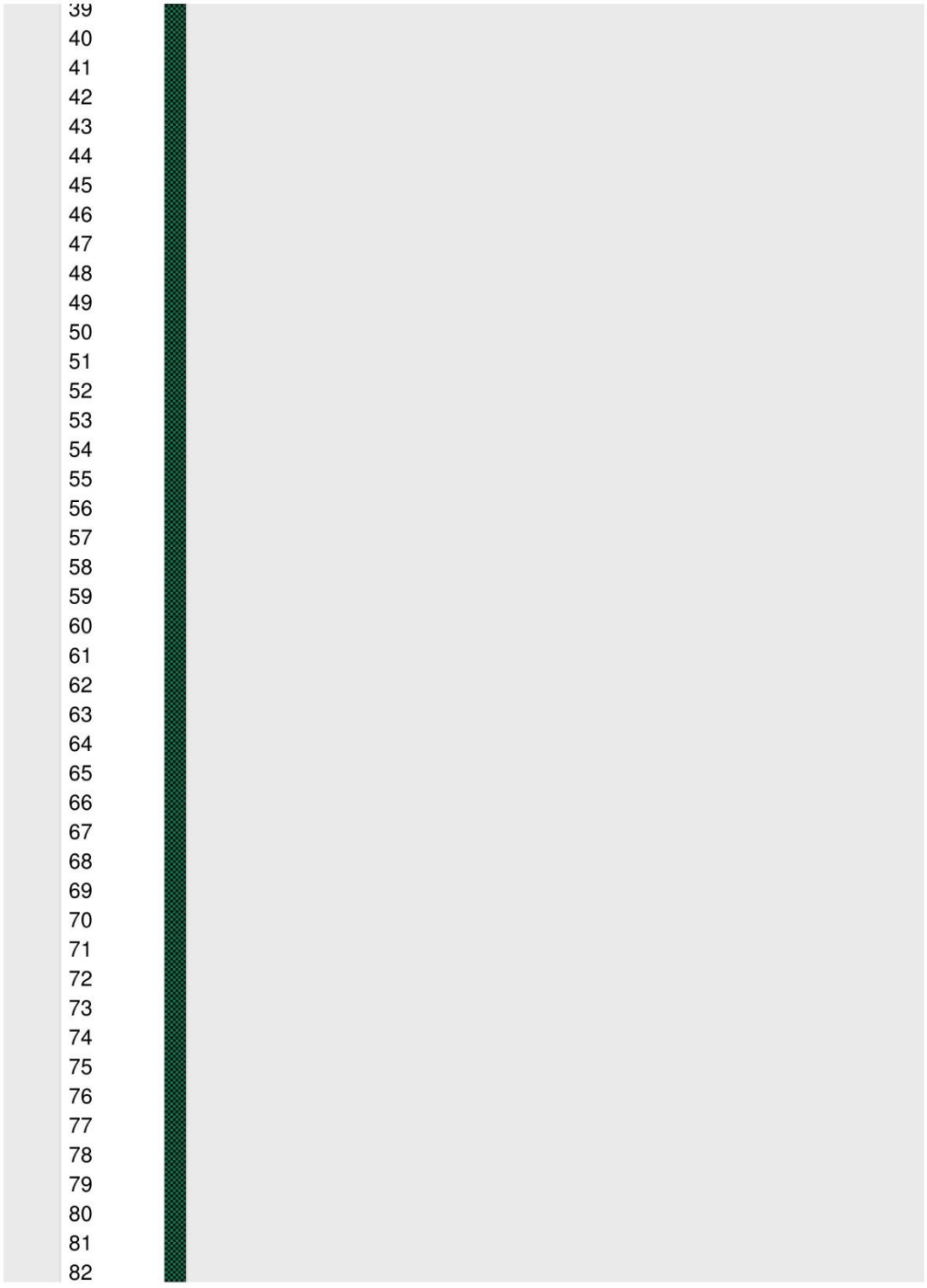
1. What is your gender? *

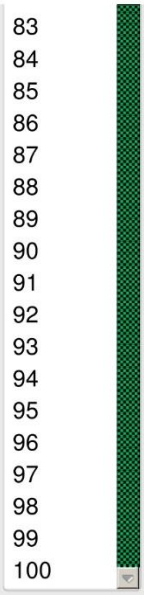
- Female
- Male
- Transgender Male
- Transgender Female

VALIDATION

2. What is your age? (in years) *

Under 18
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38





Page exit logic: Disqualify
IF: ((Question "What is your gender?" #1 is one of the following answers ("Female","Transgender Male") OR Question "What is your age? (in years)" #2 is one of the following answers ("Under 18")) OR Question "Have you had sex with a man in the past 6 months?" #3 is one of the following answers ("No")) **THEN:** Disqualify and display:
Sorry, you do not qualify to take this survey.

3. Have you had sex with a man in the past 6 months? *

- Yes
- No

Race, Education, Income

Random number for MCQ/SDT randomization **Action: Hidden Value**
Value: populates with a randomly generated number between 1 and 2

VALIDATION

4. What is your race? Check all that apply.

- [ ] Black/African American
- [ ] White/Caucasian
- [ ] Hispanic
- [ ] Asian
- [ ] Native Hawaiian/Pacific Islander
- [ ] American Indian/Alaska Native
- [ ] I decline to answer
- [ ] I don't know
- [ ] Other

VALIDATION

5. What is the highest level in school that you completed?

College, post graduate, or professional school
Some college, Associate's degree, and/or Technical school
High school or GED
Some high school
Less than high school
Never attended school
Don't Know

VALIDATION

6. What is your annual household income?

- 0 to $417 (monthly) / 0 to $4,999 (yearly)
- $418 to $833 (monthly) / $5,000 to $9,999 (yearly)
- $834 to $1250 (monthly) / $10,000 to $14,999 (yearly)
- $1251 to $1667 (monthly) / $15,000 to $19,999 (yearly)
- $1668 to $2500 (monthly) / $20,000 to $29,999 (yearly)
- $2501 to $3333 (monthly) / $30,000 to $39,999 (yearly)
- $3334 to $4167 (monthly) / $40,000 to $49,999 (yearly)
- $4168 to $6250 (monthly) / $50,000 to $74,999 (yearly)
- $6251 or more (monthly) / $75,000 or more (yearly)
- Don't know

Relationship Status

LOGIC Show/hide trigger exists.

7. Which of the following best describes your current marital status?

- ○ Legally married
- ○ Registered domestic partnership or civil union
- ○ Widowed
- ○ Divorced
- ○ Separated
- ○ Never married

LOGIC Hidden unless: Question "Which of the following best describes your current marital status?" #7 is one of the following answers ("Legally married","Registered domestic partnership or civil union","Widowed","Divorced","Separated")

8. Is/was this partner:

- Female
- Male
- Transgender male
- Transgender female

LOGIC Hidden by default Hidden unless: Question "Which of the following best describes your current marital status?" #7 is one of the following answers ("Widowed","Divorced","Separated","Never married")

Are you currently in a committed relationship with a male partner?

(Someone that you feel committed to above all others - this is someone you might call your boyfriend, significant other, or life partner.)

- Yes
- No
- Don't know

HIV/STI Testing and Diagnosis History 1

LOGIC Show/hide trigger exists.

9. Have you ever been tested for HIV?

- Yes
- No

LOGIC Hidden by default Hidden unless: Question "Have you ever been tested for HIV?" #9 is one of the following answers ("Yes")

When was your most recent HIV test?

- Within the last month
- 1-2 months ago
- 3-6 months ago
- 7-12 months ago
- More than one year ago

LOGIC Show/hide trigger exists. Hidden unless: Question "Have you ever been tested for HIV?" #9 is one of the following answers ("Yes")

10. Have you ever had a positive HIV test?

- Yes
- No

LOGIC Hidden by default Hidden unless: Question "Have you ever had a positive HIV test?" #10 is one of the following answers ("Yes")

When did you first test positive for HIV?

- Within the last month
- 1-2 months ago
- 3-6 months ago
- 7-12 months ago
- More than one year ago

VALIDATION

11. Have you ever been diagnosed with any of the following? (Select all that apply.)

- ☐ Gonorrhea
- ☐ Chlamydia
- ☐ Syphilis
- ☐ None of the above

HIV/STI Testing and Diagnosis History 2

Page entry logic:
This page will show when: Question "Have you ever been diagnosed with any of the following? (Select all that apply.)" #11 is one of the following answers ("Gonorrhea","Chlamydia","Syphilis")

VALIDATION

12. Have you been diagnosed with any of the following in the **past 12 months**?

- ☐ None of the above

Self-assessed HIV Risk

Page entry logic:
This page will show when: (Question "Have you ever been tested for HIV?" #9 is one of the following answers ("No") OR Question "Have you ever had a positive HIV test?" #10 is one of the following answers ("No"))

13. What would you say your chances are of getting infected with HIV?

- None
- Low
- Medium
- High

PrEP Use

Page entry logic:
This page will show when: Question "Have you ever had a positive HIV test?" #10 is one of the following answers ("No")

LOGIC Show/hide trigger exists.

14. A new method of preventing HIV involves taking the same pill that is used to treat HIV to prevent people from becoming infected with HIV if they are exposed. This is called pre-exposure prophylaxis, or PrEP. It is also sometimes called Truvada. Have you ever heard of taking a pill to prevent HIV?

- Yes
- No

LOGIC Show/hide trigger exists. Hidden unless: Question "A new method of preventing HIV involves taking the same pill that is used to treat HIV to prevent people from becoming infected with HIV if they are exposed. This is called pre-exposure prophylaxis, or PrEP. It is also sometimes called Truvada. Have you ever heard of taking a pill to prevent HIV?" #14 is one of the following answers ("Yes")

15. Have you ever taken anti-HIV medication (e.g., PrEP, Truvada) to prevent getting HIV?

- ○ Yes
- ○ No

LOGIC Hidden unless: Question "Have you ever taken anti-HIV medication (e.g., PrEP, Truvada) to prevent getting HIV?" #15 is one of the following answers ("Yes")

16. Are you currently taking anti-HIV medication (e.g., PrEP, Truvada)?

- ○ Yes
- ○ No

LOGIC Hidden unless: (Question "A new method of preventing HIV involves taking the same pill that is used to treat HIV to prevent people from becoming infected with HIV if they are exposed. This is called pre-exposure prophylaxis, or PrEP. It is also sometimes called Truvada. Have you ever heard of taking a pill to prevent HIV?" #14 is one of the following answers ("No") OR Question "Have you ever taken anti-HIV medication (e.g., PrEP, Truvada) to prevent getting HIV?" #15 is one of the following answers ("No"))

17. PrEP involves taking a pill every day. The pill might have some side effects such as nausea or weight loss, but it could also prevent HIV down the road. Would you be willing to take a daily anti-HIV pill to prevent HIV infection?

- ○ Yes ○ No

HIV Treatment Adherence

Page entry logic:
This page will show when: Question "Have you ever had a positive HIV test?" #10 is one of the following answers ("Yes")

LOGIC Show/hide trigger exists.

18. Have you been prescribed medication, sometimes known as antiretrovirals, to treat your HIV?

- ○ Yes
- ○ No

VALIDATION Min = 0 Max = 30 Max character count = 2 Min character count = 0

LOGIC Hidden unless: Question "Have you been prescribed medication, sometimes known as antiretrovirals, to treat your HIV?" #18 is one of the following answers ("Yes")

19. In the past 30 days, on how many days did you miss at least one dose of any of your HIV medicines?

_____ days

General Medication Adherence (HIV- Only)

Page entry logic:
This page will show when: (Question "Have you ever been tested for HIV?" #9 is one of the following answers ("No") OR Question "Have you ever had a positive HIV test?" #10 is one of the following answers ("No"))

LOGIC Show/hide trigger exists.

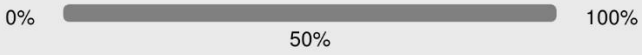
20. Lots of people take medications on a daily basis that are either prescribed by a physician, such as blood pressure medication, or bought over-the-counter, such as vitamins. Do you take any medications daily?

- ○ Yes
- ○ No

VALIDATION Min = 0 Max = 100

LOGIC Hidden unless: Question "Lots of people take medications on a daily basis that are either prescribed by a physician, such as blood pressure medication, or bought over-the-counter, such as vitamins. Do you take any medications daily?" #20 is one of the following answers ("Yes")

21. We would be surprised if most people take 100% of their medications. Below 0% means you have taken none of your daily medication this past month, 50% means you have taken half of your daily medication this past month, and 100% means you have taken every single dose this past month. What percent of your medication did you take?



Drug and Alcohol Use - p12m

22. In the past 12 months, how frequently did you drink alcohol?

- Did not drink alcohol
- More than once a day
- Once a day
- More than once a week
- Once a week
- More than once a month
- Once a month
- Less than once a month

VALIDATION

LOGIC Show/hide trigger exists.

23. Have you used any drugs, including marijuana, in the past 12 months?

- ○ Yes
- ○ No

VALIDATION

LOGIC Hidden unless: Question "Have you used any drugs, including marijuana, in the past 12

months?" #23 is one of the following answers ("Yes")

24. In the past 12 months how often did you use the follow drugs?

	Didn't use	More than once a day	Once a day	More than once a week	Once a week	More than once a month	Once a month	Less than once a month
Marijuana	○	○	○	○	○	○	○	○
Crystal meth (tina, crank, or ice)	○	○	○	○	○	○	○	○
Crack cocaine	○	○	○	○	○	○	○	○
Powered cocaine that is smoked or snorted	○	○	○	○	○	○	○	○
Downers such as Valium, Ativan, or Xanax	○	○	○	○	○	○	○	○
Painkillers such as Oxycontin, Vicodin, or Percocet	○	○	○	○	○	○	○	○

	Didn't use	More than once a day	Once a day	More than once a week	Once a week	More than once a month	Once a month	Less than once a month
Hallucinogens such as LSD or mushrooms	○	○	○	○	○	○	○	○
X or Ectasy	○	○	○	○	○	○	○	○
Special K (ketamine)	○	○	○	○	○	○	○	○
GHB	○	○	○	○	○	○	○	○
Heroin that is smoked or snorted	○	○	○	○	○	○	○	○
Poppers (amyl nitrate)	○	○	○	○	○	○	○	○

VALIDATION
25. In the past 12 months, have you injected a drug not prescribed to you by a doctor or other health care provider?

- Yes
- No

Sexual Behavior - Number of male partners

VALIDATION Min = 1 Max = 500 Must be numeric Whole numbers only Positive numbers only Max character count = 3
LOGIC Show/hide trigger exists.
26. How many different men have you had oral or anal sex with in the past 12 months?

Number of partners beyond two most recent **Action: Hidden Value**
Value:

Sexual Behavior - One partner reported

Page entry logic:
This page will show when: Question "How many different men have you had oral or anal sex with in the past 12 months?" #26 is exactly equal to "1"

27. Please provide a nickname for the man that you had sex with in the last 12 months. This does not need to be his actual name. It will be how we refer to him for the next few questions.

nickname

Sexual Behavior - One partner reported

Page entry logic:
This page will show when: Question "How many different men have you had oral or anal sex with in the past 12 months?" #26 is exactly equal to "1"

28. Was [question("value"), id="167"] a main partner? That is, someone you feel/felt committed to above all others.

- Yes
- No

LOGIC Show/hide trigger exists.
29. Did you know the HIV status of [question("value"), id="167"]?

- Yes
- No

LOGIC Show/hide trigger exists. Hidden unless: Question "Did you know the HIV status of [question("value"), id="167"]?" #29 is one of the following answers ("Yes")
30. What was [question("value"), id="167"]'s HIV status?

- HIV-positive
- HIV-negative

LOGIC Hidden unless: Question "What was [question("value"), id="167"]'s HIV status?" #30 is one of the following answers ("HIV-positive")
31. As far as you know, is/was [question("value"), id="167"] on treatment for HIV?

- Yes
- No

LOGIC Hidden unless: Question "What was [question("value"), id="167"]'s HIV status?" #30 is one of the following answers ("HIV-positive")

32. As far as you know, does/did [question("value"), id="167"] have a suppressed, or undetectable, viral load? This means tests show they have no HIV virus in their blood.

- Yes
- No

Sexual Behavior - One partner reported

Page entry logic:
This page will show when: Question "How many different men have you had oral or anal sex with in the past 12 months?" #26 is exactly equal to "1"

LOGIC Show/hide trigger exists.

33. In the past 12 months, did you have anal sex with [question("value"), id="167"]?

- Yes
- No

LOGIC Show/hide trigger exists. Hidden unless: Question "In the past 12 months, did you have anal sex with [question("value"), id="167"]?" #33 is one of the following answers ("Yes")

34. In the past 12 months, did you have anal sex with [question("value"), id="167"] without a condom?

- Yes
- No

LOGIC Hidden unless: Question "In the past 12 months, did you have anal sex with [question("value"), id="167"] without a condom?" #34 is one of the following answers ("Yes")

35. What type of anal sex did you have with [question("value"), id="167"] without a condom?

- Receptive (i.e., you were the bottom)
- Insertive (i.e., you were the top)
- Both receptive and insertive

Sexual Behavior - Two+ partners reported

Page entry logic:
This page will show when: Question "How many different men have you had oral or anal sex with in the past 12 months?" #26 is greater than "1"

Action: Custom Script

set hidden value for number of partners beyond two

36. Partner 1:

nickname 1

37. Partner 2:

nickname 2

Sexual Behavior - Two partners reported - Partner 1

Page entry logic:
This page will show when: Question "How many different men have you had oral or anal sex with in the past 12 months?" #26 is greater than "1"

38. Was [question("value"), id="177"] a main partner? That is, someone you feel/felt committed to above all others.

- Yes
- No

LOGIC Show/hide trigger exists.
39. Did you know the HIV status of [question("value"), id="177"]?

- Yes
- No

LOGIC Show/hide trigger exists. Hidden unless: Question "Did you know the HIV status of [question("value"), id="177"]?" #39 is one of the following answers ("Yes")
40. What was [question("value"), id="177"]'s HIV status?

- HIV-positive
- HIV-negative

LOGIC Hidden unless: Question "What was [question("value"), id="177"]'s HIV status?" #40 is one of the following answers ("HIV-positive")
41. As far as you know, is/was [question("value"), id="177"] on treatment for HIV?

- Yes
- No

LOGIC Hidden unless: Question "What was [question("value"), id="177"]'s HIV status?" #40 is one of the following answers ("HIV-positive")

42. As far as you know, does/did [question("value"), id="177"] have a suppressed, or undetectable, viral load? This means tests show they have no HIV virus in their blood.

- Yes
- No

Sexual Behavior - Two partners reported - Partner 1

Page entry logic:
This page will show when: Question "How many different men have you had oral or anal sex with in the past 12 months?" #26 is greater than "1"

LOGIC Show/hide trigger exists.

43. In the past 12 months, did you have anal sex with [question("value"), id="177"]?

- Yes
- No

LOGIC Show/hide trigger exists. Hidden unless: Question "In the past 12 months, did you have anal sex with [question("value"), id="177"]?" #43 is one of the following answers ("Yes")

44. In the past 12 months, did you have anal sex with [question("value"), id="177"] without a condom?

- Yes
- No

LOGIC Hidden unless: Question "In the past 12 months, did you have anal sex with [question("value"), id="177"] without a condom?" #44 is one of the following answers ("Yes")

45. What type of anal sex did you have with [question("value"), id="177"] without a condom?

- Receptive (i.e., you were the bottom)
- Insertive (i.e., you were the top)
- Both receptive and insertive

Sexual Behavior - Two partners reported - Partner 2

Page entry logic:
This page will show when: Question "How many different men have you had oral or anal sex with in the past 12 months?" #26 is greater than "1"

46. Was [question("value"), id="178"] a main partner? That is, someone you feel/felt committed to above all others.

- Yes
- No

LOGIC Show/hide trigger exists.

47. Did you know the HIV status of [question("value"), id="178"]?

- Yes
- No

LOGIC Show/hide trigger exists. Hidden unless: Question "Did you know the HIV status of [question("value"), id="178"]?" #47 is one of the following answers ("Yes")

48. What was [question("value"), id="178"]'s HIV status?

- HIV-positive
- HIV-negative

LOGIC Hidden unless: Question "What was [question("value"), id="178"]'s HIV status?" #48 is one of the following answers ("HIV-positive")

49. As far as you know, is/was [question("value"), id="178"] on treatment for HIV?

- Yes
- No

LOGIC Hidden unless: Question "What was [question("value"), id="178"]'s HIV status?" #48 is one of the following answers ("HIV-positive")

50. As far as you know, does/did [question("value"), id="178"] have a suppressed, or undetectable, viral load? This means tests show they have no HIV virus in their blood.

- Yes
- No

Sexual Behavior - Two partners reported - Partner 2

Page entry logic:
This page will show when: Question "How many different men have you had oral or anal sex with in the past 12 months?" #26 is greater than "1"

LOGIC Show/hide trigger exists.

51. In the past 12 months, did you have anal sex with [question("value"), id="178"]?

- Yes
- No

LOGIC Show/hide trigger exists. Hidden unless: Question "In the past 12 months, did you have anal sex with [question("value"), id="178"]?" #51 is one of the following answers ("Yes")

52. In the past 12 months, did you have anal sex with [question("value"), id="178"] without a condom?

- Yes
- No

LOGIC Hidden unless: Question "In the past 12 months, did you have anal sex with [question("value"), id="178"] without a condom?" #52 is one of the following answers ("Yes")

53. What type of anal sex did you have with [question("value"), id="178"] without a condom?

- Receptive (i.e., you were the bottom)
- Insertive (i.e., you were the top)
- Both receptive and insertive

Sexual Behavior - Three or more partners

Page entry logic:
This page will show when: Question "How many different men have you had oral or anal sex with in the past 12 months?" #26 is greater than "2"

VALIDATION Min = 0 Must be numeric Whole numbers only Positive numbers only
LOGIC Show/hide trigger exists.

54. Of the [question("value"), id="189"] men you had sex with except [question("value"), id="177"] and [question("value"), id="178"], how many did you have anal sex with without a condom?

Sexual Behavior - Three or more partners - CAI position

Page entry logic:
This page will show when: Question "Of the [question("value"), id="189"] men you had sex with except [question("value"), id="177"] and [question("value"), id="178"], how many did you have anal sex with without a condom?" #54 is greater than "0"

Action: Custom Script

Check that number of anal sex does not exceed total minus 2

LOGIC Hidden unless: Question "Of the [question("value"), id="189"] men you had sex with except [question("value"), id="177"] and [question("value"), id="178"], how many did you have anal sex with without a condom?" #54 is exactly equal to "1"

55. What type of anal sex did you have without a condom?

- Receptive (i.e., you were the bottom)
- Insertive (i.e., you were the top)
- Both receptive and insertive

VALIDATION Must be numeric

LOGIC Hidden unless: Question "Of the [question("value"), id="189"] men you had sex with except [question("value"), id="177"] and [question("value"), id="178"], how many did you have anal sex with without a condom?" #54 is greater than "1"

56. Of the [question("value"), id="190"] men you had condomless anal sex with, what type of sex did you have without a condom?

	Receptive (i.e., you were the bottom)
	Insertive (i.e., you were the top)
	Both receptive and insertive

Total : 0

hidden value to hold continuous sum for custom script on next page **Action: Hidden Value**
Value:

Check continuous sum on previous page

Action: Custom Script

Check that continuous sum == number of CAI partners

Kirby Questionnaire - 1

VALIDATION

57. Would you prefer $54 today or $55 in 117 days?

- $54 today
- $55 in 117 days

VALIDATION

58. Would you prefer $55 today or $75 in 61 days?

- $55 today
- $75 in 61 days

VALIDATION

59. Would you prefer $19 today or $25 in 53 days?

- $19 today
- $25 in 53 days

VALIDATION

60. Would you prefer $31 today or $85 in 7 days?

- $31 today
- $85 in 7 days

VALIDATION

61. Would you prefer $14 today or $25 in 19 days?

- $14 today
- $25 in 19 days

Kirby Questionnaire - 2

VALIDATION

62. Would you prefer $47 today or $50 in 160 days?

- $47 today
- $50 in 160 days

VALIDATION

63. Would you prefer $15 today or $35 in 13 days?

- $15 today
- $35 in 13 days

VALIDATION

64. Would you prefer $25 today or $60 in 14 days?

- $25 today
- $60 in 14 days

VALIDATION

65. Would you prefer $78 today or $80 in 162 days?

- $78 today
- $80 in 162 days

VALIDATION

66. Would you prefer $40 today or $55 in 62 days?

- $40 today
- $55 in 62 days

Kirby Questionnaire - 3

VALIDATION

67. Would you prefer $11 today or $30 in 7 days?

- $11 today
- $30 in 7 days

VALIDATION

68. Would you prefer $67 today or $75 in 119 days?

- $67 today
- $75 in 119 days

VALIDATION

69. Would you prefer $34 today or $35 in 186 days?

- $34 today
- $35 in 186 days

VALIDATION

70. Would you prefer $27 today or $50 in 21 days?

- $27 today
- $50 in 21 days

VALIDATION

71. Would you prefer $69 today or $85 in 91 days?

- $69 today
- $85 in 91 days

Kirby Questionnaire - 4

VALIDATION

72. Would you prefer $49 today or $60 in 89 days?

- $49 today
- $60 in 89 days

VALIDATION

73. Would you prefer $80 today or $85 in 157 days?

- $80 today
- $85 in 157 days

VALIDATION

74. Would you prefer $24 today or $35 in 29 days?

- $24 today
- $35 in 29 days

VALIDATION

75. Would you prefer $33 today or $80 in 14 days?

- $33 today
- $80 in 14 days

VALIDATION

76. Would you prefer $28 today or $30 in 179 days?

- $28 today
- $30 in 179 days

Kirby Questionnaire - 5

VALIDATION

77. Would you prefer $34 today or $50 in 30 days?

- $34 today
- $50 in 30 days

VALIDATION

78. Would you prefer $25 today or $30 in 80 days?

- $25 today
- $30 in 80 days

VALIDATION

79. Would you prefer $41 today or $75 in 20 days?

- $41 today
- $75 in 20 days

VALIDATION

80. Would you prefer $54 today or $60 in 111 days?

- $54 today
- $60 in 111 days

Kirby Questionnaire - 6

VALIDATION

81. Would you prefer $54 today or $80 in 30 days?

- $54 today
- $80 in 30 days

VALIDATION

82. Would you prefer $22 today or $25 in 136 days?

- $22 today
- $25 in 136 days

VALIDATION

83. Would you prefer $20 today or $55 in 7 days?

- $20 today
- $55 in 7 days

Script to randomize MCQ/SDT

Action: Custom Script

If rannum = 1 go to SDT, if rannum = 2 go to BIS

SDT - Photo Select Page

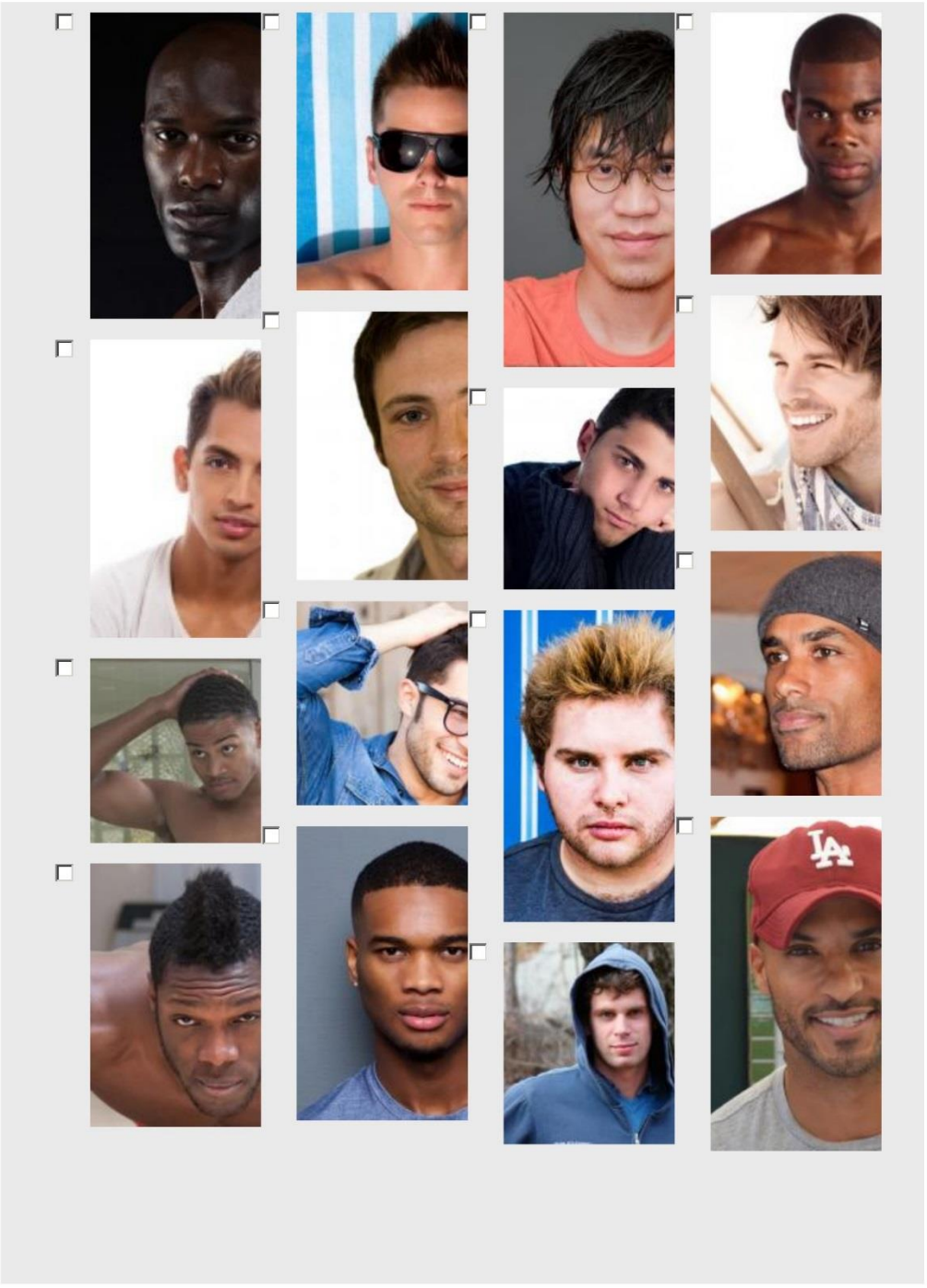
84.

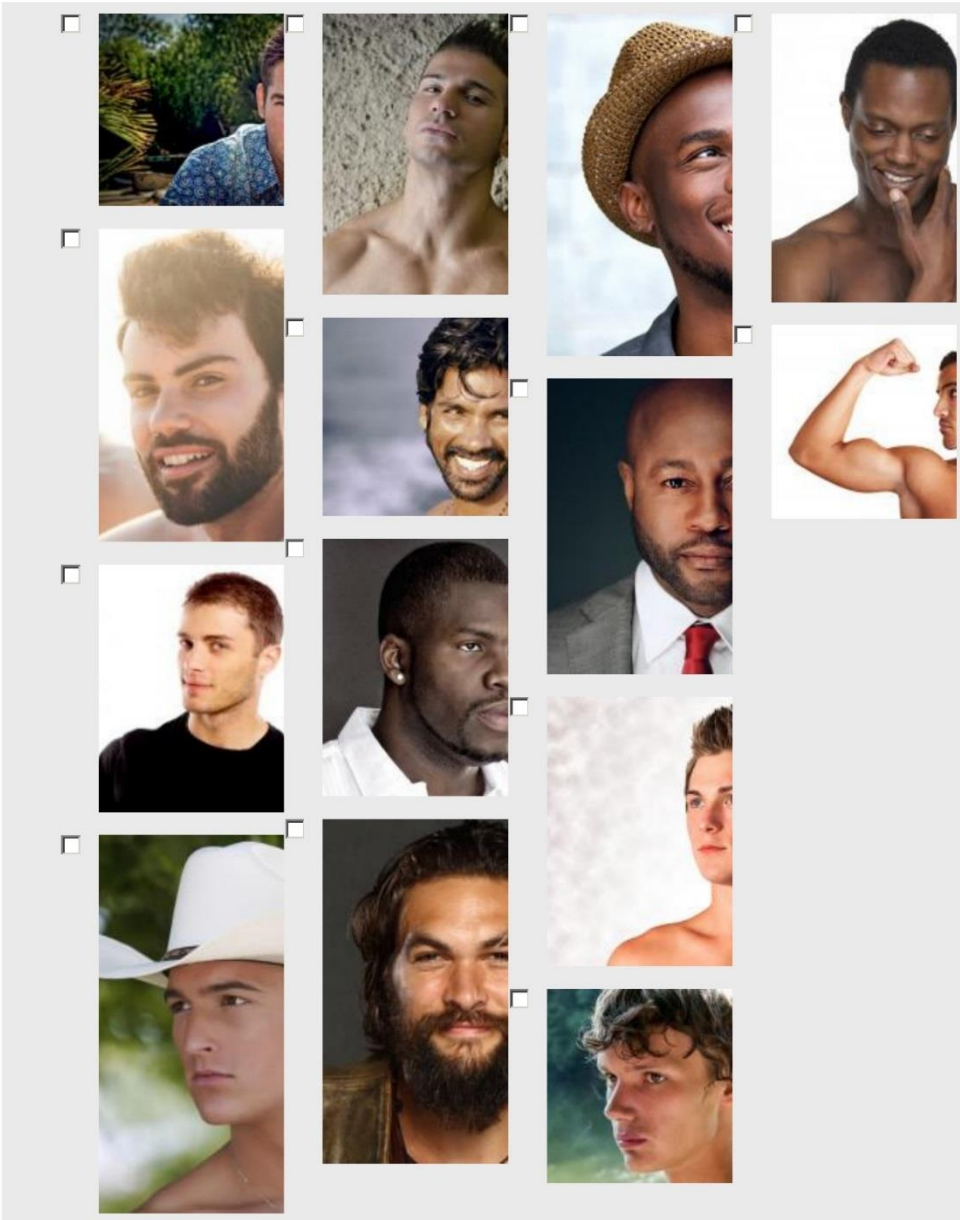
Based on physical appearance, and assuming you liked his personality, please select the images of the men that you would consider having sex with in the right environment.

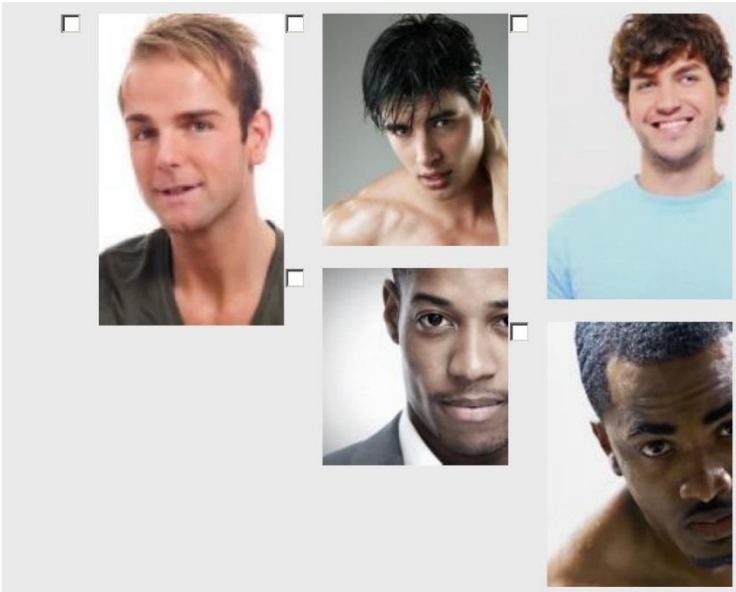
*









Record number of images selected

LOGIC Show/hide trigger exists.
numphotosSDT **Action: Hidden Value**
Value:

Action: Custom Script

set hidden value for number of pictures selected and set value for mostsex

Action: Custom Script

If only one image selected skip to mostsex task

SDT - MostSex

85. Please select the image of the man you would *most* like to have sex with.

SDT - LeastSex

86. Please select the image of the man you would *least* like to have sex with.

SDT - MostSTI

87. Please select the image of the man you think is *most* likely to have a sexually transmitted infection (such as gonorrhea, syphilis, chlamydia, or herpes), including HIV.

SDT - LeastSTI

88. Please select the image of the man you think is *least* likely to have a sexually transmitted infection (such as gonorrhea, syphilis, chlamydia, or herpes), including HIV.

SDT - MostSex - ALL

VALIDATION Min = 0 Max = 100

89.

Please rate how likely you are to have sex now **without** a condom versus having sex now **with** a condom.

I will definitely have sex **now without** a condom.

I will definitely have sex **now with** a condom.

VALIDATION Min = 0 Max = 100

90.

Please rate how likely you are to have sex now **without** a condom versus having sex in 1 hour **with** a condom.

I will definitely have sex **now** **without** a condom.

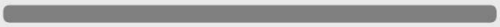
I will definitely wait **1** **hour** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

91.

Please rate how likely you are to have sex now **without** a condom versus having sex in 3 hours **with** a condom.

I will definitely have sex **now** **without** a condom.



I will definitely wait **3** **hours** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

92.

Please rate how likely you are to have sex now **without** a condom versus having sex in 6 hours **with** a condom.

I will definitely have sex **now without** a condom.

I will definitely wait **6 hours** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

93.

Please rate how likely you are to have sex now **without** a condom versus having sex in 1 day **with** a condom.

I will definitely have sex **now without** a condom.

I will definitely wait **1 day** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

94.

Please rate how likely you are to have sex now **without** a condom versus having sex in 1 week **with** a condom.

I will definitely have sex **now without** a condom.

I will definitely wait **1 week** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

95.

Please rate how likely you are to have sex now **without** a condom versus having sex in 1 month **with** a condom.

I will definitely have sex **now without** a condom.

I will definitely wait **1 month** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

96.

Please rate how likely you are to have sex now **without** a condom versus having sex in 3 months **with** a condom.

I will definitely have sex **now without** a condom.

I will definitely wait **3 months** to have sex **with** a condom.

Check number of pictures selected

Action: Custom Script

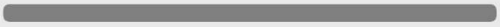
If only one image selected skip to script page for randomizing MCQ/SDT end

SDT - LeastSex - All

VALIDATION Min = 0 Max = 100

105. Please rate how likely you are to have sex now **without** a condom versus having sex now **with** a condom.

I will definitely have sex **now without** a condom.

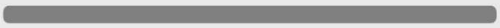


I will definitely have sex **now with** a condom.

VALIDATION Min = 0 Max = 100

106. Please rate how likely you are to have sex now **without** a condom versus having sex in 1 hour **with** a condom.

I will definitely have sex **now without** a condom.



I will definitely wait **1 hour** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

107. Please rate how likely you are to have sex now **without** a condom versus having sex in 3 hours **with** a condom.

I will definitely have sex **now without** a condom.

I will definitely wait **3 hours** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

108. Please rate how likely you are to have sex now **without** a condom versus having sex in 6 hours **with** a condom.

I will definitely have sex **now** **without** a condom.

I will definitely wait **6 hours** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

109. Please rate how likely you are to have sex now **without** a condom versus having sex in 1 day **with** a condom.

I will definitely have sex **now** **without** a condom.

I will definitely wait **1 day** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

110. Please rate how likely you are to have sex now **without** a condom versus having sex in 1 week **with** a condom.

I will definitely have sex **now** **without** a condom.

I will definitely wait **1 week** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

111. Please rate how likely you are to have sex now **without** a condom versus having sex in 1 month **with** a condom.

I will definitely have sex **now** **without** a condom.

I will definitely wait **1** **month** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

112. Please rate how likely you are to have sex now **without** a condom versus having sex in 3 months **with** a condom.

I will definitely have sex **now** **without** a condom.

I will definitely wait **3** **months** to have sex **with** a condom.

SDT - Evaluate whether MOSTSTI was selected for either of mostsex or leastsex

Action: Custom Script

WILL NEED TO ADJUST WHEN COPYING TO ANOTHER SURVEY

If MostSTI == (MostSex OR LeastSex) Then go to Evaluate LeastSTI

SDT - MostSTI - ALL

VALIDATION Min = 0 Max = 100

121.

Please rate how likely you are to have sex now **without** a condom versus having sex now **with** a condom.

I will definitely have sex **now without** a condom.

I will definitely have sex **now with** a condom.

VALIDATION Min = 0 Max = 100

122.

Please rate how likely you are to have sex now **without** a condom versus having sex in 1 hour **with** a condom.

I will definitely have sex **now without** a condom.

I will definitely wait **1 hour** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

123.

Please rate how likely you are to have sex now **without** a condom versus having sex in 3 hours **with** a condom.

I will definitely have sex **now without** a condom.

I will definitely wait **3 hours** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

124.

Please rate how likely you are to have sex now **without** a condom versus having sex in 6 hours **with** a condom.

I will definitely have sex **now without** a condom.

I will definitely wait **6 hours** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

125.

Please rate how likely you are to have sex now **without** a condom versus having sex in 1 day **with** a condom.

I will definitely have sex **now without** a condom.

I will definitely wait **1 day** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

126.

Please rate how likely you are to have sex now **without** a condom versus having sex in 1 week **with** a condom.

I will definitely have sex **now without** a condom.

I will definitely wait **1 week** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

127.

Please rate how likely you are to have sex now **without** a condom versus having sex in 1 month **with** a condom.

I will definitely have sex **now without** a condom.

I will definitely wait **1 month** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

128.

Please rate how likely you are to have sex now **without** a condom versus having sex in 3 months **with** a condom.

I will definitely have sex **now without** a condom.

I will definitely wait **3 months** to have sex **with** a condom.

SDT - Evaluate whether LEASTSTI was selected for either of mostsex or leastsex

Action: Custom Script

WILL NEED TO ADJUST WHEN COPYING TO ANOTHER SURVEY

If LeastSTI == (MostSex OR LeastSex) Then go to End

SDT - LeastSTI - ALL

VALIDATION Min = 0 Max = 100

137. Please rate how likely you are to have sex now **without** a condom versus having sex now **with** a condom.

I will definitely have sex **now without** a condom.

I will definitely have sex **now with** a condom.

VALIDATION Min = 0 Max = 100

138. Please rate how likely you are to have sex now **without** a condom versus having sex in 1 hour **with** a condom.

I will definitely have sex **now without** a condom.

I will definitely wait **1 hour** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

139. Please rate how likely you are to have sex now **without** a condom versus having sex in 3 hours **with** a condom.

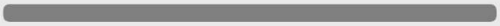
I will definitely have sex **now without** a condom.

I will definitely wait **3 hours** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

140. Please rate how likely you are to have sex now **without** a condom versus having sex in 6 hours **with** a condom.

I will definitely have sex **now** **without** a condom.



I will definitely wait **6 hours** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

141. Please rate how likely you are to have sex now **without** a condom versus having sex in 1 day **with** a condom.

I will definitely have sex **now** **without** a condom.

I will definitely wait **1 day** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

142. Please rate how likely you are to have sex now **without** a condom versus having sex in 1 week **with** a condom.

I will definitely have sex **now** **without** a condom.

I will definitely wait **1 week** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

143. Please rate how likely you are to have sex now **without** a condom versus having sex in 1 month **with** a condom.

I will definitely have sex **now** **without** a condom.

I will definitely wait **1** **month** to have sex **with** a condom.

VALIDATION Min = 0 Max = 100

144. Please rate how likely you are to have sex now **without** a condom versus having sex in 3 months **with** a condom.

I will definitely have sex **now** **without** a condom.

I will definitely wait **3** **months** to have sex **with** a condom.

SDT Comment

153. The questions you just finished answering are new questions that we have not asked in the past. We would appreciate any feedback that you have about them. For example, did you find the questions easy to answer? If you have any comments please write them below. If not, please click Next.

Script to randomize MCQ/SDT

Action: Custom Script

If rannum = 1 go to BIS, else if rannum = 2 go to MCQ

BIS-15

pagepath **Action: Hidden Value**
Value: 1

154. For each statement, please select the option to the right that indicates how well it describes you.

	Rarely/Never	Occasionally	Often	Almost always
I plan tasks carefully.	○	○	○	○
I do things without thinking.	○	○	○	○
I don't "pay attention."	○	○	○	○
I concentrate easily.	○	○	○	○
I save money on a regular basis.	○	○	○	○

	Rarely/Never	Occasionally	Often	Almost always
I squirm at plays or lectures.	○	○	○	○
I am a careful thinker.	○	○	○	○
I plan for job security.	○	○	○	○
I say things without thinking.	○	○	○	○
I act "on impulse."	○	○	○	○

	Rarely/Never	Occasionally	Often	Almost always
I get easily bored when solving thought problems.	○	○	○	○
I act on the spur of the moment.	○	○	○	○
I buy things on impulse.	○	○	○	○
I am restless at lectures or talks.	○	○	○	○
I plan for the future.	○	○	○	○

Emory University Men's Health and Behavior Survey

Thank you for taking our survey. We sincerely appreciate your time.

If you have questions or comments, you may contact the Principal Investigator, Jeb Jones of Emory University, at jsjone2@emory.edu.

To find an HIV testing location near you, please visit:

www.hivtest.org

To get more information about HIV, please visit:

www.cdc.gov/hiv

Otherwise, you can close your browser.

Appendix B. Components of a network model of a delay discounting intervention for MSM.

This appendix briefly describes the nodal attributes and dyad-level characteristics that are present in the EpiModelHIV network that was adapted for the current study. All model components except for the delay discounting parameters were already present in the model and described in fuller detail in Jenness et al.[79] Race specific parameters are available in the model; however, the network in the current study was initialized as 50% black and 50% white and averages of the race-specific parameters were applied to all nodes.

Nodal attributes	**Dyad-level attributes**	**HIV-specific parameters**
Delay discounting status	HIV concordance	HIV status and stage
Age	Partnership type	HIV testing frequency
Race	Condom use	HIV treatment initiation
Probability of CAI	Disclosure of serostatus	Viral load
Sexual role (insertive, receptive, versatile)	Delay discounting concordance	CCR-5 status (none, heterozygous, homozygous)
Circumcision status		

Appendix C. Key parameters in a network model of a delay discounting intervention for MSM.

Parameter	Values	Source
Delay discounting status	Network initialized with 63% discounters, 37% non-discounters	Online survey of US MSM
Delay discounting intervention effectiveness	Varied: 20%, 50%, 90%	N/A
Delay discounting intervention coverage	Varied: 20%, 50%, 90% of eligible men	N/A
Per-act probability of condom use – Main partnerships[1]	21%, independent of discounting status	Jenness et al.
Per-act probability of condom use – Casual partnerships[1]	Discounters: 20% Non-discounters: 36%	Calculated based on distribution of delay discounting in online survey, prevalence ratio for CAI based on discounting status, and probabilities for per-act condom use in Jenness et al.
Per-act probability of condom use – One-off partnerships[1]	Discounters: 20% Non-discounters: 36%	Calculated based on distribution of delay discounting in online survey, prevalence ratio for CAI based on discounting status, and probabilities for per-act condom use in Jenness et al.
Probability that intervention effect wanes	1/52 (Average intervention duration is one year)	N/A
Probability of always using condoms with casual partners	22%	Jenness et al.
Probability of always using condoms with one-off partners	33%	Jenness et al.
Sexual role	Insertive: 24.2% Receptive: 32.1% Versatile: 43.7%	Jenness et al.
Age	18-39 years; Active nodes exit at age 40 to maintain a network representative of the source data	Jenness et al.

[1]These probabilities are further modified by HIV diagnosis and disclosure of serostatus as described in Jenness et al[79]