Incarceration and Sexual Risk:

An examination of how incarceration shapes the context of HIV risk

by

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To my parents

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ABSTRACT

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This dissertation introduces a conceptual framework theorizing that incarceration and the inequities inherent in the current criminal justice system in the United States render changes in individual sexual decision-making among those incarcerated and their partners that ultimately increase community HIV risk. The three chapters to follow offer evidence to support this theory.

Chapter two examines the patterns of sexual behavior of a nationally representative sample of young men, comparing those who have been incarcerated to those who have not. A key finding of this study is that men who have been incarcerated have higher lifetime rates of partnership, and are more likely to have partners with concurrent partners than their never-incarcerated counterparts. This analysis also looks backward in time and compares these two groups of young men at a point *before* adult incarceration, and finds that prior to incarceration, there were very few significant differences between these groups, adding strength to the argument for a causal relationship between incarceration and riskier sexual behavior.

In chapter three, I develop and describe an agent-based model of sexual partnership and behavior, ultimately validating that the methodology has value for testing hypotheses about the link between individual-level partnering behavior and community-level sexual networks. The model generates rates of partnership and concurrency, as well as measures of relationship duration and similarity between sexual partners that match the findings of empirical data from the United States.

Chapter four extends the model to include incarceration and presents a series of model experiments that explore how rates of incarceration, the specific effects of incarceration on sexual partnerships, and other community characteristics interact to determine sexual partnership dynamics in any given community. Model results demonstrate increases in the number of sexual partners in the community, distinct from the effects of incarceration on incarcerated agents. These results provide "proof of principle" that incarceration may well explain part of the differences observed between patterns of sexual behavior in communities with low rates of incarceration and those with high rates of incarceration.

Finally, the fifth and concluding chapter presents a synthesis of these results and proposes a research program based on these findings. It highlights the need for further investigation into the process through which incarceration shapes sexual behavior, both for those individuals who are incarcerated, and for their partners.

Chapter I

Introduction

In 2006, one in seven Americans living with HIV infection was among the 9.1 million passing through the correctional system in that year, a decrease from 1997, when recently released inmates accounted for approximately one in five of all HIV-infected Americans (Spaulding et al., 2009). For black and Hispanic males, however, the figure remains high, where one in five of those groups' total HIV-infected persons were incarcerated during 2006 (Spaulding, et al., 2009). These data suggest that particularly for those populations most at risk for incarceration the criminal justice system continues to be an important point of contact for public health interventions. In 2008, state and federal inmates had a 1.5% prevalence of HIV, with a higher prevalence in women (1.9%) than in men (1.5%) and significant regional variation (Maruschak, 2009). Among state prison inmates, reported HIV/AIDS cases in 2008 ranged from 3.2% of the state prison population in the Northeast region to 0.7% in the West, with the South (1.9%) and Midwest (0.8%) in the middle (Maruschak, 2009).

HIV/AIDS in urban African American communities is a substantial public health concern. Based on an analysis of surveillance data, Karon and colleagues (2001) report that as early as 1999, 51% of the 11 700 men and 71% of the 4500 women newly diagnosed with HIV were African American. The trend continues, with data from the Centers for Disease Control and Prevention (CDC) showing that African Americans

accounted for 49% of new HIV infections nationwide in 2005, despite accounting for only 13% of the US population (Centers for Disease & Prevention, 2007; McKinnon, 2003). Figures based on 2006 CDC surveillance data show that 45% percent of new infections in that year were among black individuals (Hall, Song, & Rhodes, 2008). Though the rate of new infections may be decreasing slightly, these data taken together suggest a disproportionately more serious epidemic among African Americans in the US.

In addition, although residents of the poorest counties made up only one quarter of the US 1998 population, more than 40% of AIDS diagnoses during 1999 were located in these counties (Karon, et al., 2001). In a review of the social epidemiology literature on HIV, Poundstone et al (2004) identify exposure to poor socioeconomic conditions, high unemployment, and the proliferation of illicit drug markets as social risk factors for HIV. They also highlight Wallace's work in New York City, demonstrating the complex interplay of public policies, which systematically withdrew public services from poor neighborhoods, with HIV epidemic dynamics in the Bronx, and "documenting the 'synergy of plagues' that has accompanied rapid social change and the destruction of essential protective networks in poor communities" particularly those in urban areas (Poundstone, et al., 2004, p. 26). Highlighting the interaction between poverty and racial segregation, Douglas Massey (1990) describes the transformation of segregated urban neighborhoods into "physically deteriorated areas of high crime, poor schools, and excessive mortality" (p. 329).

Considering HIV/AIDS requires a consideration of structural factors based on race, socioeconomic status, and gender. A conceptual framework proposed by Link and Phelan (1996) suggests that high rates of HIV in urban African American communities

are yet another symptom of the "fundamental causes" of health disparities, the systematic neglect of and lack of resources in urban areas. Incarceration may be a mediator between more distal inequalities and disparities in HIV infection. In this dissertation I introduce a conceptual model for HIV risk that describes the mechanisms through which high community risks of incarceration may effect the sexual decision-making and sexual network structures of urban African Americans, and as such influence their population-level risk for HIV. The model is shown in Figure 1.1. First, I present the most distal (left-most) constructs in the model, and argue that race and class determine who is incarcerated for what kinds of offenses, resulting in over-representation of urban African American residents in the criminal justice system. This section describes the relationship between community risk and incarceration. Second, I review the evidence demonstrating how the context of urban African American communities affects sexual network structure and HIV risk, explaining the most proximal (right-most) constructs in the model. Third, and finally, I propose pathways through which incarceration effects both individual- and population-level sexual decision making and sexual network structure and increases the risk of HIV for urban African Americans, filling in the central relationships in the model. This section describes the key mediators between incarceration and changes in sexual network structure and sexual decision-making.

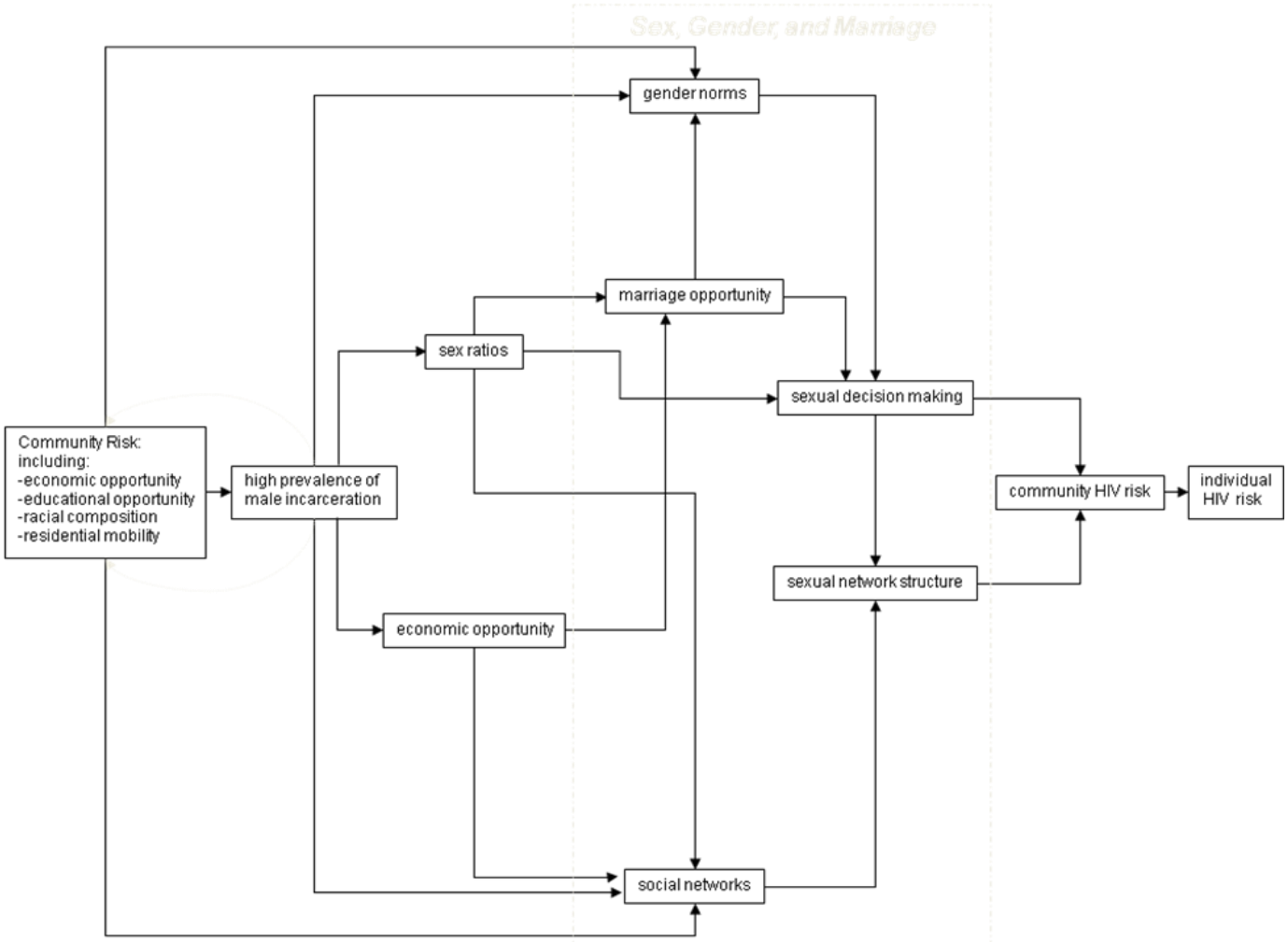

Figure 1.1. Full conceptual model linking high prevalence of male incarceration to community and individual level HIV risk.

Theoretical Framework

Several different theoretical orientations inform the conceptual model presented here. Incarceration and sexual networks have been addressed in sociology, public health, anthropology, and complex systems science, each with slightly different theoretical groundings. My primary conceptual orientation comes from complex systems, though several other theoretical traditions influence the model.

A complex systems approach begins with five core assumptions: (1) that the whole is more than the sum of its parts; (2) that heterogeneity is important for the behavior of the system; (3) that individuals get feedback from their actions as well as from other individuals and from the system itself; (4) that contacts are not random and the network of connections is important; and (5) that the interest is in studying emergence of macro-system behaviors from underlying micro-components (Simon & Koopman, 2005). Using a complex systems orientation means that although understanding individual behavior is important, the behavior of the system is inexplicable without considering the interactions between individuals and the context. "The very essence of the system lies in the interaction between the parts and the overall behavior that emerges from the interactions" (Ottino, 2003, p. 293). This conceptual framework is particularly informative for community- or population-level outcomes and has strong implications for model specification: a complex systems approach requires a consideration of structural and community factors that constrain and influence individual behaviors and outcomes. Though complex systems theory does not propose specific constructs with regard to incarceration and sexual networks, it supports the use of conceptual frameworks that

describe networks of individuals and their relationships as well as the gender and racial norms and ideologies that shape both incarceration and sexual networks.

The theory and practice of network analysis have emerged over the last seventy years from mathematical graph theory and sociological social network analysis and have been used since the mid-1980s to investigate patterns of sexually transmitted disease (Borgatti, Mehra, Brass, & Labianca, 2009; Ottino, 2003; Potterat, Rothenberg, & Muth, 1999). Though much of the earlier epidemiological literature had focused on individual risk factors and behaviors, the last 10-15 years have brought increasing recognition that individuals do not exist in a vacuum and that particularly sexually transmitted diseases must be studied in the context of sexual networks, as an individual's risk is directly affected by the risk level of his or her partner(s) (Aral, 1999).

Considering sexual decision-making on an individual level, the model is informed by sexual scripting theory. Lewis and Kertzner (2003) define sexual scripts as "frameworks of meanings and behaviors built by cultural or social groups and transformed by persons in order to contextualize their (sexual) experiences (p. 391)." These scripts exist at the level of "cultural scenarios," or collectively shared general guidelines, "interpersonal scripts," or individuals' interpretations of cultural scenarios, and "intrapsychic scripts," which are the internalization of the socially shared scripts and scenarios (Hynie, Lydon, Cote, & Wiener, 1998, p.370-371). The interaction between these levels makes this theoretical orientation particularly useful where particular social contexts uniquely constrain individual sexual behavior.

When considering the structural influences that shape sexual networks, conceptualizations of gender and influences on gender norms are critical. Whitehead and

colleagues (1994) proposed a framework for African American masculinity in which he describes the concepts of respectability and reputation as contrasting ways of being a "big man," or attaining an elevated social status. Though Whitehead's framework may overstate the opposition of these two constructs, it usefully acknowledges that men who are unable to obtain respectability (evidenced by being able to provide for a family, etc) as a result of living in high-poverty areas with few job opportunities may compensate for this perceived lacking by expressing reputational attributes such as having masculine "gamesmanship" skills and sexual prowess (Whitehead, et al., 1994). Aronson, working with Whitehead and Baber, (2003) has helped to develop this work further, showing that masculinity is constructed in a subtle fashion, with constant negotiation between what is expected or desired and what is possible. This more nuanced framework helps to illustrate the complex role of incarceration in the formation of gender norms, and the forces that shape sexual network structure. Other more general theories of gender are available, but the specificity of these constructs to urban African American men makes this framework more useful for this particular purpose.

As with Whitehead's theoretical framework for considering African American masculinity, the Theory of Gender and Power is most appropriate for an examination of how African American femininity and female gender roles fit into the context of HIV. Developed to guide HIV prevention work with women, Wingood and DiClemente (1998) emphasize the importance of the sexual division of labor, the sexual division of power, and the structure of social norms that "govern appropriate sexual behavior for women and … the emotional attachments involved in social relationships (p. 33-34)." This theoretical perspective integrates feminist historical analyses that draw on stereotypical

sexual representations of African American women as well as field work with incarcerated women that describes poor African American women as "restricted by their gender roles, stigmatized by their racial/ethnic and class position, and constrained by the competing forces of tremendous unmet need and very limited resources" (Collins, 2000; Richie, 1996, p. 2).

In addition to conceptualizations of gender, theories of race and class in relation to the criminal justice system shape the model. Though the criminology literature proposes specific theories that address economic and political explanations for the "prison boom" in the 1980s, as well as a large body of work exploring the hypothesis that "racial threat" motivated this increase, it remains unclear whether any one of these should be privileged over the others (Eitle, D'Alessio, & Stolzenberg, 2002; Ousey & Lee, 2008) Instead, the literature describing the determinants of incarceration portrays a complex interaction between racialized fears of and responses to crime from politicians, increasing economic disparity, the influx of crack cocaine into already struggling urban neighborhoods, and political responses to the drug "epidemic" (Kent & Jacobs, 2005; Stolzenberg, D'Alessio, & Eitle, 2004; Western, 2006). Rather than choosing a single theory to inform my conceptual model, I draw from this literature more broadly to explore the determinants of incarceration, particularly as they affect urban African American communities.

The theories discussed above form a framework in which to examine incarceration. Goffman's conceptualization of total institutions (1962) and Rose and Clear's hypothesis of coercive mobility (1998) motivate the specific consideration of incarceration as an important community level factor influencing sexual network

structure and sexual health. On an individual level, Goffman's theory of total institutions suggests a systematic (if individually variable) process of dehumanization and acculturation that occurs when an individual enters an institution. He suggests that the removal of all signifiers of prior social context (except those which cannot be removed such as race and sex) and resocialization into the institutional culture complicate the later reentry of the inmate into a cultural context outside of the institution. Rose and Clear discuss the implications of incarceration on a community or neighborhood level, hypothesizing that incarceration creates a uniquely transient population. Especially at high rates, Clear and colleagues hypothesize that incarceration disrupts social networks by damaging familial, economic, and political sources of informal social control, the agreed-upon norms and day-to-day interaction that result in a natural kind of supervision within families and communities (Clear, Rose, Waring, & Scully, 2003). Contrary to the stated goals of incarceration, this is likely to increase rather than decrease crime and other behaviors under informal social control. Thomas (2006) applies coercive mobility to sexual relationships, suggesting that high rates of incarceration may also interfere with the ability to "agree on and enforce a code of norms and values such as those that might regulate sexual relationships (p. S8)"

Antecedents of Incarceration

Though the most obvious and proximal cause of incarceration is participation in criminal activity, well documented disparities in incarceration based on race and socioeconomic status necessitate a deeper examination of who is incarcerated. In the model, I pose the rather amorphous construct of community risk (see Figure 1.1, far left), in which I include variables from several theoretical traditions. Though a fuller treatment

of these variables and their relationship to incarceration is not the intent of this paper, in this section I explore the relationship between incarceration and race and class, as it has substantial bearing on the interpretation of the rest of the conceptual model. This section addresses the context of incarceration, setting the stage for the discussion of the rest of the constructs in the model.

It is clear that incarceration is differentially experienced by young urban African American men, most often poor men with little education (Western, 2006). The Bureau of Justice Statistics reports that if incarceration rates remain constant 32% of black males will enter State or Federal prison during their lifetime compared to 17% of Hispanic males and 5.9% of white males, and that nearly 6 in 10 persons in local jails in 2009 were racial or ethnic minorities (Bonczar, 2003; Minton, 2010). As Western calculates, these rates are even more striking if one further limits the analysis to high-school dropouts; in 2000 among high school drop-out men between the ages of 20 and 40, 32.4% of African Americans were in prison or jail, compared with 6.7% of whites and 6.0% of Hispanics (Western, 2006, p. 17)). Strikingly, this incredible disparity in incarceration arose only recently, during the prison boom of the late 1980s and early 1990s.

Establishing the cause of both the rise in incarceration and the rising inequality in incarceration during the 1980s is difficult, though it is clear that there were both economic and political drivers, each with substantial racial undertones. Between 1980 and 1996, state and federal incarceration rates increased by over 200 percent, driven primarily by a 10-fold increase in incarceration for drug offending (Blumstein & Beck, 1999). Western (2006) emphasizes that increasing rates of arrest for drug-related crimes did not reflect an increase in drug use, but rather increased enforcement of drug laws in

the "war on drugs" focusing on crack cocaine in African American neighborhoods. As economic forces pushed more urban African Americans into the drug trade, political rhetoric emphasized incarceration as the most appropriate response to the crack "epidemic" in urban areas. Western (2006)argues that both political and economic forces were necessary for the prison boom. "The jobless ghetto supplied a pool of potential inmates, but policy makers had also to decide that crime, and street crime in particular, deserved imprisonment (p. 57)."

Wilson highlights the decline of manufacturing, the suburbanization of blue-collar employment, and the rise of the service-sector as eliminating well-paying jobs for unskilled minorities (as cited in Massey, 1990). Western describes the shift of jobs out of urban African American communities which left many young men out of work even in a time of relative prosperity for the nation as a whole (Western, 2006). Mauer (1999) suggests that "those young people who are so isolated from the mainstream that they are not even looking for work have little incentive to conform to societal norms (p. 123)," and may turn to illegal ways of making ends meet. Driven in large part by racial segregation, rising unemployment and concentrated poverty in primarily African-American urban areas combined with an increasing gap between the wealthy and the poor in the United States created "the threat of … an entirely property-less class" (Massey, 1990; Western, 2006, p. 54).

The US also saw a political shift in the late 1980s toward "law-and-order" and "tough on crime" politicians. The racial undertones (and sometimes explicit rationales) of these policies have been examined in several contexts. Western (2006) highlights how "law and order" rhetoric provided a way to address crime broadly, but also to craft a

response to civil rights protests and race riots that would code African American citizens as lawless and dangerous, particularly to white citizens. Using South Carolina's National Individual-Based Reporting System in 1992 and 1994, David Eitle and colleagues (2002) demonstrate that only rates of black-on-white crime significantly predict black arrest levels, controlling for the violent crime rate, population density, and other potential measures of perceived racial threat, while rates of black-on-black crime has only a small and statistically insignificant effect. Kent and Jacobs (2005) find that the proportion of black residents is positively related to the size of the police force, and that this relationship is stronger in 1990 and 2000 compared to 1980. Though much of the work in this area is limited by methodological concerns including measurement issues, the body of literature suggests complicated effects of race on political responses to crime.

Whether through an intentional or explicit devaluation of black crime victims or a series of unintentional institutional decisions that ultimately give rise to racial disparities in arrest, prosecution, and incarceration, the scale of incarceration in the US means that even slight biases in the system can exert a substantial effect. Though the evidence does not point to overt racial discrimination at every step, neither does it suggest that the current criminal justice system blindly metes out justice for all, starting with policing and ending with sentencing. Urban residents frequently report that they are overly policed, but that they do not receive sufficient protection or response from law enforcement officials (Walker, Spohn, & DeLone, 1996). In their analysis of 2000 US Census data from 1356 US cities, Ousey and Lee (2008) find support for what they call the "spatial opportunity model," where decisions "may ultimately result in concentrating police

attention on spatially distinct Black communities that are perceived to be crime 'hot spots' (p. 331)".

As a result of the Sentencing Guidelines and Policy Statements of the Sentencing Reform Act of 1984, possession of 5 grams of crack cocaine is a felony with a 5-year minimum sentence, while possession of 5 grams of powdered cocaine is a misdemeanor punishable by less than 1 year in jail (Mustard, 2001). African Americans are overrepresented among users of crack cocaine, which mean that these sentencing laws sent large numbers of young African American men to prison in spite of being no more likely than young White men to use drugs (Mustard, 2001; National Center for Health Statistics, 2009).

Justification for a Focus on Male Incarceration

In the United States, men are incarcerated at much higher rates than women. In 2009, women represented 12.2% of jail inmates and 68 per 100,000 women was in a state or federal prison compared to 954 per 100,000 men in the US (Minton, 2010; West, 2010). In addition to the wide gap in incarceration rates, it is likely that male and female incarceration have very different effects on individuals, families, and communities. Much of the work evaluating the outcomes of male incarceration focus on diminished economic opportunity, and the effect that this, in combination with a criminal record, has on desirability as a marriage partner. Women who are incarcerated are more likely than incarcerated men to have engaged in sex work, and drug use, and to have partners who are injection drug users (Braithwaite, Arriola, & Newkirk, 2006). These different circumstances before incarceration suggest that imprisonment would have a different effect.

Although it has been documented that many men who are incarcerated have children at the time of their incarceration, they are much less likely than incarcerated women to be the primary caregivers for their children at the time of incarceration (Braithwaite, et al., 2006). In contrast, incarcerated women are likely to have been single heads of households with children under 18 at the time of their incarceration (Braithwaite, Treadwell, & Jacob Arriola, 2005). In addition, because there are so many fewer incarcerated women, they are often all incarcerated in one facility in each state, making it less likely that they will be near their families and able to maintain relationships while they are incarcerated (Braithwaite, et al., 2006). One notable study strongly linked female incarceration to growth in foster care caseloads, and preliminary work suggests that female incarceration effects infant mortality rates as well (Swann & Sylvester, 2006; Wildeman, 2009). These studies suggest that because of women's unique and disproportionate responsibility for child rearing, the incarceration of women is likely to have unique and complex effects on family structure that should be considered theoretically distinct from the effects of men's incarceration.

Because of these substantial differences in the effects of male and female incarceration, in this section describing the effects of incarceration on sexual networks I focus specifically on male incarceration. Women are incarcerated at substantially lower rates than men, and it is likely that incarceration affects their sexual networks in ways that are unique from the effects on men's sexual networks, due to their position as caregivers of children and also due to different gender norms. For these reasons, I hypothesize that a separate conceptual model would be needed in order to explore the effects of female incarceration and the direct effects of women's incarceration are not

considered here. Because of the scale of male incarceration, a conceptual model limited to male prisoners is still likely to give considerable insight into the vast disparity in HIV infection observed in urban African Americans and as such the focus of this review is limited to male incarceration.

Determinants of Sexual Network Structure, Sexual Decision-Making and HIV Risk

This section moves to the right side of the model, demonstrating first how social networks constrain sexual network structure, and then how sex ratios, marriage opportunity, and gender norms all affect individual sexual decision-making, which ultimately also shapes sexual network structure. I also justify the use of sexual network structure and sexual decision-making as important markers of HIV risk.

Sexual networks are typically formed under many of the same forces that structure social networks through which individuals meet friends and find jobs (Laumann, Gagnon, Michael, & Michaels, 1994). Individuals are constrained by geography and biography, limited by who they encounter in the ordinary course of their lives. Most partnerships are initiated through self-introductions or introductions by friends, and many introductions take place in the contexts of school or work (Laumann, et al., 1994). As a result of decades of discriminatory lending policies and federal and state housing policy, residents of urban areas are likely to live in segregated neighborhoods (Massey, 1990). Frey and Meyers (2005) use the dissimilarity index to compare segregation in 1990 and 2000 (with 100 indicating complete segregation, and 0 representing complete integration). In 2000, the average dissimilarity index for metropolitan areas was 58.7 (60 is the conventional benchmark of high segregation) (Frey & Meyers, 2005). They find that although segregation nearly uniformly declined

during the period of study, these decreases were relatively small and the "national pecking order of different racial groups" had not changed substantially (Frey & Meyers, 2005). Johnston et al (2004) calculate a modified isolation index (the probability that minority individuals will only encounter other minority individuals, corrected to take into account the size of the ethnic group) for a large number of metropolitan statistical areas using both 1980 and 2000 US Census data, and find that the mean of 0.253 for 1980 has only dropped slightly, to 0.208 in 2000, and the maximum values at each time point are 0.660 and 0.600 respectively. These data show that in many cities, minority members have a high probability of interacting only with other minority members, and that though this has diminished slightly over the past 20 years, these areas remain highly segregated. Though the labor market is often segregated by both race and sex or gender, Dickerson (2007) found that measures of segregation had similar effects on black men's and black women's employment. The high level of segregation in central cities across the country makes it unlikely that urban African Americans will encounter a large number of non-African Americans during their daily lives, so their social networks, and thus sexual networks will be relatively racially homogeneous.

Data on interracial marriages also illustrate highly segregated social and sexual networks, though patterns over the past few decades suggest a more nuanced picture. Interracial marriage has increased tremendously since the 1967 Supreme Court ruling *Loving v. Commonwealth of Virginia*, from 150,000 marriages in 1960 to 1.6 million in 1990 (Lee, Beam, Batalova, & Sandhu, 2003). Between 1980 and 1990, analyses of US Census data show that interracial marriage of whites occurs most frequently with Asian Americans, followed by Hispanics, and then by African Americans (Qian, 1997). Qian

(1997) notes that interracial marriages tend to be educationally homogamous and that the odds of interracial marriage increase with couples' educational attainments. Using subsequent US Census data, Lee and colleagues (2003) report that between 1990 and 2000, overall rates of interracial marriage increased from 4.4% to 6.4%. Though rates of exogamy among couples that include at least one African American increase during that period from 8.4% to 12.6%, the rate at the most recent measurement is still dwarfed by the rates of intermarriage in couples made up of at least one Asian or Latino individual at the same time point (30.9% and 29.3% respectively). These data suggest that although rates of interracial marriage have increased dramatically, this increase has been fueled primarily by more recently immigrated Latinos and Asian Americans intermarrying with whites, mirroring the increase in interethnic marriage among whites following earlier waves of immigration, rather than a substantial shift in intermarriage among African Americans and whites (Lee, et al., 2003).

Sexual networks that form in highly constrained situations are likely to exhibit unique features as a result of those constraints. One unique characteristic of urban African American social networks that influences sexual networks is the distorted sex ratios, with men underrepresented. Using data from 270 metropolitan areas defined in the 1980 US Census, Fossett and Kiecolt (1993) find that the median ratio of men to women (non-institutionalized, aged 16 and above) is 0.84, with a wide interdecile range (0.31). These highly skewed sex ratios are attributed to a combination the high rates of incarceration discussed previously as well as high rates of male mortality. In calculating excess mortality for poor African Americans in central city areas, Geronimus et al (1996) report higher excess mortality for men than for women in all areas. This differential

mortality is further exacerbated by high rates of unemployment that reduce the number of desirable available partners. When restricting the sample to men in the labor force and non-institutionalized women, the median drops to 0.59 men for each woman, with a similar spread (interdecile range = 0.33) (Fossett & Kiecolt, 1993).

Adimora and Schoenbach (2005) have suggested that an imbalance of available men and women, with more women than men**,** makes women less able to negotiate in sexual relationships, and biases sexual network structure toward masculine constructions of ideal sexual relationships, where men have multiple partners and women have relatively fewer. Analyses of two different waves of the National Survey of Family Growth show a difference in numbers of partners between men and women. An analysis of the 1995 survey showed that only 13% of black women reported having 10 or more partners over the lifetime, while in 2002 30% of black men reported having 10 or more partners over the lifetime (Adimora et al., 2002; Adimora, Schoenbach, & Doherty, 2007). There is likely some reporting bias as a result of social pressures on sexual performance reports, but qualitative work describing contexts of masculinity and partner choice suggests that this result is not entirely a result of differential reporting. Laumann and Youm (1999) also report that African American sexual networks tend to have a greater degree of connection between men in the core of the sexual network (those with a large number of partners) and women who are peripheral in the network (those with only one partner), which also matches the pattern presented above.

Definitions of masculinity that derive from local cultural experiences as well as larger cultural messages about gender roles also determine how sexual partnerships form. Whitehead et al (1994) have described the concept of respectability in African American

masculinity in terms of being a strong family economic provider, entering into a legal marriage, respectable levels of material possessions such as a home, higher education, and economic independence as being one side of the Big Man/Little Man Complex. They contrast this with the concept of reputation, defined by sexual prowess, masculine "gamesmanship" skills, fathering numerous children, and "smarts," (outwitting other men and "sweet talking" women) (Whitehead, et al., 1994). Aronson, Whitehead, and Baber (2003) refine this framework slightly, focusing on the constant negotiation between these ideals of masculinity, with obvious consequences for sexual network structure, particularly in contexts where higher education and legal employment are hard to come by. If men are left with only reputational attributes, normative measures of masculinity are likely to shift toward sexual prowess and an increased number of partnerships.

A natural extension of masculinity rooted in the sexual conquest of women in African American culture is the prohibition of same-sex partnerships. This combined with strong community ties to the church create a context in which sexual networks are socially expected to be completely heterosexual (Lane et al., 2004). The broader experiences of African American gay and bisexual men and women is beyond the scope of this paper, and it is sufficient here only to recognize that same-sex partnerships are stigmatized and often not disclosed even if they are part of a sexual network, and that these stigmatizing social expectations and norms may exacerbate sexual risk. Though there is likely some non-zero number of bisexually behaving individuals, it is unlikely that HIV in urban African American communities can be explained by this alone.

The Theory of Gender and Power emphasizes the gendered constraints placed on women that often place them in a position of financial dependence and economic

vulnerability and suggests that these constraints limit many women in their sexual relationships as well. Within urban African American communities, and particularly in the context of incarceration, male employment is often low and those men engaged in the drug trade or other forms of extralegal employment are at increased risk of interaction with the criminal justice system and a concurrent loss of income. The gendered norms of relationship control are likely maintained in spite of this, however, as Comfort (2008) describes men returning from a period of incarceration and expecting to regain full control of all household decisions though their partners had managed affairs in their absence. Wingood and DiClemente (1998) show that women who are economically vulnerable, as measured by indicating AFDC as the main source of income, have 3.3 times the odds of non-condom use as women who report having a job as their main source of income. This suggests that economic vulnerability may play a role in how women's relationships are structured even if it does not exclusively motivate their formation.

On an individual level, all of the factors described above shape the sexual scripts that individuals interpret and use when they decide with whom to have sex. Much of the literature on sexual scripts and African American sexuality focuses on urban adolescents, but insights can nonetheless be gained. Gilmore and her colleagues (1996) found in a qualitative study that inner city Black young men use a complex script for heterosexual sexuality that includes considering whether a girl is considered to be promiscuous, how likely it is that she is trying to get pregnant, and their conflicts with other men when they decide whether or not to pursue a potential partner, and then whether or not to use a condom. Decisions about sex and condom use must balance the risk of retaliation from

men previously involved with the potential partner as well as the likelihood that the potential partner is trying to get them "hooked up," or trick them into being fathers (Gilmore, et al., 1996). The young men in the study distinguished between "good girls," those with little sexual experience or steady boyfriends, and "bad girls," those perceived to be promiscuous, with good girls as the ideal longer-term partners with whom condoms were unnecessary unless there was a fear of unwanted pregnancy (Gilmore, et al., 1996). Their beliefs about condoms and AIDS, as well as what it means to be a man are also considered (Gilmore, et al., 1996). Stephens and Phillips (2003) discuss the limited sexual scripts available to young African American women influenced of racialized sociohistorical images, most of which allow little actual sexual decision-making by women. Studies by Hynie et al (1998) show that individuals struggle to incorporate new elements such as condom use, suggesting that there is a complicated internalization process through which individuals incorporate their experiences, knowledge, and beliefs into the cultural scenarios.

These individual decisions and the resultant sexual network structures have important implications for HIV risk, though some of these remain unclear and will need to be investigated empirically. On the individual level the engagement and interpretation of sexual scripts may lead to risky behavior such as having multiple partners and not using condoms. Stephens and Phillips (2003) express concern that young African American women's sexual scripts reflect gender norms based on male desires and risky sexual norms, rather than women's voices and healthy sexuality. The expectations of men in these scripts reflect neither a broad spectrum of men's experiences nor healthy sexuality, and instead reinforce limiting ideas about masculinity. The difficulty of

incorporating elements not already present in socially accepted scripts, such as condom use, documented by Hynie et al (1998) suggests that other factors, such as self-efficacy, perceptions of invulnerability, trust, and perceptions of safe partners also play a role in how sexual scripts are enacted (Emmers-Sommer & Allen, 2005). The interaction between drug use and sexual risk-taking is also an important determinant of individual risk, but is beyond the scope of this conceptual model. It is sufficient to recognize that an increase in drug use will almost always also increase sexual risk-taking (Flom et al., 2001).

The structure of sexual networks has been shown to determine how sexually transmitted diseases spread. Shorter distance to the core group is a risk factor for sexually transmitted diseases, showing that the extended network structure is critical in determining even individual risk (Klovdahl et al., 1994). Morris and Kretzschmar (M. Morris & Kretzschmar, 1997) have also demonstrated using simulations that increases in partner concurrency, or having multiple partners at the same time, dramatically increases both the size and variability of an epidemic, even as the absolute number of partners is held constant. Based on simulation of the partnering dynamics in African American sexual networks, Laumann and Youm (1999) conclude that any sexually transmitted infections would spread more widely within African American sexual networks, and also remain within African American networks rather than diffusing into broader sexual networks.

Effects of High Rates of Incarceration on Sexual Network Structure

This section explains the rationale for a relationship between incarceration and HIV risk behavior-related constructs. As demonstrated in the previous two sections, it is

clear that there are social determinants of incarceration above and beyond engagement in criminal activity, and factors that shape sexual decision-making and sexual network structure also affect HIV risk. Here I present the key mediating relationships between incarceration and changes in sexuality-related variables that may ultimately result in changes in community and individual HIV-risk.

Individual Level Effects

On the individual level, incarceration can have profound and immediate effects on partnerships (Braman, 2004; Comfort, 2008). Women's experiences of their partners' incarceration and the incarceration of other men in their communities are likely to have a nuanced effect on sexual decision-making. The incarceration of a partner is likely to have substantial emotional consequences, ranging from anger and frustration with the criminal justice system to relief at the removal of a potentially dangerous member of the household. The financial implications of incarceration cover as broad a range, from removing a primary breadwinner to removing an individual with an expensive drug and alcohol habit. Comfort (2008) even identifies partnerships in which the criminal justice system is used to maintain an otherwise untenable relationship situation; the woman depends on the intervention of police when her partner becomes overly destructive, whether through theft or domestic violence, but the relationship resumes after a period of incarceration. Braman (2004) also focuses on the effects of stigma on the partners and families of incarcerated men, emphasizing the decision of some women to hide their partner's incarceration even from family members.

The complex interaction between female partners of incarcerated men and the criminal justice system makes it difficult to predict, on a population level, how this will

affect sexual decision-making. Women whose partners are incarcerated have many reasons to end relationships permanently: the difficulty of maintaining contact through visits and short phone calls, the expense of maintaining a relationship through packages and collect calls, and the wish to shield children and extended family from the shame or stigma of association with an incarcerated family member. In addition, Morris (1965) observes that many inmates had difficult relationships before incarceration, though it is unclear how this influences the effects of incarceration on the relationship.

In spite of these difficulties, Comfort (2008) identifies several core reasons that women sustain relationships with incarcerated men in her qualitative work with women visiting partners at the San Quentin Penitentiary in California. She describes women as predominantly either viewing their partners as victims of a racist or unjust criminal justice system, being disillusioned with "free" men (and drawn to the enforced "feminization" of men who can only communicate through writing and occasional phone calls), experiencing the incarceration of a partner as normal, or not wanting to give up on a relationship in which they had invested a great deal (Comfort, 2008). Incarcerated men also have a significant motivation to maintain relationships in order to secure emotional and material support as well as a connection to the outside world.

Incarceration is often a reason for at least a temporary break in a relationship (Braman, 2004). Thomas et al (2007) conducted ethnographic research in urban North Carolina to investigate changes in partnerships that occurred as a result of incarceration. They find that particularly among young couples where the male partner is sentenced to a long prison term, young women chose or are encouraged to "go on about [their lives]" (Thomas, et al., 2007, p. 94). A woman may be unable to maintain a relationship with

her partner because he is incarcerated in a facility far away from her home due to the prohibitive expense of receiving collect calls and visiting (Braman, 2004). Additionally, she may consciously or unconsciously wish to distance herself and her children from the stigma of incarceration. For the partner of an incarcerated man, the loss of financial support can be acute, particularly if she is supporting children as well (Braman, 2004; Thomas, et al., 2007). Whether her relationship with the incarcerated man ends permanently or not, she may have to rely on other relationships for financial support during his incarceration, either her kin network or new partners. Although Western does not find a significant effect on divorce among African Americans as a result of incarceration, he attributes this to low rates of marriage and not necessarily low rates of partnership break-up (Lopoo & Western, 2005; Western, 2006).

The Theory of Gender and Power emphasizes the gendered constraints placed on women that often place them in a position of financial dependence and economic vulnerability. The above discussion suggests, however, that though economic forces may motivate some women to find new (and potentially concurrent) partners while their partners are incarcerated in order to support themselves or their children, the situation is much more complicated. It may be that when women choose to maintain their relationships with incarcerated men, an "extramarital opportunity structure," a concept proposed by Hirsch et al (2009) is created, providing a situation in which having partners outside the primary partnership is facilitated because of the physical separation between the couple and potential social allowances made in a time of crisis. In spite of this, gendered norms of fidelity and control in a relationship likely influence how women make decisions about sex in response to the incarceration of a partner. If a relationship

resumes after a period of incarceration, or conjugal visits are allowed during incarceration, norms about condom use in primary or committed relationships may shape decisions about condom use or other safer sex practices.

If the relationship between the incarcerated man and his partner is sustained during his incarceration or resumed after his release there is a high potential for the introduction of concurrent sexual partners through several mechanisms. First, as discussed above, the non-incarcerated partner may form new relationships either to fill emotional or economic needs, with some overlap in sexual relationships either during incarceration or afterward. Second, male inmates are dependent on women on the outside for many things, often including sex. It has been suggested that inside prison women are viewed simply as bearers of commodities, and that it is common for men to have multiple relationships with women on the outside in order to increase access to those things, though there is currently no empirical evidence of this (Smith, 1998). Third, some recently released inmates may have higher rates of concurrency immediately following release. In a sample of 14 ex-inmates, several men said they "needed to have sex with more than one woman upon release to satisfy their pent-up desires (Thomas, et al., 2007, p. 96)." Each of these situations changes the network structure, increasing the number of concurrent partners.

In addition to the heterosexual partnerships that may be added to the sexual network during incarceration, up to 44% men who have been incarcerated report same-sex sexual behavior while in prison (Krebs, 2002). Although this seems to run contrary to the most widely accepted definitions of masculinity, the use of sex for power is not really different from many accepted heterosexual partnership models. It is possible that

men have sex with other men because no women are available, but also reasonable to conclude that rape has nothing to do with sex and is a tool for dominance in a setting defined by rigid hierarchies and a lack of power for those incarcerated. Indeed, in their interviews with former inmates, Thomas and his colleagues (2007) find that men explained having sex with other men in prison as a way of coping with sexual tension and gaining a protector from violence. These violations also change the inmate's sexual network to include other inmates.

Whitehead's framework outlined earlier is clearly applicable on the individual level, where an incarcerated or previously incarcerated man is unable to meet "respectable" goals of masculinity and instead strives for "reputational" attributes. Others have suggested that incarceration reinforces a "hyperaggressive masculinity" with a strong emphasis on reputation that carries over outside of the criminal justice system, perhaps increasing the motivation to express these reputational attributes (Miller, 2006; Phillips, 2001). Smith (1998) also notes that unfortunately, even those politically conscious prisoners who are radicalized by prison life rarely consider issues of sexism in discussions of racism and classism. Several studies have documented that men who have been incarcerated have an increased number of partners, and high rates of concurrency, and though the mechanisms have not been fully explored, expressions of masculinity is likely to play a role (Adimora, et al., 2007; Laumann, et al., 1994).

Family Level Effects

The effects of incarceration at the family level are substantial, and likely in part mediate the relationship between the effects of sexual decision-making and sexual networks and community and population level HIV risk. Though some individuals who

are incarcerated may have been a financial or emotional burden to their families, the literature suggests that a large proportion of inmates were connected to families before incarceration and that these kin networks suffer for their loss. Most notably when children are involved, but also when they are not, families suffer financial and emotional losses that contribute to changed partnership dynamics, and children's experiences with the incarceration of a parent likely has lasting effects that ultimately also affect sexual decision-making and sexual networks. It is notable that although the families of all incarcerated individuals must cope with the loss, the families from which most prisoners are removed and to whom they are returned are often the families that are already struggling, and incarceration "in most cases adds to the burdens of a family already struggling to overcome life's obstacles and setbacks (Travis & Waul, 2003)." The family effects of incarceration fit into the overall social patterning of incarceration, with poor urban African American families differentially affected.

The family effects of incarceration are most often considered when children are involved. Although family members may be involved even when there are no children, these effects are likely covered in the sections on individual and population level effects of incarceration, either affecting only partners or affecting the entire community. The loss of a financial and emotional provider may be particularly acute when children are involved, and the rest of the discussion in this section will focus on the immediate and extended families of inmates with children.

The break-up of partnerships as a result of male incarceration often involves children. Approximately 1.5 million children in the US have a parent who is incarcerated, and the number of effected children increases to 3.2 million if adults who

have recently been released from prisons or jails and those adults on parole (Travis & Waul, 2003). Most of these parents are fathers, as many more men are incarcerated than women. When a father is incarcerated, children often either remain with the unincarcerated parent (90%) or with other extended family. As mentioned briefly in the discussion of the incarceration of women, some children do end up in the formal foster care system (2%), though most often they are absorbed into extend kin networks (Mumola, 2000). Though children's reactions to their parent's incarceration vary with age and other contextual factors, Travis and Waul (2003) review the literature and identify several key themes: children always experience the loss of a parent as a traumatic event; trauma diverts children's energy from developmental tasks; children experience the stigma of having a parent in prison.

Children of incarcerated parents have been documented to have a wide variety of emotional and behavioral difficulties, and though pinpointing the cause of these problems is difficult, it is likely that the incarceration of a parent contributes or exacerbates these problems. Describing Charles, 13, whose father has been in and out of the criminal justice system several times during his childhood, Braman notes that although he gets straight A's in school and is clearly intelligent, he has had "a host of problems with the criminal justice system, having been arrested three times for auto theft and once for shoplifting (Braman & Wood, 2003, p. 178)." Parke and Clarke-Stewart (2003) suggest that young children may have a variety of negative outcomes relating to insecure attachments such as anxiety, withdrawal, anger, and agression, and that school-age children may have school-related problems and problems with peer relationships. Incarcerated parents and caregivers of their children identify school difficulties,

withdrawal, acting out behavior, and excessive crying as behaviors they believe to be related to parental absence and incarceration (Hairston, 2003).

Sampson (1987) also proposes that black family disruption substantially increases the rates of black murder and robbery, especially by juveniles. He suggests that this link is a result of "structural linkages among unemployment, economic deprivation, and family disruption in urban black communities (Sampson, 1987, p. 348). While he notes that white family disruption has the same effect on white violence, it is important to recognize that because of the disproportionate rates of incarceration among poor African Americans, particularly in urban areas, it is also disproportionately poor African American urban families and youth who suffer as a result of incarceration. To the extent that having an incarcerated parent predisposes children of incarcerated parents to experiences with the criminal justice system, the family-level effects of incarceration likely perpetuate the changes in sexual partnering decisions and sexual networks that effect incarcerated parents.

Population Level Effects

The effects of incarceration on sexual networks at the population level are potentially striking. Effects on any individual inmate and his partners may be highly variable. Incarcerating a large percentage of the men from urban African American communities, however, constitutes a broader and more continuous assault on sexual networks in those communities. Because their networks are already likely to be more densely connected and segregated, incarceration has the potential to significantly change the sexual network structure for the entire community.

Incarceration directly affects the sex ratio, with the removal of large numbers of men from the community exacerbating the already uneven numbers of women and men. Skewed sex ratios have several effects. Simply changing the composition of the social networks in a given community changes the sexual network structure, given that approximately 38% of married couples and 33% of short-term partners met either at work or school, and 50% of married couples and 40% of short-term partners were introduced either by a friend or family member (Laumann, et al., 1994). Adimora and Schoenbach (2005) also argue that a skewed sex ratio makes women less able to negotiate in their relationships and more likely to overlook infidelity. On a population level this creates sexual networks in urban African American communities that are more densely connected through male partners than they would be if more men were available as partners. Both the change in the number of available partners and the ability of women to negotiate for monogamy would decrease the opportunity for marriage.

Incarceration also affects the opportunity for marriage through its effect on economic opportunity. In addition to the fact that individuals who are incarcerated often have relatively little education or job skills, incarceration has been shown to reduce hourly wages by approximately 15% compared to the wages of similar unincarcerated men (Western, 2006, p. 119). This combined with a negative effect on annual employment means that men with prison records earn 30-40% each year than similar men without a record (Western, 2006, p. 120). Western (2006) suggests that decreased wages for former inmates may be a result of the stigma of incarceration, the erosion of job skills during incarceration, and the loss of a contact network to help find work. As a result of this decreased economic opportunity, the effective sex ratio, or the number of men who

are desirable long-term partners compared to the women who are desirable long-term partners, may be even more skewed by incarceration than the actual physical ratio of men to women.

Mass incarceration may also affect definitions of masculinity and attitudes towards women and relationships in the urban African American communities that experience it. Incarceration effectively limits the ability of men to fulfill the respectability construct in Whitehead's model, forcing them into reputational forms of expressing masculinity. Amplifying the individual potential effects on attitudes to a population or community level results in a potential cultural shift toward masculinities defined by the experience of incarceration, even for individuals who have never themselves spent time in a prison or jail.

As prison limits social networks while the inmate is incarcerated, it is likely to have an effect on social and sexual networks after release as well. Men who are incarcerated may lose many of their connections to community and family as a result of the stigma and physical separation (Braman, 2004). Those links that they retain may be with other individuals who are involved in drug use or criminal activity. New social ties formed in prison are also likely to be with similar individuals. As discussed above, a limited social network subsequently limits sexual networks. Flom and colleagues (2001) found that in a group of drug-using young adults, there were substantial rates of partner sharing and concurrency. On a population or community level, this means that there will be an increasing number of connections between the relatively low risk sexual networks of unincarcerated partners and high risk networks of individuals of individuals who have

been incarcerated, and the larger the proportion of incarcerated men, the denser the connection between these two groups.

Unresolved issues

There are several qualitative studies examining the potential effects of incarceration on sexual networks, and relatively limited quantitative work that addresses the effects of incarceration on sexual networks at any level, and particularly the population level. There are substantial measurement and other methodological concerns that leave substantial gaps in the empirical literature demonstrating a relationship between incarceration and sexual decision-making and sexual network structure.

The measurement of sexual behavior in surveys that also cover involvement with the criminal justice system is a substantial problem. Largely due to limitations in the data, much of the literature focused on incarceration examines principally its effects on marriage rates and rates of divorce, as well as a small amount of work on cohabitation (Heubner, 2005; Lopoo & Western, 2005; Western, 2006). This is clearly a very limited measure of sexual decision-making and sexual networks, as it excludes any relationships outside of marriage or cohabitation. Although this literature clearly contributes to our understanding of the social effects of incarceration, it leaves a substantial gap with regard to how incarceration might shape networks of sexual partnerships.

Measurement of incarceration in those surveys which gather detailed sexual histories is often only a single question asking whether an individual has spent more than 24 hours locked up, and controls for other kinds of involvement in the criminal justice system are lacking (Adimora, et al., 2007; Khan et al., 2009; Laumann, et al., 1994). Those studies which do include detailed measures of criminal justice involvement as well

as HIV risk factors tend to be focused in particularly vulnerable populations, such as Epperson's work with individuals attending methadone maintenance clinics (Epperson, El-Bassel, Chang, & Gilbert, 2010; Epperson, El-Bassel, Gilbert, Orellana, & Chang, 2008; Epperson, Khan, El-Bassel, Wu, & Gilbert, 2011). With the exception of one of Epperson's studies (2011) with men on methadone maintenance therapy, none of the previous studies have included a longitudinal component, making causal inference more difficult.

Although several ecological studies have found statistically significant associations between incarceration and STD or HIV rates, the constant concern about the ecological fallacy is present (Johnson & Raphael, 2005; Thomas, et al., 2007). Drawing conclusions based on ecological level data is risky even in well designed and controlled studies if the data cannot be linked to individuals to show that it is the incarcerated individuals themselves who increase rates of STDs, or to demonstrate a mechanism through which they affect community-level risk for individuals who have not been incarcerated.

Though rigorous qualitative work has documented changes in sexual decision-making and partnership decisions as a result of incarceration, and some quantitative work suggests an effect both at the individual and community level, the measurement issues necessitate more extensive data collection and further quantitative work to explore the issue.

Implications for reduction or elimination of HIV/AIDS in urban African Americans

An analysis of the effects of incarceration on sexual networks and as such on HIV risk in urban African American communities suggests that without addressing

incarceration, it is impossible to adequately address HIV risk. In order to eliminate the damaging effects of incarceration on urban African American sexual networks, we must stop incarcerating men from those communities at such high rates through sentencing reform, drug courts, and reinvestment in urban areas. This would help to restore the actual sex ratios in urban communities as well improve the economic outlook for these men, increasing the effective sex ratio. Additionally, although institutional culture is difficult to change, fundamentally altering prisons to reduce violence and disconnection from family would improve both population and individual level outcomes. Removing the barriers to visitation by family members and sexual relationships with partners is likely to not only reduce disruption to family structures, but also help inmates to reintegrate more easily after release from prison.

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Chapter II

Incarceration and HIV: Examining the relationship between incarceration and sexual risk

Research Problem and Significance

The United States has one of the highest rates of incarceration in the world (Mauer & The Sentencing, 1999). In addition, incarceration in the US is disproportionately experienced by young urban African American men, most often poor men with little education (Western, 2006). The Bureau of Justice Statistics reports that the imprisonment rate in 2009 for black non-Hispanic males (3,119 per 100,000 U.S. residents) was more than 6 times higher than for white non-Hispanic males (487 per 100,000), and almost 3 times higher than for Hispanic males (1,193 per 100,000) (West, Sabol, & Greenman, 2010). As large numbers of poor urban African American men are incarcerated, it is critical to consider what unintended side effects may arise from this phenomenon, termed "mass incarceration" by Marc Mauer and Mada Chesney-Lind (2002) and "hyperincarceration" by Loïc Waquant (2008). One domain likely to be effected by high rates of incarceration is both the nature and structure of romantic and sexual relationships, with potential implications for HIV and other STD transmission.

In 2006, one in seven Americans living with HIV infection was among the 9.1 million passing through the correctional system in that year, a decrease from 1997, when recently released inmates accounted for approximately one in five of all HIV-infected Americans (Spaulding et al., 2009). For black and Hispanic males, however, the figure

remains high, with one in five HIV-infected persons incarcerated during 2006 (Spaulding, et al., 2009). The high prevalence of HIV/AIDS in the criminal justice system, particularly among black and Hispanic men, reflects that those individuals at highest risk for incarceration are also those at highest risk for HIV. Figures based on 2006 CDC surveillance data show that 45% percent of new infections in that year were among black individuals (Hall, Song, & Rhodes, 2008). In addition, poor communities represent a disproportionate number of AIDS cases (Karon, Fleming, Steketee, & De Cock, 2001). Although the co-occurrence of HIV and incarceration in poor urban African American communities does not, in itself, indicate a causal relationship, it suggests a need to investigate how high rates of incarceration might contribute to the disparities in HIV infection.

On an ecological level several studies have shown associations between rates of incarceration and rates of STDs or HIV. Johnson and Raphael compare lagged state-wide incarceration rates with state-wide reports of AIDS diagnoses and show a statistically significant relationship (Johnson & Raphael, 2005). On a smaller ecological scale, Thomas et al (2007) use census tract data to compare rates of incarceration with rates of gonorrhea in urban North Carolina, and also find a significant relationship.

At an individual level, significant associations between incarceration and certain types of sexual decision-making have also been shown, although incarceration has not been directly linked to HIV-status. In one of the earliest studies Laumann, Gagnon, Michael, & Michaels (1994) show that individuals who have spent any time in a jail report a statistically significantly larger number of partners than individuals who have never been incarcerated (26.4% versus 18.1% - report having had 11+ partners since age

18). Other more recent studies support the conclusion that criminal justice involvement generally, and incarceration in particular, is associated with having an increased number of partners (Adimora, Schoenbach, & Doherty, 2007; Epperson, El-Bassel, Gilbert, Orellana, & Chang, 2008; Khan et al., 2009; Laumann, et al., 1994; Seal et al., 2007). Epperson and colleagues (2011) also found that, among individuals on methadone maintenance therapy, incarceration of a female partner predicted increased rates of multiple partnerships over the previous six months although there was no direct association between the respondent's incarceration and the likelihood of multiple partnerships. Seal et al (2007) note that the effects of incarceration on number of partners vary with the consistency of social relationships the former inmate is able to maintain after release.

In addition to increases in the absolute number of partners, increased riskiness of partnerships has also been shown to be associated with incarceration. Multiple studies among men in methadone maintenance have shown that incarceration is associated with increased rates of unsafe sex, as well as concurrent partnerships (Epperson, El-Bassel, Chang, & Gilbert, 2010; Epperson, et al., 2008; Epperson, et al., 2011). Khan et al (2009) also find that incarceration is associated with multiple and concurrent partnerships, as well as unprotected sex among a nationally representative sample of men in the US. Adimora and colleagues (2007) find that men who have been incarcerated for more than 24 hours within the past 12 months have 2.10 times the odds of having concurrent partners, but that this drops to 1.08 times the odds for men who were incarcerated more than a year ago. Work by Khan and colleagues (2008) adds an

additional layer of temporal complexity, suggesting that high risk partnerships are associated with short-term, but not long term incarceration.

There have also been rigorous and thought-provoking qualitative analyses of the experiences of individuals coming out of prison and jail reported in the literature, illustrating the disruptive effect of incarceration on relationships and even the potential for recently incarcerated men to seek out new multiple new partners to make up for lost time (Braman, 2004; Thomas, et al., 2007). Luke Bergman's (2008) ethnographic work with young people in Detroit also shows the instability of families and relationships due in part to incarceration. The fact that similar themes emerge from qualitative data from populations as unique as Washington, DC, North Carolina, and Detroit, MI suggests a possible broader level of generalizability, and in part motivates the quantitative study proposed here.

Taken together, these studies suggest that above and beyond the clear relationship between risky sexual behavior and involvement in the criminal justice system, incarceration affects sexual risk. Whether due to disruption of existing partnerships, compensation for enforced periods of celibacy, or some other mechanism, incarceration is associated with higher rates of sexual partnership, including concurrent partnerships, and also with unsafe sex. Studies showing significant effects of a partner's incarceration also emphasize the interconnected and contextual nature of sexual decision-making, and indicate that the effects of incarceration go beyond the individual.

Despite the preponderance of these findings, several substantial gaps remain. Many studies that do directly measure incarceration and HIV risk factors such as number of partners and rates of concurrency or rates of STDs suffer from measurement and data

limitations. Alhough several ecological studies have found statistically significant associations between incarceration and STD or HIV rates, the constant concern about the ecological fallacy is present (Johnson & Raphael, 2005; Thomas, et al., 2007). Drawing conclusions based on ecological level data is risky even in well designed and controlled studies if the data cannot be linked to individuals to show that it is the incarcerated individuals themselves who increase rates of STDs, or to demonstrate a mechanism through which they affect community-level risk for individuals who have not been incarcerated.

At the individual level, lack of data is a substantial problem as few studies measure both incarceration-related variables and sex-related variables outside of specific, high-risk populations, such as injection drug users. Measurement of incarceration is often only a single question asking whether an individual has spent more than 24 hours locked up, and controls for other kinds of involvement in the criminal justice system are lacking (Adimora, et al., 2007; Khan, et al., 2009; Laumann, et al., 1994). Those studies which do include detailed measures of criminal justice involvement as well as HIV risk factors are focused in particularly vulnerable groups, such as Epperson's work with individuals attending methadone maintenance clinics. With the exception of one of Epperson's studies (2011) with men on methadone maintenance therapy, none of the previous studies have included a longitudinal component, making causal inference more difficult.

The proposed study advances the literature in several ways. First, it uses individual level data to draw conclusions about populations, rather than ecological data. In addition, the data allows for much more comprehensive controls for engagement in

criminal activity, increasing confidence that the results represent an actual effect of incarceration, rather than a spurious association reflecting other unmeasured variables. Finally, the opportunity to compare individuals at earlier points in time (prior to adult incarceration) provides an additional opportunity to check for confounding relationships.

In this paper I test relationships described in a conceptual model linking high community rates of male incarceration to changes in sexual decision-making and sexual network structure, shown graphically in Figure 2.1. The model tested here is a greatly reduced model from the full model described in the introduction. As shown below, a series of factors contribute to incarceration of young men, which then affects the community gender norms, economic and marriage opportunities, sex ratios, and social networks. Many of the risk factors for incarceration independently shape sexual decision-making and sexual networks, and through many of the same mediators. Through each of these mechanisms, an individual's number of partners and whether they have concurrent partners are determined both by individual decisions, and the context in which those decisions are made.

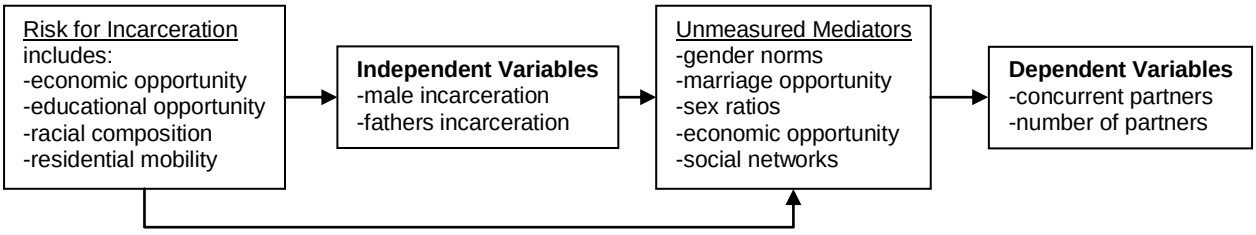

Figure 2.1. Reduced conceptual model describing the relationship between incarceration and sexual decision-making/sexual network structure.

Ultimately, high rates of incarceration may contribute to community level changes in sexual networks, and concomitant changes in community and individual HIV risk. The outcomes of interest emphasized then are at the population level - changes in

community networks of sexual partnerships must be evaluated in order to understand the impact of incarcerating large numbers of individuals from a single community. However, a critical first step is documenting some type of change in individual sexual-decision making or sexual partnership behavior as a result of incarceration. Even small changes in the behavior of large numbers of individuals are likely to affect network dynamics. An individual level analysis of the effects of incarceration on sexual decision-making and sexual partnership patterns would establish a basis for community- or population-level effects as well as motivate additional data collection. This study addresses how adult incarceration and high levels of community incarceration affect individual young adults' sexual partnering decisions.

Research Objectives

1. To examine the effect of male adult incarceration on number of partners and rates of concurrency among young adults.
2. To determine whether there is an effect of race on the relationship between incarceration and number of partners.
3. To evaluate whether young men who were later incarcerated had different numbers of sexual partners and rates of concurrency compared to those who were not, at a time point prior to adult incarceration.

Research Hypotheses

1. Individuals who have been incarcerated will have more partners, and more concurrent partners than individuals who have never been incarcerated, even after controlling for factors known to affect sexual network structure and factors that might be confounded with incarceration and sexual network structure.

2. There will be a significant interaction between race and incarceration after controlling for potential confounders.
3. After controlling for involvement in criminal activity, there will not be significant differences in the number of partners or concurrent partners between individuals who will later be incarcerated and those who will not.

Data

The National Longitudinal Study of Adolescent Health was developed in response to a mandate from the U.S. Congress to fund a study of adolescent health (Harris & Udry, 2008). A basic description of the survey is presented here, and more extensive details about the design and data collection are available in the survey documentation (Harris & Udry, 2008). Waves I and II focus on the forces that may influence adolescents' health and risk behaviors, including personal traits, families, friendships, romantic relationships, peer groups, schools, neighborhoods, and communities. Wave III was conducted when respondents were between 18 and 26 years old and focuses on how adolescent experiences and behaviors are related to decisions, behavior, and health outcomes in the transition to adulthood.

Add Health offers the opportunity to look at the development of young adult sexual networks over time, and examine the effect of adult incarceration on those networks. Preliminary cross-sectional analyses of the public use subset of Wave III suggested an effect of incarceration on sexual network variables, with adult incarceration being a significant predictor of number of lifetime partners. A refinement of this cross-sectional analysis is necessary, however, as well as an examination of these young adults

at earlier time points, in order to fully understand the relationship between incarceration and sexual decision-making.

Sampling Design: Add Health is a school-based longitudinal study of a nationally-representative sample of adolescents who were in grades 7-12 in the United States in 1994-95 (Harris & Udry, 2008). The sampling frame for the first stage of the first wave of the study was a stratified, random sample of all high schools in the United States. A school was eligible for the sample if it included an 11th grade and had a minimum enrollment of 30 students. A school that sent graduates to the high school and that included a seventh grade (a feeder school) was also recruited from the community of the selected high school. In the second stage of sampling, an in-home sample of 27,000 adolescents was drawn from the chosen communities, which included both a core sample and several oversamples. Oversamples included special samples based on ethnicity (Black, Chinese, Cuban, and Puerto Rican), saturation (to enable collection of full social network data from 16 schools), disability, and genetics (including identical twins, fraternal twins, full-sibling, half-siblings, and also non-related pairs, such as step-siblings, foster children, and adopted (non-related) siblings) (UNC Carolina Population Center).

Sample Sizes and Response Rates: For Wave I, 20,745 adolescents were interviewed for the in-home interviews (separate from the in school administration, which is not used in this study and will not be discussed further). Wave II data collection includes follow-up in-home interviews with adolescents and follow-up school administrator interviews conducted in 1996. 16,706 of the Wave I respondents were selected to be re-interviewed at Wave II when they were in grades 8-12. In general,

respondents who were seniors in high school at Wave I and were not part of a genetic pair (twin) and the disabled sample were not selected to be interviewed at Wave II. Wave III consists of all Wave I respondents who could be located and re-interviewed during the 2001-2002 field work period when they were 18-26. Interviews with 15,170 Wave I respondents were completed. Individuals who were out of the country were omitted, but an effort was made to interview individuals who were incarcerated. The response rate for Wave I is 78.9%. The response rate for Wave II is 88.2%. The response rate for Wave III is 77.4% (Harris & Udry, 2008).

Survey Content: Add Health is one of the few data sets which contain information about involvement with the criminal justice system as well as detailed information on sexual relationships. Sexual network information collected includes number of lifetime partners as well as in the last 12 months, and respondents placed these relationships on a calendar that allows for calculation of concurrency. There are additional questions about whether the individual's partners were reported to have concurrent partners as well. Incarceration data includes whether the respondent was ever incarcerated as an adult as well as the type of crime committed and whether the individual was sentenced to a jail or to a prison.

The full, restricted-access data set was used for analysis, with most analyses conducted using a subset of male respondents. In Wave III, 31% (n = 1488) of male respondents report having ever been stopped by police. Only 9.3% of the male sample (n=423) report having been convicted in an adult court (some may have been juveniles when convicted, explaining a discrepancy in rates of arrest since age 18 and conviction in adult court), and detailed information on the charges is available in the data set.

Relatively few male respondents had been in jail or prison (1.5%, n=79). Additional information about involvement in criminal activity (including arrest history) and father's history of incarceration are also available. Though these rates of incarceration are low, there are sufficient numbers of previously incarcerated individuals to allow for statistical analysis.

Power Analysis

All power analysis calculations were executed using SAS 9.2 power calculation procedure for multiple regression (SAS Institute Inc, 2009)**.** Two different types of power calculations were performed: first, for comparing number of partners across time and subgroups and second, for fitting regression models using different subsamples.

To calculate the differences in mean number of partners (either lifetime, last 12 months) detectable with my analysis, I use the standard deviation of the variable, the smallest sample size used on the analysis (N=423, where 79 individuals have been incarcerated, and the remaining 344 have been convicted in an adult court but not incarcerated), and a conventional power level of 0.8. The results of this power calculation are presented below in Table 2.1.

Measure	Upper and Lower Bounds	Mean Diff	Standard Deviation	Test	Power
Partners in the past 12 months	(0, 22)	1.01	2.90	Difference	0.8
	(0, 22)	0.88	2.90	Add. Equivalence	0.8
Lifetime partners	(0, 50)	3.77	10.76	Difference	0.8
	(0, 50)	3.28	10.76	Add. Equivalence	0.8

Table 2.1. Power calculations to detect differences in mean number of partners, and to test for equivalence in mean number of partners.

There is no consensus on how many sexual partners an individual needs to have to increase his/her risk for HIV, and it is difficult to generalize across studies with very different populations. In two studies, one focusing on women in Nairobi and another on

men who have sex with men in the US, increase of 1-2 partners in the last year has been shown to increase the odds of HIV infection by 1.5-2 times (Hunter, Maggwa, Mati, Tukei, & Mbugua, 1994; Koblin et al., 2006). Looking at non-HIV STDs among individuals in the US, individuals with 2 or more partners, compared to only 1 partner, have 1.5-3.5 times the odds of infection, and each concurrent partner increases the odds of infection by 3.2 times (Doherty, Padian, Marlow, & Aral, 2005; Potterat, Rothenberg, & Muth, 1999). Based on these data, it seems that a mean increase of only a single partner is significant in the context of STD transmission, and is likely to be significant for HIV transmission, particularly if it represents a community-level increase. The analysis is powered to detect these differences in partners in the past 12 months, but only has sufficient power to detect slightly larger differences in lifetime partners. Using a larger subsample of the population would likely address this, and as is detailed subsequently, the regression analysis are sufficiently powered to draw conclusions about lifetime partnerships.

The power calculation for model fitting was estimated using a model with 20 predictors and a total R^2 of 0.1, representing a quite low (and relatively realistic for social science research) proportion of the variance that will be explained by all of the predictors in the model. A difference in R^2 for the single predictor being tested was set to 0.01, with a significance level of 0.05.

Using a subsample of those likely at highest risk for incarceration, those young adults who have been convicted in an adult court (N = 423), the sample size is only sufficient to be 58% certain that a statistically significant effect will be detected, which is

below the conventional power threshold of 80%. Using the subsample of male respondents (N = 5005), however, the power is 99%, well above the threshhold.

Measures

Dependent Variables: The following measures of sexual network structure will be used in this study:

Number of partners: In the Wave III data the numbers of partners for each respondent are measured with questions asking about the total number of lifetime partners, and also the number of partners in the last 12 months. Respondents who reported never having had sex were coded as having zero partners. In the Wave II data, only the total number of lifetime partners is available.

Concurrency: Respondents were asked about their relationships over the preceding 18 months and asked to report the month and year of first and last time they had sex within each relationship (Ford, Sohn, & Lepkowski, 2002). Dates were recorded using a calendar format to improve recall. Individuals were considered to have concurrent partners if the dates of two or more relationships overlapped, including sexual encounters reported in the same month. The first measure of concurrency is a dichotomous indicator of concurrency based on overlap of reported sexual relationships. As part of the survey, respondents were also asked to indicate whether each of their listed partners had had other partners at the same time. Any reported partners' concurrent relationships was coded as one and no reported partners' concurrent relationships as zero. Though this measure is once removed from the individuals who responded, using all of the available concurrency data makes it more likely that the true nature of the effect of incarceration on sexual networks will be clear in the analysis. In Wave II, only the direct

calculation of concurrency is available, as respondents were not asked about their partners' concurrency.

Independent Variables: The first independent variables of interest in this study relate to adult incarceration, either incarceration history (in the Wave III analysis) or future incarceration (for the analysis of Wave II), not including involvement in the juvenile justice system.

Incarceration History: This was measured with a single question asking whether the respondent, as a result of any arrests after the age of 18, was sentenced to probation, jail, or prison. This response will be reduced to a never/ever indicator variable indicating whether the individual responded yes to either jail or prison.

Future Incarceration: The same indicator of incarceration described above in the Wave III data will be merged with the Wave II data and used as an indicator of incarceration at a future time point.

In order to adequately capture the relationship between incarceration history and sexual network structure, other factors that affect sexual network structure need to be addressed, including demographic variables and other measures of involvement in the criminal justice system. These will be used as controls in the statistical models, and are also likely to help create a richer picture of sexual decision-making among young adults.

Father's Incarceration: A dichotomous variable will be created indicating whether the respondent's biological father had ever been incarcerated. Examining the effect of the incarceration of a family member may take into account the potential effects of high rates of neighborhood incarceration on sexual networks. Because incarceration is

highly concentrated in urban African American communities, most incarcerated fathers will be from this population and their children are likely to live in these areas.

This individual measure of a family experience is only a weak proxy measure of community rates of incarceration; it is likely to miss many individuals who live in areas with high rates of incarceration, and also to include a small number of individuals who live in areas without substantial rates of incarceration, but who have had a parent incarcerated. Other measures considered, such as urbanicity, have similar problems. This is a limitation in the data set, and of the study to address the community context, but results using this variable may help to understand how family and community experiences of incarceration shape sexual behavior later in life. These results should be interpreted cautiously, and likely only as justification for further data collection and investigation. This variable is not available in Wave II.

Criminal Activity: It is possible that any observed effects of incarceration might actually be a result of involvement in criminal activity rather than incarceration itself. It is possible that individuals with a higher tolerance for risk self-select into criminal activity, or that being involved with other individuals engaging in criminal activity is the actual cause of changes in sexual behavior, rather than incarceration or explicit involvement in the criminal justice system. Limiting the analysis to those who have been convicted in an adult court would likely eliminate most of this potential bias. When using a larger subsample, a dichotomous indicator of arrest since the age of 18 or conviction in an adult court will be used as a measure of criminal activity.

Several other measures of criminal activity may also be used in building the statistical models described below. Potential indicators include: ever having been

stopped by the police or being convicted in an adult court. Each of these measures will be tested separately in the models, as the likely show substantial multicollinearity. Whichever measure is explains the greatest amount of variance in sexual decision making will ultimately be retained in the model, as this will provide the most stringent test for the effect of incarceration.

In Wave II, a delinquency scale measuring how often respondents had engaged in a variety of activities ranging from relatively mild acts of delinquency (lie to your parents or guardians about where you had been or whom you were with, take something from a store without paying for it, act loud, rowdy, or unruly in a public place,) to more serious behaviors (paint graffiti or signs on someone else's property or in a public place, deliberately damage property that didn't belong to you, run away from home, drive a car without its owner's permission, steal something worth more than $50, go into a house or building to steal something, use or threaten to use a weapon to get something from someone, sell marijuana or other drugs, steal something worth less than $50, take part in a fight where a group of your friends was against another group) and whether they had been initiated into a named gang. These were dichotomized into never or ever categories and a scale was created by tallying how many each respondent had engaged in, and then dividing respondents into quintiles of delinquent behaviors.

Age: The young adults in our sample are likely to have had a wide variety of sexual experiences, and much of this diversity is likely explained by age. Eighteen year olds just leaving home are likely to have had different experiences from twenty-six year olds who have been independent much longer. Age is coded in years and will be used as continuous predictor.

Sex: The number of partners an individual reports is affected by sex (Laumann, et al., 1994). An indicator variable for female sex was used to control for this effect when the full sample was analyzed.

Race: An individual's sexual network has been also shown to vary in predictable ways with race (Laumann, et al., 1994). Respondents in Add Health were asked to mark all racial categories that applied to them. Unique dummy variables were constructed to reflect those categories with which respondents most closely identify. Though some respondents do not fit neatly into single racial categories, this measure allows for improved comparability with earlier studies.

Hispanic ethnicity: Hispanic identified individuals have been shown to have smaller numbers of partners, but higher rates of concurrency (at least among men) compared to non-Hispanic individuals (Adimora, et al., 2007; Laumann, et al., 1994). Though Add Health included more specific questions about country of origin, a single indicator variable of Hispanic ethnicity will be used as the control variable.

Education: Education has been shown to be related both to sexual network structure and incarceration (Western, 2006). A single continuous variable indicating the number of years of education completed will be used to control for the effects of education (e.g. 12 indicates completion of high school). In Wave II, this question was phrased as the current grade level, as none of the respondents had yet graduated from high school.

Statistical Analysis

Statistical Methodology: In order to capture the richness of the complex sample and the longitudinal data, the analysis plan consists of descriptive analysis, testing of mean differences, and a sequence of multiple regression models.

The first set of difference tests and regression models will use the Wave III of the survey, in which all of the respondents are adults. This will evaluate the effects of incarceration on sexual network variables controlling for factors that have been shown to affect both risk of incarceration and determinants of sexual decision-making and sexual network structure (Hypothesis 1), and also test for a differential effect of incarceration by race (Hypothesis 2). The second set of models will use Wave II of the survey, and compare individuals who will later report incarceration and those who will not, using the same controls but from the previous time point. This supporting analysis will address the question of whether those individuals who are incarcerated between Waves II and III or during Wave III differ from those who have never been incarcerated in terms of sexual decision-making at earlier points in time (Hypothesis 3). All of these analyses will be weighted and adjusted appropriately for the stratification and clustering in the survey design.

Most of the previously incarcerated individuals in our data set are men, consistent with incarceration patterns in this country (West, 2010). In order to avoid comparing mostly male former inmates to both men and women who have not been incarcerated it is necessary to limit the analysis to only men.

Subset Analyses: Repeating the analyses outlined below among further subsets of individuals who have been convicted in an adult court, but not necessarily incarcerated, will allow for a more complete determination of the importance of incarceration, as well

as the control variables, among a population who are at higher risk for incarceration, increasing the robustness of the findings.

Descriptive Analysis: Descriptive analyses of all of the variables of interest were conducted before constructing fuller models. Important descriptive analyses included: calculating frequencies of incarceration in the full data set, examining distributions of numbers of sexual partners to determine whether Poisson or negative binomial regression is most appropriate, as well as whether a zero- or one- inflated distribution might most accurately model the distribution of the number of partners.

Testing of Mean Differences: After generating descriptive statistics for each of the variables of interests, the mean number of partners and rates of concurrency were compared. Incarcerated and unincarcerated men will be compared to address the first research hypothesis, and then to-be-incarcerated and never-incarcerated men at the earlier time point will be compared to address the third research hypothesis. For the first test, the null hypothesis is that the means are the same, with a significant result giving evidence of a difference. For the second test, the null hypothesis is that the means are different, with a significant result giving evidence of equivalence.

Multivariable Analysis: The measures of network variables described in earlier will be used as dependent variables. To model the dichotomous variables of whether or not an individual reports having concurrent partners and whether or not the respondent has concurrent partners, a logistic regression model will be used. The number of sexual partners, both over the entire lifetime and in the last 12 months, as well as variables constructed for rates of concurrency or numbers of concurrent partnerships, will be

modeled using a Poisson or negative binomial regression which is appropriate for count data.

The multivariable analysis will be conducted using a step by step procedure, adding one set of variables at a time (e.g. demographic variables or criminal justice involvement variables) and examining the fit of the model using the overall F test and also the individual significance tests for the parameters. Interaction terms will be tested where theoretically appropriate, and retained only if they are statistically significant.

Statistical analyses will be conducted using Stata/SE 11.0 and will adjusted for the sample design using the stratum and cluster codes, as well as non-response and post-stratification by age, race and gender (StataCorp, 2009). The Wave III post-stratification grand sample cross-sectional weight will be used for the analysis, as recommended in the survey documentation.

Propensity Score-Based Analysis: In addition to statistically controlling for factors associated with incarceration, a propensity score for incarceration was constructed as another approach to a more precise estimate of the unique effect of incarceration. Variables used in the construction of the propensity score were: sex, race, age, education level, income, arrest history, and reports of delinquent behaviors in the past 12 months (deliberately damaging property belonging to someone else, stealing something worth more than $50, selling marijuana or other drugs, carrying a handgun and school or work, and belonging to a named gang). The propensity score was used in two different ways: to match formerly incarcerated respondents with never incarcerated respondents with similar likelihoods of incarceration, and as an independent variable in regression models. The average treatment effect is estimated by comparing individuals who have

experienced incarceration with those most similar to them who have not experienced incarceration, with similarity measured by the propensity score. The average treatment effect of incarceration on each of the sexual behavior variables was done first using a stratified approach: the effect was estimated by weighting estimated differences between previously incarcerated and never incarcerated individuals in each strata of incarceration propensity. Second, a propensity score matching algorithm that paired "treated" (previously incarcerated) respondents with "controls" (never incarcerated) closest to them in propensity score was used, and the treatment and control groups were compared. This particular algorithm used a random draw to determine whether the nearest propensity score neighbor match was chosen above or below the respondents propensity score. When average treatment effects were calculated analysis was limited to the region of common support, defined as the range of propensity scores which contained both incarcerated and unincarcerated respondents. These analyses were conducted with the full sample, using the propensity score stratification or matching to adjust for potential confounding factors.

Wave II Analysis: Due to differences in data collection between waves, the analysis of sexual behavior at Wave II is somewhat more limited, with only a single measure of number of partners (partners over the lifetime) and of concurrency (calculated concurrency based on reported dates of sexual relationships).

Results

Descriptive Statistics: Demographic descriptive statistics are shown in Table 2.2 for the full population-based sample as well as for analytic subsets of respondents. The full Add Health Wave III population is roughly half male and half female, with a majority

of white respondents (16.4% Black, 2.6% Native American, and 4.3% Asian). Twelve percent of respondents report Hispanic ethnicity and most made less than $23,000 in 2000/2001, with only 15% earning more, and 23% falling into the lowest quintile of income ($0-$1999) for that year. The mean age of respondents in Wave III is 21 years, and the average participant had completed 1 year of post-secondary education. When the sample is limited to only male respondents most of the demographic indicators remain the same, though the male respondents are slightly overrepresented in the higher categories of income compared to the full sample. Further limiting the sample to male respondents who have been convicted in an adult court slightly increases the proportion of Black respondents and Native Americans compared to White and Asian respondents in the male subset. There are also more Hispanic respondents in the convicted subsample compared to the male subset. Respondents in the convicted subsample are the same age as other respondents, though they have slightly less education and more of them are in the highest quintiles of income.

Although no analyses are conducted within the previously incarcerated group of respondents, the descriptive statistics for this group will aid in the interpretation of all of the results. It is notable that in the entire data set only seven women report having been incarcerated, compared to 79 male respondents. For this reason, only male respondents are included in the remainder of the analyses. Of those males who have been incarcerated, 21% are Black and 12% are Native American, illustrating that these groups are highly overrepresented in correctional facilities compared to their representation in the larger population (16% and 3% respectively). In addition 27% report Hispanic ethnicity, which is more than double the proportion in the full nationally representative

sample. In terms of income, those who have been incarcerated are overrepresented in the bottom quintiles of income with 34% earning less than $2000 in the year that data was collected. Though respondents who have been incarcerated are the same age as those who have not (both have a mean just under 22 years of age), those who have been incarcerated have on average achieved only 11.2 years of education, compared to the average of nearly 13 completed by the population as a whole.

Further descriptive statistics describe only the male and convicted subsets, as these are the populations that will be used for further analysis. Involvement with the criminal justice system at a superficial level (being stopped by the police) is relatively common, with roughly a third of male respondents reporting having ever been stopped, though only 9% report having been convicted in an adult court, 5% arrested as adults, and only 1.5% have been incarcerated in an adult facility. These figures are shown in Table 2.3. Of the subset that have been convicted in an adult court, already selected as a highly criminally involved group, only one respondent had NOT been stopped by the police, roughly one third had been arrested as an adult, and nearly 17% had been incarcerated in an adult facility. Experiencing a father's incarceration showed the same trends, with 13% of the male subset reporting that their biological father had been incarcerated compared to more than twice that (28%) among the convicted subset.

Sexual experiences varied widely across the male and convicted subsamples, and descriptive statistics are shown in Table 2.4. The majority of respondents were sexually experienced (85% of the male subset and 97% of the convicted subset). The average number of lifetime partners for the male subsample was 6.2, with those respondents having on average 1.8 partners in the past year. Approximately 24% of male respondents

had concurrent partners, and 27% reported that their partners had other partners at the same time. Among the convicted subset, the average number of lifetime partners was substantially higher (11.6) and they reported having had 2.6 partners in the past year. Just over one third had partnerships that overlapped in time, and over 40% reported that their partners had concurrent partners.

Differences in Means: Examination of differences in means is the first step in comparing the sexual behavior of men who have been incarcerated with men who have not. These differences are not adjusted for any potential confounding variables, but point to potentially significant differences between the two populations. Comparing differences in means and proportions (means of dichotomous variables) shows that there are relatively few significant differences between the groups when the statistics are not adjusted for demographic variables.

The differences are shown in Table 2.5 with the significance values derived from their associated t-tests. Differences in the total number of partners and the proportion of partners with concurrent partners are significant within the male subset. There was a non-significant difference in the number of partners in the past 12 months in the same direction as lifetime partners. While none of the differences are significant within the convicted subset, the differences for total number of partners, partners in the last 12 months, and proportion of partners with concurrent partners are all in the same direction as for the full population. The difference in the proportion with concurrent partners is not significant in either subset. These results demonstrate a relationship between incarceration and sexual behavior, both of those individuals who are incarcerated and their partners, and suggest that the effect of incarceration on rates of concurrent

partnerships may be primarily through the partners of incarcerated men, rather than due to the behavior of the men themselves.

Bivariate Relationships: Looking at bivariate relationships clarifies which variables may be important determinants of sexual behavior and as such may confound the relationship between sexual behavior and incarceration. These relationships are shown in Table 2.6. Within the male subset, variables significantly associated with larger numbers of lifetime partners were: Black race, experiencing a police stop, arrest as an adult, conviction in an adult court, incarceration, the biological father serving time, being in the highest two quintiles of income, and older age. Only Asian race and increases in education were associated with fewer numbers of partners. Within the convicted subset, only *having been incarcerated* and increasing age were associated with higher numbers of lifetime partners. Increasing years of education were also significantly associated with very slightly smaller numbers of partners (OR=.99).

There were fewer significant relationships between the number of partners in the past 12 months and demographic and criminal justice involvement variables. Within the male subset Black race, being in the highest two quintiles of income, and having been stopped by the police, arrested as an adult, or convicted in an adult court predicted increased numbers of partners over the past twelve months. Only education predicted slight decreases in numbers of partners per additional year of education. Within the convicted subset only ever being stopped by the police was a significant predictor, but predicted a smaller number of partners relative to those who had never been stopped. As in the male subset, an additional year of education predicted a slight decrease in the number of partners in the past year.

The relationship between concurrency, demographic measures and criminal justice involvement is complicated. For the dichotomous measure of respondent concurrency derived from calendar date reports of partnerships Black race, and experiencing a police stop or conviction in an adult court both significantly predicted increased odds of having concurrent partnerships. The following variables all increased the odds of having a partner with concurrent partners: experiencing a police stop, adult arrest, conviction in an adult court, incarceration, or the biological father serving time. Identifying with Hispanic ethnicity decreased the odds of reporting a partner with concurrent partners. Neither measure was associated with any of the independent variables in the convicted subset.

These bivariate relationships alone are not particularly informative, as only a cursory examination of the many significant factors motivates a more substantial look at how all of these variables act, not in isolation, but in the context of the other variables in determining sexual behavior. Nonetheless, they reinforce the need to include both demographic variables and indicators of involvement with the criminal justice system in the next set of models, multivariate models that adjust the estimate of the effect of incarceration on sexual behavior using potential confounding variables.

Multivariate Relationships: The first set of multivariate models examines the effect of incarceration on the total number of lifetime partners. The Model 1 includes only incarceration as a predictor of the number of partners, and shows that within the male subset of respondents, without any control variables, those individuals who have been incarcerated have 2.56 times more partners over the lifetime than individuals who have not been incarcerated. This incidence rate ratio decreases slightly (to 2.46) when

demographic variables are controlled for, and finally to 1.63 when history of conviction in an adult court and biological father's incarceration are also included in the model, though the association remains significant. This means that over the lifetime, individuals who have been incarcerated have 63% more partners than those who have not been incarcerated. Significant demographic predictors of number of lifetime partners in this subset include Black race (IRR = 1.63, p = 0.00), Asian race (IRR = 0.54, p = 0.00), age (IRR = 1.12, p = 0.00), years of education completed (IRR = 0.98, p = 0.01), and being in either of the top two quintiles of income (IRR = 1.27, p = 0.01 and IRR = 1.38, p = 0.00 respectively). Both history of adult arrest and history of conviction in an adult court predicted increased rates of partnership over the lifetime, though due to collinearity both could not be included in the same model. Conviction in an adult court reduced the effect of incarceration on partnership most substantially, so this indicator of criminal justice involvement was retained in the final model. These models are shown in Table 2.7.

Among respondents who had been convicted in an adult court, incarceration was also a significant predictor of increased rates of partnership over the lifetime, with a final adjusted incidence rate ratio of 1.93 (p = 0.01), meaning that within this group, the estimate of the effect of incarceration is actually higher than in the full population, with men who had been convicted in an adult court and incarcerated having 93% more partners over the lifetime than men who had been convicted in an adult court, but were not incarcerated. These models are also shown in Table 2.7. Within this subset of men who had been convicted (only some of whom had been incarcerate), age was also a predictor of increased rates of partnership (IRR = 1.32, p = 0.00), as was being in the

second quintile of income (IRR = 1.51, p = 0.08). Incarceration of the biological father was also a nearly significant predictor, with an incidence rate ratio of 1.19 (p = 0.07).

Although there was a significant bivariate relationship between incarceration and the number of partners in the past 12 months, this association was completely attenuated by controlling for demographic and criminal justice involvement variables, as shown in Table 2.8. Significant predictors of increased rates of partnership among the male subset included Black race (IRR = 1.58), being in the highest two quintiles of income (IRR = 1.21 and IRR = 1.22 respectively), and experiencing either adult arrest or conviction in an adult court (IRR = 1.42 and IRR = 1.43 respectively). Asian race was the only significant predictor of decreased rates of partnership in the past 12 months (IRR = 0.65, p = 0.01). This negative relationship was also the only significant relationship within the convicted subset.

Using the direct measure of concurrency (calculated using reported sexual relationship dates), incarceration was not significantly associated with concurrency in either the male or convicted subsets, as shown in Figure 8. Within the male subset Black race and history of conviction in an adult court were the only significant predictors of concurrency, with the odds of having at least one concurrent partner increasing by 1.67 and 1.90 times respectively. Experiencing the incarceration of the biological father decreased the odds of concurrency by 33%. Among convicted male respondents there were no significant predictors of concurrency.

Incarceration was associated with reporting that one's partners had concurrent partners (concurrency once removed) in the male subset with respondents who had been incarcerated having 2.69 times the odds of reporting partners with concurrent partners

compared to respondents who had never been incarcerated, even when controlling for demographic variables. However, inclusion of the variable indicating history of conviction in an adult court caused this association to lose significance. Both having a history of adult arrest and a history of conviction in an adult court were associated with increased odds of having partners with concurrent partners, as was experiencing the incarceration of the biological father. Among the convicted subset there were no significant predictors of reporting partners with concurrent partners. These results are shown in Table 2.10.

These multivariate models are highly suggestive of a significant effect of incarceration on sexual behavior, and particularly on rates of lifetime partnership. They represent, however, only one potential method for controlling for potential confounders. In order to increase confidence in the significance and magnitude of these effects, another approach is necessary.

Propensity Score Analysis: Propensity score analyses allow for the control of confounding variables in two different ways: first, individuals can be matched based on the likelihood that that will be incarcerated, and within levels of likelihood, those individuals who have been incarcerated can be compared to those who have not; second, the propensity score can be used as a summary measure of the likelihood of incarceration to control for confounding variables in regression analyses. Using the first approach, matching individuals by propensity score suggested that on average, individuals who had been incarcerated had between 4 and 5 more partners over the lifetime compared to individuals who had never been incarcerated, as shown in Table 2.11. The stratified average treatment effect was 4.34 and nearest neighbor propensity score matching

resulted in an average treatment effect of 4.76. The estimated differences of numbers of partners in the past 12 months between previously incarcerated respondents and never incarcerated respondents were very small (ATT = -0.091 and ATT = 0.055 for stratified and nearest neighbor matched comparisons respectively), with quite high standard errors. Estimates of the differences between ever incarcerated and never incarcerated respondents in terms of the proportion with concurrent partners were -4.5% and -8.5% by stratified and nearest neighbor matching methods respectively, suggesting that ever incarcerated individuals actually had fewer concurrent partnerships. This was not the case for reporting partners with concurrent partners, however, and between 5.8% and 12.7% (estimated by nearest neighbor and stratified methods respectively) more previously incarcerated individuals had partners with concurrent partners.

The propensity score was also evaluated as a predictor of sexual behavior on its own (using bivariate regression analyses) to validate its use as a control for the many demographic and criminal justice variables that went into it, which have already been shown to be related to sexual behavior, and the results are shown in Figure 11. Within the male subset, the propensity score predicted increased numbers of total partners, partners in the last month, and increased the odds of having a partner with concurrent partners significantly (IRR = 37.34, IRR = 8.0, OR = 11.13, respectively), but was not significantly associated with increased odds of concurrent partnership, though the trend was in the same direction as the other relationships (OR = 3.94, p = 0.21). Propensity for incarceration was not a significant predictor of any sexual behaviors among the convicted subset.

When used as a single control variable in regression analyses of the effect of incarceration on sexual behavior variables, the propensity score retained the same significant relationships described above. Within the male subset, even when controlling for the propensity for incarceration, having actually been incarcerated still significantly predicted an increased rate of partnership over the lifetime (OR = 1.90, p = 0.00) as well as increased odds of reporting partners with concurrent partners (OR = 2.03, p = 0.05). Within the convicted subset, the propensity score remained a non-significant predictor of sexual behavior, though even when controlling for the propensity for incarceration, incarceration predicted an increased rate of partnership over the lifetime (IRR = 1.45), though the effect was just above the cutoff for significance (p = 0.07).

Wave II Analysis: To test the final hypothesis, that prior to incarceration all individuals have similar sexual behavior, an earlier round of questions is used. These data were collected when the same respondents were younger, and prior to the adult incarceration of any of the respondents. The full sample at Wave II was on average almost 16 years old and was finishing the 9th grade. All but the top 17% of respondents made less than $6000 in the year of the survey. The male subset was very similar, though slightly overrepresented in the highest quintiles of income. The convicted subset was also similar, but with approximately 30% of the subset falling into the highest quintile of yearly income. Wave II descriptive demographic statistics are shown in Figure 12.

More than half of the male subset had committed either zero or one delinquent behavior in the past 12 months (none: 32%, one: 20%), with less than one percent of the subset in each of the categories above 8 (out of 14 behaviors), as shown in Figure 13. The average number of delinquency events in this subset was 4.2 in the past 12 months.

For the convicted subset, a larger proportion of respondents had been involved in more different delinquent behaviors, and the average number of delinquency events in this group was higher (7.6).

By Wave II, approximately 40% of the male subset had ever been sexually active, with just under 4% having concurrent partners. Among those sexually active male respondents, the mean number of lifetime partners at Wave II is 5.2. A substantially larger proportion of the convicted subset reported having been sexually active (70%), and nearly 7% had concurrent partners. The mean number of sexual partners was only slightly higher (5.7). Descriptive statistics of sexual behavior are shown in Figure 14.

Differences in the mean number of lifetime partners at Wave II between individuals who would not be later incarcerated and those who would were not significant, and are shown in Figure 15. This means that earlier in their lives, those individuals who would later be incarcerated seem very similar to those who will not experience incarceration later in their lives. Within the male and convicted subsets the differences were approximately 1.4 and 1.6 partners respectively, with substantial standard errors, and these differences were not significant. With the convicted subset, there was a significant difference in the proportion with concurrent partnerships between individuals who would later be incarcerated and those who would not, with 6% more individuals who would NOT be incarcerated having concurrent partners at Wave II. This effect is in the opposite direction from that observed after incarceration. The difference in the male subset was not significant.

Predictors of increased rates of lifetime partnership at Wave II were limited, but included years of education completed for the male subset (IRR = 1.12, $p = 0.05$) and

Asian race and number of delinquent behaviors in the past 12 months for the convicted subset (IRR = 7.46, p = 0.00 and IRR = 1.11, p = 0.00 respectively). Within the male subset, Black race, number of delinquent behaviors in the past 12 months, years of education completed, being in the top two quintiles of income, and age all predicted increased odds of having any concurrent partnerships. Asian race and being in the bottom two quintiles of income predicted decreased odds of having any concurrent partnerships. Among the convicted subset, the only significant predictor of concurrency was Asian race (OR = 0.06, p = 0.01). These models are shown in Table 2.17.

Multivariate models showed no relationship between future incarceration and total lifetime partners and odds of concurrency at Wave II, and are shown in Tables 2.18 and 2.19. Among the male subset, significant predictors of the number of lifetime partners included Asian race and years of education completed (both predicting decreased rates of partnership) and being in the top two quintiles of income, the number of delinquent behaviors in the past 12 months, and having a biological father incarcerated (with the last four predicting increased rates of partnership). Within the convicted subset, predictors of lower rates of partnership over the lifetime included Asian race and being in the 4^{th} quintile of income. Predictors of higher rates of partnership were being in the 2^{nd} quintile for income and the number of delinquent behaviors in the past 12 months. Increased odds of having concurrent partners within the male subset was associated only with the number of delinquent behaviors in the past 12 months, and decreased odds of having concurrent partners were predicted by Native American or Asian race.

Discussion

These analyses highlight a significant relationship between incarceration and patterns of sexual behavior: incarceration was associated with an increased rate of lifetime sexual partnership as well as increased odds of having partners who report concurrent partnerships. In both the male subset and the subset of respondents who had been convicted in an adult court, the incarceration consistently and significantly increased the number of lifetime partners. The relationship between incarceration and partners' concurrency was attenuated once conviction in an adult court was accounted for, though the direction of the effect remained the same. Propensity score matching and regression analyses supported these conclusions.

Individuals who would later be incarcerated did not differ significantly from those who would not be incarcerated in terms of the number of sexual partners and rate of concurrency. The only significant relationship between incarceration and a measure of sexual behavior was a much decreased likelihood of having concurrent partners among the convicted subset, an effect in the opposite direction of that observed at Wave III. This suggests that prior to incarceration, these two groups were similar and that incarceration altered the trajectory of sexual behavior that might otherwise have been observed.

These results fit clearly into the framework of previous work suggesting that men who had been incarcerated had higher numbers of partners (Epperson, et al., 2010; Epperson, et al., 2008; Seal, et al., 2007). Demonstrating the lack of significant differences between the two groups of men prior to incarceration adds a temporal component to the analysis and strengthens the argument for causality. The finding that

the number of partners in the past year is unaffected by incarceration, while the number of lifetime partners is increased, suggests a longer-term mechanism may be at work here, but further work is needed to examine potential underlying mechanisms.

Incarceration was not associated with having concurrent partners, which conflicts with earlier work (for example, Adimora, et al., 2007), though this may be a reflection of the study population: Add Health represents a relatively young population with overall high rates of concurrency compared to older nationally representative samples. Adimora and colleagues (2007) also find that for men incarcerated more than a year ago, the odds ratio for having concurrent partners drops from 2.1 (for men incarcerated in the past 12 months) to 1.08, suggesting that the effect of incarceration on concurrency may be temporally brief, and perhaps as a result not captured in the data analyzed here.

This study addresses several important gaps in the literature. The data set provides a great deal of information about criminal justice involvement as well as sexual activity, allowing for more appropriate comparison groups and controls. As a result, in spite its limitations, the findings in this study are more likely to demonstrate the true effects of incarceration, rather than the effects of important unmeasured variables such as involvement in crime. Many studies have used aggregate ecological data to draw conclusions about individuals. This study uses individual level data allowing for comparison of young men who have been incarcerated to those at risk for incarceration. Finally, the opportunity to track individuals through their sexual development to demonstrate that effects of incarceration are not exclusively the result of earlier experiences provides an additional opportunity to check for confounding relationships.

This study is not without weaknesses. Even in a large nationally representative data set there are relatively few individuals who have been incarcerated. This limitation may arise in part because the sample began as a school-based sample. Limiting the analysis to the most relevant comparison group within this sample means that the power of the data set is decreased significantly. In order to improve our understanding of the unintended consequences of incarceration, future national data collection projects should consider enriching their samples with both individuals who are currently incarcerated and individuals who have previously been in jail or prison.

That the sample began as a school-based sample also raises conceptual questions. While the study started before participants could legally stop attending school, it is likely that those who have dropped out of school over time are under-represented both in the initial waves of the survey and in later waves. This suggests that those individuals who remain in the sample are likely those with relatively greater support or resources. Conclusions based on this data set are as such likely to be "best case scenarios," and more representative data set, may show even more dire consequences for young adults who have been incarcerated. This should be explored further, and is yet another motivation for specific data collection around issues of incarceration. Given the proportion of the US population affected by incarceration, such studies are highly recommended.

Measurement of community and network level constructs is another limitation of the project. Though concurrency and number of partners capture some information about sexual networks, they are not perfect measures. More comprehensive measures that require enumeration of the complete network would be much more informative, but are

not available in the data set. The most notable measurement challenge is that surrounding "community risk" for incarceration. Though some of this construct is likely captured in the race variable, as well as father's incarceration, there is not a good indicator in the data set. As discussed above, using father's incarceration is likely to reflect the effects of family more than the effects of an entire community, though other measures available in the data set, such as urbanicity, are also problematic. Results using these variable should be interpreted cautiously, and likely only as justification for further investigation.

Overall, in spite of its limitations, the study demonstrates a substantial effect of incarceration on rates of sexual partnership and on the sexual behavior of the partners of individuals who are incarcerated. The relative lack of observed effects at a time point before incarceration supports the conclusion of a unique effect of incarceration, rather than a selection effect into the criminal justice system, as does the persistence of the effect of incarceration even when controlling for a variety of indicators of criminal justice involvement. Further work is necessary to determine the mechanisms through which incarceration may act.

Table 2.2. Demographic descriptive statistics for the full survey population and analytical subsets.

	Full Sample		Male Only Subsample		Convicted Male Subsample	
	Weighted Proportion	Unweighted Frequency	Weighted Proportion	Unweighted Frequency	Weighted Proportion	Unweighted Frequency
Sex						
Male	50.14	5092	100	5092	100	423
Female	49.86	5736	0	0	0	0
Race						
White	76.75	7157	76.72	3408	75.46	300
Black	16.36	2349	15.94	1010	16.64	75
Native American	2.62	340	2.85	171	5.71	25
Asian	4.27	831	4.49	431	2.19	16
Hispanic						
No	88.05	9069	87.78	4226	88.54	357
Yes	11.95	1741	12.22	855	11.46	65
Income (quintiles)						
$0-$1999	22.83	1932	19.47	789	16.61	67
$2000-$7999	20.5	1764	18.25	773	17.18	56
$8000-$14999	24.96	2021	24.37	926	24.42	83
$15000-$22999	16.22	1471	17.59	761	19.63	68
$23000-$500909	15.48	1441	20.32	910	22.17	80
	Mean	N	Mean	N	Mean	N
Age	21.4	10828	21.49	5092	21.71	
Education	13.08	10827	12.88	5092	12.61	

Table 2.3. Criminal justice involvement descriptive statistics for the analytic subsets.

		Male Subset		Convicted Subset	
		Weighted Proportion	Unweighted Frequency	Weighted Proportion	Unweighted Frequency
Ever been stopped by the police					
	No	68.75	3533	0.73	1
	Yes	31.25	1488	99.27	414
History of adult arrest					
	No	95	4885	66.1	289
	Yes	5	202	33.9	133
History of conviction in an adult court					
	No	90.74	4658	0	0
	Yes	9.26	423	100	423
History of incarceration in an adult facility					
	No	98.46	5005	83.2	342
	Yes	1.54	79	16.8	79
Biologic father ever served time					
	No	86.09	4091	72.27	270
	Yes	13.91	691	27.73	114

Table 2.4. Sexual experience descriptive statistics for the analytical subsets.

	Male Subset		Convicted Subset	
	Weighted Proportion	Unweighted Frequency	Weighted Proportion	Unweighted Frequency
Ever had sex				
No	14.5	764	3.05	16
Yes	85.5	4279	96.95	404
Concurrent partnerships				
No	75.88	3143	66.35	229
Yes	24.12	942	33.65	116
Report partners with concurrent partners				
No	72.45	3011	58.36	203
Yes	27.55	1074	41.64	142
	Mean	N	Mean	N
Total number of lifetime partners	6.2	4991	11.56	410
Partners in the last 12 months	1.78	4974	2.57	415

Table 2.5. Estimated differences in means and proportions between incarcerated respondents and unincarcerated respondents.

	Difference	Std. Err.	p-value	Confidence Interval	
Total Number of Partners				Upper Bound	Lower Bound
Male Subset	9.44	2.88	(0.00)	3.748	15.12764
Convicted Subset	5.05	3.72	(0.18)	-2.32	12.41921
Partners in the past 12 months					
Male Subset	0.87	0.58	(0.14)	-0.28	2.020664
Convicted Subset	0.31	0.89	(0.73)	-1.45	2.062321
Proportion concurrent					
Male Subset	0.03	0.08	(0.72)	-0.12	0.1759124
Convicted Subset	-0.09	0.09	(0.33)	-0.27	0.0911597
Proportion partners with concurrent partners					
Male Subset	0.24	0.07	(0.00)	0.093	0.3881894
Convicted Subset	0.12	0.09	(0.18)	-0.06	0.291032

Table 2.6. Bivariate relationships between sexual behaviors and demographic and criminal justice involvement variables.

Total number of lifetime partners - Bivariate	Male Subset		Convicted Male Subset	
	OR	p-value	OR	p-value
Race (ref = White)				
Black	**1.42**	**(0.00)**	1.22	(0.28)
Native American	1.14	(0.26)	1.01	(0.96)
Asian	**0.53**	**(0.00)**	0.48	(0.27)
Hispanic	0.99	(0.94)	1.19	(0.50)
Ever been stopped by the police (ref = no)	**1.52**	**(0.00)**	0.3	.
History of Adult Arrest (ref = no)	**2.32**	**(0.00)**	1.17	(0.26)
History of Conviction in an Adult Court (ref = no)	**2.05**	**(0.00)**		
Ever been incarcerated (ref = no)	**2.56**	**(0.00)**	**1.45**	**(0.05)**
Biological father ever served time (ref = no)	**1.23**	**(0.01)**	1.14	(0.33)
Years of Education Completed	**0.97**	**(0.02)**	0.99	(0.02)
Income (ref = Quintile 3)				
incQuin==1	1.01	(0.92)	0.99	(0.97)
incQuin==2	0.97	(0.73)	1.54	(0.06)
incQuin==4	**1.3**	**(0.00)**	1.3	(0.28)
incQuin==5	**1.46**	**(0.00)**	1.23	(0.45)
Age	**1.14**	**(0.00)**	**1.23**	**(0.00)**

Partners in the last 12 months - Bivariate	Male Stuset		Convicted Male Subset	
	OR	p	OR	p-value
Race (ref = White)				
Black	**1.39**	**(0.00)**	1.13	(0.49)
Native American	1.15	(0.33)	1.2	(0.51)
Asian	0.89	(0.71)	**0.25**	**(0.00)**
Hispanic	1.14	(0.30)	1.27	(0.32)
Ever been stopped by the police (ref = no)	**1.35**	**(0.00)**	**0.36**	**(0.00)**
History of Adult Arrest (ref = no)	**1.62**	**(0.00)**	1.07	(0.71)
History of Conviction in an Adult Court (ref = no)	**1.52**	**(0.00)**		
Ever been incarcerated (ref = no)	1.49	(0.07)	1.03	(0.91)
Biological father ever served time (ref = no)	1.07	(0.34)	0.9	(0.55)
Years of Education Completed	**0.95**	**(0.01)**	**0.98**	**(0.05)**
Income (ref = Quintile 3)				
incQuin==1	1.08	(0.36)	0.69	(0.16)
incQuin==2	1.01	(0.89)	1.48	(0.24)
incQuin==4	**1.19**	**(0.04)**	0.97	(0.91)
incQuin==5	**1.19**	**(0.03)**	0.84	(0.55)
Age	0.99	(0.78)	0.98	(0.72)

Concurrent Partnerships - Bivariate	Male Subset		Convicted Male Subset	
	OR	p-value	OR	p-value
Race (ref = White)				
Black	**1.43**	**(0.01)**	1.31	(0.47)
Native American	0.95	(0.85)	0.27	(0.13)
Asian	0.57	(0.07)	0.24	(0.17)
Hispanic	0.89	(0.37)	0.42	(0.07)
Ever been stopped by the police (ref = no)	**1.73**	**(0.00)**	**	
History of Adult Arrest (ref = no)	1.38	(0.13)	-0.31	(0.28)
History of Conviction in an Adult Court (ref = no)	**1.68**	**(0.00)**	**	
Ever been incarcerated (ref = no)	1.15	(0.72)	0.66	(0.36)
Biological father ever served time (ref = no)	0.87	(0.35)	0.61	(0.15)
Years of Education Completed	1	(0.86)	1	(0.86)
Income (ref = Quintile 3)				
incQuin==1	0.73	(0.09)	0.75	(0.57)
incQuin==2	1.02	(0.90)	1.82	(0.27)
incQuin==4	1.04	(0.85)	1.03	(0.96)
incQuin==5	0.96	(0.79)	0.79	(0.61)
Age	1.01	(0.64)	1.05	(0.54)

Partners with concurrent partners - Bivariate				
	OR	p-value	OR	p-value
Race (ref = White)				
Black	1.08	(0.55)	1.73	(0.12)
Native American	0.82	(0.56)	1	(1.00)
Asian	**0.63**	**(0.03)**	0.17	(0.06)
Hispanic	0.77	(0.05)	0.73	(0.50)
Ever been stopped by the police (ref = no)	**1.75**	**(0.00)**	**	
History of Adult Arrest (ref = no)	**1.75**	**(0.00)**	1.11	(0.74)
History of Conviction in an Adult Court (ref = no)	**2.03**	**(0.00)**	**	
Ever been incarcerated (ref = no)	**(2.83)**	**(0.00)**	(1.62)	(0.18)
Biological father ever served time (ref = no)	**(1.80)**	**(0.00)**	(1.70)	(0.12)
Years of Education Completed	(0.98)	(0.33)	(0.98)	(0.24)
Income (ref = Quintile 3)				
incQuin==1	(0.96)	(0.79)	(0.98)	(0.97)
incQuin==2	(1.14)	(0.47)	(1.27)	(0.63)
incQuin==4	(1.14)	(0.41)	(1.52)	(0.41)
incQuin==5	(0.90)	(0.50)	(0.80)	(0.63)
Age	(0.99)	(0.86)	(0.94)	(0.53)

Table 2.7. Multivariate relationships between number of lifetime sexual partners and demographic and criminal justice involvement variables.

Male Subset	IRR	p-value	IRR	p-value	IRR	p-value	IRR	p-value	IRR	p-value
Ever been incarcerated	**2.56**	**(0.00)**	**2.46**	**(0.00)**	**1.79**	**(0.00)**	**1.43**	(0.11)	**1.63**	**(0.04)**
Race (ref = White)										
Black			**1.55**	**(0.00)**	**1.52**	**(0.00)**	**1.57**	**(0.00)**	**1.63**	**(0.00)**
Native American			1.23	(0.15)	1.20	(0.22)	1.13	(0.43)	1.17	(0.33)
Asian			**0.53**	**(0.00)**	**0.55**	**(0.00)**	**0.55**	**(0.00)**	**0.54**	**(0.00)**
Hispanic			0.90	(0.25)	0.90	(0.24)	0.92	(0.35)	0.95	(0.60)
Age			**1.13**	**(0.00)**	**1.13**	**(0.00)**	**1.11**	**(0.00)**	**1.12**	**(0.00)**
Years of Education Completed			**0.98**	**(0.06)**	**0.98**	**(0.01)**	**0.97**	**(0.01)**	**0.98**	**(0.01)**
Income (ref = Quintile 3)										
incQuin==1			0.96	(0.66)	0.98	(0.76)	0.98	(0.77)	1.00	(0.97)
incQuin==2			0.97	(0.73)	0.98	(0.87)	0.92	(0.40)	0.93	(0.43)
incQuin==4			**1.26**	**(0.01)**	**1.22**	**(0.01)**	**1.22**	**(0.02)**	**1.27**	**(0.01)**
incQuin==5			**1.36**	**(0.00)**	**1.34**	**(0.00)**	**1.36**	**(0.00)**	**1.38**	**(0.00)**
History of Adult Arrest					**1.92**	**(0.00)**				
History of Conviction in an Adult Court							**1.82**	**(0.00)**	**1.68**	**(0.00)**
Biological father ever served time									1.11	(0.28)

Convicted Subset	IRR	p-value	IRR	p-value	IRR	p-value
Ever been incarcerated	**1.45**	**(0.05)**	**1.68**	**(0.03)**	**1.93**	**(0.01)**
Rac e (ref = White)						
Black			1.07	(0.73)	1.09	(0.68)
Native American			1.31	(0.31)	1.20	(0.61)
Asian			0.46	(0.20)	0.52	(0.22)
Hispanic			0.92	(0.69)	1.12	(0.71)
Age			**1.28**	**(0.00)**	**1.32**	**(0.00)**
Years of Education Completed			0.99	(0.10)	0.99	(0.15)
Income (ref = Quintile 3)						
incQuin==1			0.86	(0.40)	0.84	(0.37)
incQuin==2			1.62	(0.03)	1.51	(0.08)
incQuin==4			1.28	(0.25)	1.27	(0.28)
incQuin==5			1.14	(0.63)	0.82	(0.38)
Biological father ever served time					1.19	(0.07)

Table 2.8. Multivariate relationships between number of sexual partners in the past 12 months and demographic and criminal justice involvement variables.

Male Subset	IRR	p-value	IRR	p-value	IRR	p-value	IRR	p-value	IRR	p-value
Ever been incarcerated	1.49	(0.07)	1.39	(0.25)	1.17	(0.57)	0.95	(0.87)	1.00	(1.00)
Race (ref = White)										
Black			**1.51**	**(0.00)**	**1.49**	**(0.00)**	**1.52**	**(0.00)**	**1.58**	**(0.00)**
Native American			1.25	(0.12)	1.23	(0.14)	1.19	(0.24)	1.17	(0.34)
Asian			**0.70**	**(0.05)**	0.71	(0.06)	0.72	(0.07)	**0.65**	**(0.01)**
Hispanic			0.96	(0.70)	0.97	(0.71)	0.98	(0.84)	1.00	(0.96)
Age			0.98	(0.30)	0.98	(0.33)	0.98	(0.18)	0.98	(0.35)
Years of Education Completed			0.98	(0.09)	0.99	(0.06)	0.99	(0.06)	0.99	(0.15)
Income (ref = Quintile 3)										
incQuin==1			1.04	(0.66)	1.05	(0.56)	1.05	(0.53)	1.07	(0.46)
incQuin==2			1.00	(0.97)	1.00	(0.97)	0.98	(0.81)	1.00	(0.97)
incQuin==4			**1.19**	**(0.02)**	**1.19**	**(0.02)**	**1.19**	**(0.02)**	**1.21**	**(0.01)**
incQuin==5			**1.22**	**(0.01)**	**1.22**	**(0.01)**	**1.22**	**(0.01)**	**1.22**	**(0.02)**
History of Adult Arrest					**1.42**	**(0.01)**				
History of Conviction in an Adult Court							**1.52**	**(0.00)**	**1.43**	**(0.00)**
Biological father ever served time									1.03	(0.75)
Convicted Subset	IRR	p-value	IRR	p-value	IRR	p-value				
Ever been incarcerated	1.03	(0.91)	1.03	(0.91)	1.08	(0.79)				
Race (ref = White)										
Black			1.09	(0.63)	1.23	(0.30)				
Native American			1.27	(0.40)	1.05	(0.85)				
Asian			**0.23**	**(0.00)**	**0.26**	**(0.00)**				
Hispanic			1.01	(0.98)	1.15	(0.67)				
Age			1.02	(0.59)	1.03	(0.49)				
Years of Education Completed			0.98	(0.27)	0.98	(0.26)				
Income (ref = Quintile 3)										
incQuin==1			0.67	(0.10)	0.70	(0.16)				
incQuin==2			1.46	(0.25)	1.42	(0.35)				
incQuin==4			0.99	(0.96)	0.99	(0.96)				
incQuin==5			0.86	(0.57)	0.66	(0.08)				
Biological father ever served time					1.01	(0.93)				

Table 2.9. Multivariate relationships between proportion with concurrent partners and demographic and criminal justice involvement variables.

Male Subset	IRR	p-value	IRR	p-value	IRR	p-value	IRR	p-value	IRR	p-value
Ever been incarcerated	1.15	(0.72)	1.15	(0.72)	0.98	(0.97)	0.69	(0.43)	0.59	(0.28)
Race (ref = White)										
Black			**1.62**	**(0.00)**	**1.60**	**(0.00)**	**1.65**	**(0.00)**	**1.67**	**(0.00)**
Native American			1.13	(0.67)	1.12	(0.70)	1.06	(0.83)	1.45	(0.23)
Asian			0.69	(0.24)	0.70	(0.24)	0.70	(0.26)	0.70	(0.27)
Hispanic			0.80	(0.17)	0.80	(0.16)	0.82	(0.21)	0.80	(0.22)
Age			1.00	(0.94)	1.00	(0.93)	1.00	(0.99)	1.00	(0.92)
Years of Education Completed			1.00	(0.75)	1.00	(0.77)	1.00	(0.80)	1.00	(0.74)
Income (ref = Quintile 3)										
incQuin==1			0.70	(0.06)	0.69	(0.06)	0.70	(0.07)	0.73	(0.11)
incQuin==2			0.99	(0.95)	0.99	(0.94)	0.99	(0.93)	1.00	(0.99)
incQuin==4			1.03	(0.89)	1.02	(0.93)	1.02	(0.93)	0.97	(0.89)
incQuin==5			0.97	(0.83)	0.96	(0.78)	0.96	(0.79)	0.99	(0.94)
History of Adult Arrest					1.40	(0.15)				
History of Conviction in an Adult Court							**1.75**	**(0.01)**	**1.90**	**(0.00)**
Biological father ever served time									0.67	(0.02)

Convicted Subset	IRR	p-value	IRR	p-value	IRR	p-value
Ever been incarcerated	0.66	(0.36)	0.79	(0.64)	0.60	(0.37)
Race (ref = White)						
Black			1.46	(0.34)	1.54	(0.31)
Native American			0.63	(0.70)	1.08	(0.95)
Asian			0.32	(0.29)	0.26	(0.22)
Hispanic			0.27	(0.11)	0.49	(0.39)
Age			1.02	(0.81)	0.97	(0.74)
Years of Education Completed			0.99	(0.65)	0.99	(0.49)
Income (ref = Quintile 3)						
incQuin==1			0.94	(0.91)	1.28	(0.67)
incQuin==2			2.18	(0.15)	2.03	(0.21)
incQuin==4			1.03	(0.95)	1.27	(0.65)
incQuin==5			0.79	(0.64)	0.97	(0.95)
Biological father ever served time					0.50	(0.09)

Table 2.10. Multivariate relationships between proportion reporting partners with concurrent partners and demographic and criminal justice involvement variables.

Male Subset	IRR	p-value	IRR	p-value	IRR	p-value	IRR	p-value	IRR	p-value
Ever been incarcerated	**2.83**	**(0.00)**	**2.69**	**(0.01)**	**2.18**	**(0.03)**	1.63	(0.23)	1.88	(0.16)
Race (ref = White)										
Black			1.09	(0.61)	1.07	(0.65)	1.08	(0.62)	1.12	(0.53)
Native American			0.88	(0.75)	0.86	(0.71)	0.83	(0.64)	0.87	(0.72)
Asian			0.79	(0.32)	0.79	(0.33)	0.80	(0.36)	0.82	(0.42)
Hispanic			0.73	(0.08)	0.72	(0.08)	0.74	(0.12)	0.74	(0.11)
Age			1.02	(0.56)	1.02	(0.56)	1.02	(0.65)	1.02	(0.63)
Years of Education Completed			0.98	(0.39)	0.98	(0.39)	0.98	(0.37)	0.99	(0.57)
Income (ref = Quintile 3)										
incQuin==1			0.94	(0.70)	0.93	(0.67)	0.97	(0.85)	0.95	(0.79)
incQuin==2			1.14	(0.46)	1.14	(0.47)	1.14	(0.47)	1.27	(0.21)
incQuin==4			1.12	(0.49)	1.11	(0.54)	1.13	(0.47)	1.14	(0.46)
incQuin==5			0.88	(0.42)	0.87	(0.37)	0.90	(0.48)	0.87	(0.43)
History of Adult Arrest					**1.67**	**(0.01)**				
History of Conviction in an Adult Court							**1.73**	**(0.00)**	**1.63**	**(0.01)**
Biological father ever served time									**1.79**	**(0.00)**
Convicted Subset	IRR	p-value	IRR	p-value	IRR	p-value				
Ever been incarcerated	1.62	(0.18)	1.72	(0.25)	1.92	(0.23)				
Race (ref = White)										
Black			2.01	(0.10)	2.14	(0.11)				
Native American			1.34	(0.72)	1.45	(0.64)				
Asian			0.21	(0.16)	0.27	(0.23)				
Hispanic			0.45	(0.16)	0.70	(0.56)				
Age			0.93	(0.45)	0.94	(0.54)				
Years of Education Completed			0.98	(0.25)	0.98	(0.29)				
Income (ref = Quintile 3)										
incQuin==1			0.84	(0.74)	0.93	(0.90)				
incQuin==2			1.40	(0.48)	2.03	(0.17)				
incQuin==4			1.70	(0.31)	1.79	(0.29)				
incQuin==5			0.91	(0.85)	0.92	(0.87)				
Biological father ever served time					1.92	(0.14)				

Table 2.11. Relationships between sexual behavior measures and incarceration history controlling for propensity score.

	Male Subset		Convicted Subset	
	IRR	p-value	IRR	p-value
Total number of lifetime partners				
Ever been incarcerated	1.90	(0.00)	1.45	(0.07)
Estimated propensity score	22.20	(0.00)	1.52	(0.53)
Partners in the last 12 months				
Ever been incarcerated	1.12	(0.69)	0.93	(0.80)
Estimated propensity score	7.39	(0.00)	2.36	(0.32)
	OR	p-value	OR	p-value
Any concurrent partnerships				
Ever been incarcerated	0.92	(0.85)	0.73	(0.48)
Estimated propensity score	4.06	(0.23)	0.34	(0.47)
Report partners with concurrent partners				
Ever been incarcerated	2.03	(0.05)	1.54	(0.30)
Estimated propensity score	6.36	(0.05)	1.40	(0.78)
Constant	0.38	(0.00)	0.63	(0.02)

Table 2.12. Estimated effects of incarceration on sexual behavior measures using propensity score matching.

Lifetime partners	N treatment	N control	ATT	Std. Err.	t
Stratification	94	11873	4.34	1.593	2.724
Nearest neighbor matching	95	97	4.76	1.812	2.626
Partners in the past 12 months	N treatment	N control	ATT	Std. Err.	t
Stratification	94	11873	-0.091	0.308	-0.3
Nearest neighbor matching	95	98	0.055	0.392	0.14
Concurrent partners	N treatment	N control	ATT	Std. Err.	t
Stratification	94	11873	-0.045	0.052	-0.85
Nearest neighbor matching	95	81	-0.085	0.075	-1.14
Partners with concurrent partners	N treatment	N control	ATT	Std. Err.	t
Stratification	94	11873	0.127	0.057	2.215
Nearest neighbor matching	95	81	0.058	0.078	0.75

Table 2.13. Demographic descriptive statistics for the full survey population and analytical subsets at Wave II

	Full Sample		Male Subset		Convicted Subset	
	Mean	N	Mean	N	Mean	N
Current Grade Level	9.94	9898	9.93	4619	9.73	174
Calculated Age	15.94	10828	16.02	5092	15.95	207
	Weighted Proportion	Unweighted Frequency	Weighted Proportion	Unweighted Frequency	Weighted Proportion	Unweighted Frequency
Income (quintiles)						
$0-$1465	24.61	1286	19.41	507	19.67	17
$1466-$2795	21.75	1252	21.34	573	22.38	24
$2796-4420	19	1243	18.67	588	18.46	24
$4421-$6616	17.23	1181	19.2	665	8.77	18
$6617-$38229	17.41	1187	21.37	717	30.72	39

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Table 2.14. Criminal justice involvement/delinquency descriptive statistics for the analytic subsets at Wave II.

		Male Subset		Convicted Subset	
		Weighted Proportion	Unweighted Frequency	Weighted Proportion	Unweighted Frequency
Number of Different Delinquent Behaviors in the Past 12 Months					
	0	31.72	1627	18.52	88
	1	20.19	1033	17.03	60
	2	14.84	779	10.95	52
	3	11.07	533	13.29	52
	4	7.11	348	8.99	37
	5	5.62	266	8.51	40
	6	2.99	184	5.06	29
	7	2.2	98	5.68	16
	8	1.52	78	3.5	13
	9	0.78	42	1.6	7
	10	0.84	40	3.2	10
	11	0.55	30	1.62	9
	12	0.18	15	0.84	5
	13	0.21	10	1.03	3
	14	0.19	9	0.19	2
		Mean	N	Mean	N
Number of Events of Delinquent Behavior in the Past 12 Months		4.2	5092	7.61	423

Table 2.15. Sexual behavior descriptive statistics for the analytic subsets at Wave II.

		Male Subset		Convicted Subset	
		Weighted Proportion	Unweighted Frequency	Weighted Proportion	Unweighted Frequency
Ever had sex					
	No	59.13	2875	29.67	62
	Yes	40.87	2190	70.33	144
Concurrent partnerships					
	No	96.45	4889	93.11	395
	Yes	3.55	203	6.98	28
		Mean	N	Mean	N
Total Lifetime Partners		5.2	1225	5.65	84

Table 2.16. Estimated differences in means between individuals who will later be incarcerated (by Wave III) and those who will not be incarcerated, measured at Wave II

Wave II	Difference	Std. Err.	p-value
Total Number of Partners			
Male Subset	1.39	1.57	(0.38)
Convicted Subset	1.61	1.65	(0.33)
Concurrent Partners			
Male Subset	-0.02	0.02	(0.30)
Convicted Subset	**-0.06**	**0.03**	**(0.02)**

Table 2.17. Bivariate relationships between sexual behaviors and demographic and criminal justice involvement variables at Wave II.

	Male Subset		Convicted Subset	
	IRR	p-value	IRR	p-value
Total Number of Lifetime Partners				
Race (ref = White)				
Black	0.95	(0.81)	0.99	(0.95)
Native American	1.15	(0.77)	1.32	(0.46)
Asian	0.96	(0.91)	**7.46**	**(0.00)**
Hispanic	1.86	(0.26)	1.06	(0.85)
Number of delinquent behaviors in past 12 months	1.05	(0.25)	**1.11**	**(0.00)**
Ever been incarcerated	1.27	(0.35)	1.32	(0.30)
Biological father ever served time	1.38	(0.36)	0.84	(0.54)
Years of Education Completed (Wave II)	1.21	(0.05)	1.13	(0.31)
Income (ref = Quintile 3)				
inc2Quin==1	0.96	(0.87)	1.77	(0.30)
inc2Quin==2	1.36	(0.36)	0.87	(0.78)
inc2Quin==4	1.19	(0.38)	1.68	(0.15)
inc2Quin==5	1.55	(0.20)	1.25	(0.21)
Age	1.15	(0.07)	1.08	(0.31)
Wave II - Any concurrent partnerships	OR	p-value	OR	p-value
Race (ref = White)				
Black	**1.95**	**(0.00)**	1.25	(0.67)
Native American	1.46	(0.42)	3.03	(0.11)
Asian	**0.17**	**(0.05)**	**0.06**	**(0.01)**
Hispanic	1.21	(0.57)	1.27	(0.69)
Number of delinquent behaviors in past 12 months	1.16	(0.00)	1.08	(0.24)
Ever been incarcerated	0.55	(0.43)	0.24	(0.08)
Biological father ever served time	1.21	(0.51)	1.34	(0.57)
Years of Education Completed (Wave II)	**1.63**	**(0.00)**	1.11	(0.63)
Income (ref = Quintile 3)				
inc2Quin==1	**0.13**	**(0.01)**	1.00	.
inc2Quin==2	**0.30**	**(0.02)**	1.00	.
inc2Quin==4	**2.32**	**(0.02)**	3.19	(0.21)
inc2Quin==5	**2.36**	**(0.02)**	2.27	(0.37)
Age	1.57	(0.00)	1.25	(0.13)

Table 2.18. Multivariate relationships between number of lifetime partners, future incarceration, and demographic and criminal justice involvement variables at Wave II.

Male Subset	IRR	p-value	IRR	p-value	IRR	p-value	IRR	p-value
Ever been incarcerated	1.27	(0.35)	0.77	(0.42)	0.68	(0.29)	0.51	(0.08)
Race (ref = White)								
Black			0.93	(0.70)	0.99	(0.97)	0.99	(0.96)
Native American			2.86	(0.17)	2.32	(0.21)	1.58	(0.50)
Asian			0.78	(0.45)	0.70	(0.22)	**0.65**	**(0.04)**
Hispanic			1.05	(0.86)	0.93	(0.76)	1.01	(0.95)
Age			1.03	(0.74)	1.06	(0.41)	1.09	(0.18)
Years of Education			0.90	(0.22)	0.91	(0.14)	**0.88**	**(0.03)**
Income (ref = Quintile 3)								
inc2Quin==1			0.90	(0.68)	0.83	(0.30)	0.91	(0.68)
inc2Quin==2			1.45	(0.22)	1.49	(0.17)	1.46	(0.18)
inc2Quin==4			1.28	(0.16)	1.14	(0.36)	1.27	(0.16)
inc2Quin==5			1.95	(0.12)	1.95	(0.11)	**1.82**	**(0.03)**
# of delinquent behaviors					**1.12**	**(0.00)**	**1.11**	**(0.00)**
Biological father ever							**1.99**	**(0.04)**
Convicted Subset	IRR	p-value	IRR	p-value	IRR	p-value	IRR	p-value
Ever been incarcerated	1.32	(0.30)	1.06	(0.84)	1.20	(0.63)	1.16	(0.72)
Race (ref = White)								
Black			0.75	(0.33)	0.87	(0.58)	0.96	(0.89)
Native American			1.40	(0.56)	0.93	(0.89)	0.81	(0.71)
Asian			###	**(0.00)**	**0.21**	**(0.00)**	**0.20**	**(0.00)**
Hispanic			0.59	(0.25)	0.90	(0.80)	0.96	(0.92)
Age			1.38	(0.15)	1.21	(0.24)	1.16	(0.35)
Years of Education			0.94	(0.80)	1.07	(0.74)	1.06	(0.76)
Income (ref = Quintile 3)								
inc2Quin==1			2.64	(0.07)	2.32	(0.08)	2.32	(0.08)
inc2Quin==2			2.34	(0.22)	3.06	(0.07)	3.29	(0.04)
inc2Quin==4			1.93	(0.06)	**2.05**	**(0.04)**	**2.51**	**(0.01)**
inc2Quin==5			1.49	(0.22)	1.40	(0.26)	1.49	(0.18)
# of delinquent behaviors					**1.09**	**(0.01)**	**1.13**	**(0.00)**
Biological father ever							1.03	(0.91)

Table 2.19. Multivariate relationships between proportion of respondents with concurrent partners, future incarceration, and demographic and criminal justice involvement variables at Wave II.

Male Subset	OR	p-value	OR	p-value	OR	p-value	OR	p-value
Ever been incarcerated	0.55	(0.43)	0.31	(0.27)	0.24	(0.18)	0.26	(0.21)
Race (ref = White)								
Black			1.72	(0.07)	1.68	(0.08)	1.79	(0.09)
Native American			**0.05**	**(0.00)**	**0.03**	**(0.00)**	**0.04**	**(0.00)**
Asian			**0.01**	**(0.00)**	**0.01**	**(0.00)**	**0.01**	**(0.00)**
Hispanic			1.40	(0.47)	1.38	(0.49)	1.36	(0.52)
Age			1.28	(0.06)	1.31	(0.05)	1.28	(0.09)
Years of Education Completed			1.09	(0.54)	1.12	(0.50)	1.19	(0.30)
Income (ref = Quintile 3)								
inc2Quin==1			0.23	(0.06)	0.24	(0.07)	0.29	(0.11)
inc2Quin==2			**0.31**	**(0.03)**	**0.34**	**(0.04)**	0.38	(0.08)
inc2Quin==4			1.77	(0.12)	1.84	(0.10)	2.05	(0.07)
inc2Quin==5			1.95	(0.11)	2.12	(0.07)	2.23	(0.06)
Number of delinquent behaviors in past 12 months					**1.20**	**(0.00)**	**1.21**	**(0.00)**
Biological father ever served time							0.88	(0.78)
Convicted Subset	**OR**	**p-value**	**OR**	**p-value**	**OR**	**p-value**	**OR**	**p-value**
Ever been incarcerated	0.24	(0.08)	**0.09**	**(0.04)**	**0.10**	**(0.04)**	**0.09**	**(0.05)**
Race (ref = White)								
Black			0.70	(0.71)	0.75	(0.76)	0.82	(0.84)
Native American			**0.05**	**(0.04)**	**0.03**	**(0.03)**	0.04	(0.10)
Asian			1.00	.	1.00	.	1.00	.
Hispanic			2.64	(0.31)	2.61	(0.37)	5.10	(0.15)
Age			1.72	(0.27)	1.65	(0.30)	1.65	(0.37)
Wave II Centered Years of Education Completed			0.61	(0.40)	0.66	(0.46)	0.66	(0.48)
Income (ref = Quintile 3)								
inc2Quin==1			1.00	.	1.00	.	1.00	.
inc2Quin==2			1.00	.	1.00	.	1.00	.
inc2Quin==4			2.56	(0.35)	2.92	(0.33)	4.44	(0.25)
inc2Quin==5			4.57	(0.07)	5.05	(0.07)	5.16	(0.11)
Number of delinquent behaviors in past 12 months					1.09	(0.46)	1.14	(0.27)
Biological father ever served time							0.75	(0.76)

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Chapter III

Development and validation of an agent-based model of sexual partnership

Introduction

Sexual interactions are bounded by individuals' contacts in their everyday lives and as such strongly responsive to geographical, historical and biographical boundaries (Adimora & Schoenbach, 2005; Fichtenberg, Jennings, Glass, & Ellen, 2010; Laumann, Gagnon, Michael, & Michaels, 1994). Less clear, however, are the ways in which social factors influence sexual decision-making and give rise to specific patterns of sexual partnership behavior. Evolutionary psychologists have worked to quantify some aspects of partnership preferences and strategies in experimental settings (e.g., Buss, 2006; Shackelford, Schmitt, & Buss, 2005), yet the observational nature of data on the social structures that shape decisions about which partners and types of partnerships are chosen over others complicates causal inference. Computational models have contributed substantially to our understanding of sexual disease transmission (see for example, Garnett & Anderson, 1996; Morris & Kretzschmar, 1997), and have the potential to allow for testing of conceptual frameworks and to guide data collection about the processes that determine sexual decision-making and patterns of sexual behavior.

Computational models of mate choice for first marriage in the US, which use courtship as a period of comparison, have matched observed correlations between partner attributes such as attractiveness and income and the distribution of marriage timing, although it is unclear how detailed measures of mate quality should be, and how best to

reflect social norms about dating and sexual decision-making in the models (Alam, Meyer, & Norling, 2008; French & Kus, 2008; Simao & Todd, 2002, 2003). The models previously available in the literature have helped to shape insight about sexual decision-making, but they suffer a substantial limitation: they are described broadly as "partnership" models, but assume that partnering is for life, and that each individual can have only one partner. The model described by Alam et al is an exception here, as it allows for multiple partnerships for men; however, none of the models allow for multiple partnerships for women. It is clear from data from the National Health and Social Life Survey, as well as the National Survey of Family Growth and the National Longitudinal Survey of Adolescent Health, that upwards of 70% of individuals have more than one sexual partner during their lives, and that substantial numbers of individuals have concurrent partners, defined as relationships that overlap in time (Adimora et al., 2002; Adimora, Schoenbach, & Doherty, 2007; Ford, Sohn, & Lepkowski, 2002; Laumann, et al., 1994). The model described here builds on existing models to more accurately reflect sexual partnerships over a 5-year period, rather than simply first marriage. The results show that the model can produce patterns of sexual behavior that are similar to data available from nationally representative surveys from the United States. Although portions of this model may be applicable to a range of settings, the particular context of HIV/AIDS in urban areas of the United States motivated the development of this model, and this is reflected in the choice of parameters and the experimental potential of the model.

Previous partnership models

Selected characteristics of each model of sexual partnership are shown in Table 3.1, and informed the development of the model described here. In their model of mate choice in human populations, Simão and Todd (2002) create what they call a "social

ecology," a community of individuals seeking partners, based principally on a one-dimensional quality parameter "q_i." This quality parameter represents an aggregate and abstract measure of the objective quality of a potential partner, including attributes such as attractiveness, education, income, and others. Individuals also have an "aspiration level" based on successive encounters with individuals of different qualities (i.e. the aspiration level is lowered if an agent breaks off a relationship with the individual). The aspiration level also lowers gradually with time. Male and female agents meet stochastically with probabilities that depend on both the maximum meeting rate and an individual-specific factor that varies depending on whether the individual is single or not, or whether he/she is courting/dating someone at each time step. Each agent maintains a list of "alternatives" - opposite-sex individuals the agent has met and can make courting proposals to. Within this list, one individual can be the agent's current partner. Agents decide whether to make courting proposals based on a fitness function that takes into consideration the quality of the current partner, the quality of the alternative partner, an optimistic estimate of the remaining courtship time required to commit to the current partner, and an optimistic estimate of the required courting time for the alternative partner. Both agents must agree to date, and each individual has a specific "minimum courtship time" before he/she will fully commit to the relationship. After the individuals are fully committed, they mate and do not consider further dating opportunities.

This model of partner formation matches empirical data in several impressive and important ways (Simao & Todd, 2003). The correlation between the quality levels of various individuals is quite similar to actual measurements of similarity between individuals in a couple between nationally representative samples of married couples in the US. Using a normally distributed individual variation in the courtship time K, the

model also generates a distribution of marriage timing close to the distribution empirically derived from census data. They also experiment with skewed sex ratios in the population, finding that sex imbalances causes a decrease in mean mating times for those who find mates. This occurs because high quality individuals of the under-represented sex pair quickly and other partners are unable to mate at all. They conclude that this is consistent with a theoretical model postulating that an excess of members of one sex should accelerate the transition to first marriage because of increased opportunities to find a suitable mate. The authors acknowledge, however, that because their partner selection mechanism is based on agents meeting and comparing partners, seeking the best available, it is unlikely that they would find evidence for a theory based on men's reduced motivation to commit to marriage when women outnumber men, as the only motivations explicitly coded in the model are to find the best possible partner.

Although the authors find that their model replicates many of the phenomena observed in actual populations, the assumptions of monogamy and lifetime partnership are quite extreme. It is unclear whether their conclusions hold if individuals are able to partner and then "divorce" (leading to serial monogamy) or are able to have multiple partners at one time. Without a more realistic representation of the possibility of multiple partnerships, the results of this model are only applicable to first marriage markets rather than a broader definition of partnerships that include all sexual relationships.

French and Kus (2008) describe a similar, but slightly more complicated, model of partnering. Two notable differences distinguish their model from the one described above. First, they use a vector of attributes rather than simply a one-dimensional measure of "quality." These attributes are revealed only gradually, and agents assume average values in those fields they do not yet know about individuals they encounter. Individuals

also have differing weighted preferences for the attributes of individuals they marry. It is unclear whether this added complexity is necessary, as their model does not produce results that differ substantially from those of the earlier model. Second, they use "computational temperature" to determine how willing an individual is to give someone a chance, an attribute that might also be termed "desperation" of the agent. This is similar to the meeting rate set by Simão and Todd, but also influences how an individual perceives the attributes of someone the individual meets. This parameter seems to function in the same way as earlier specifications, but is a unique implementation that facilitates understanding of how the amount of effort an individual puts into finding a partner over the agent's life course, and in different relationship contexts, influences the types of partnerships that are formed.

In addition to these slightly different specifications, French and Kus address a fundamental assumption made in many models of partnership: that men ask women for a date and women respond relatively quickly, without a great deal of time to amass other offers. They find that only when this assumption is implemented are they able to generate the age-lag differential in marriage hazard rates for men and women (that women typically marry several years earlier than men). When they implement mechanisms through which females always ask males or both males and females can initiate partnerships, the curves change substantially. Though they state that the first model is "traditional Western dating" it is unclear whether empirical data support this assertion.

One model that does address one aspect of multiple partnerships is that described by Alam et al (2008). They build on Simão and Todd's model, using their method of mate selection, but allow multiple partnerships for men in the model. This model is built

very specifically around detailed survey data of the Sekhukhune District in Limpopo, South Africa. Their focus is principally on using this model to predict and explain HIV epidemic behavior in this area. They modify the sexual mixing scheme by allowing male agents to have multiple partners and also by specifying that young female agents prefer males of similar age, while older female agents prefer unmarried suitors who have some employment. Female agents do not have sexual partnerships outside of their primary relationship or marriage. Child agents are born to couples or single mothers with pregnancy only occurring when the male partner is not away on migration. The authors model HIV transmission both sexually and mother-to-child. They also explicitly model a social network and use it to constrain meetings between individuals.

The principle focus of their simulation results is HIV prevalence after 75 simulation-years. They show that increasing the number of random contacts (versus contacts constrained by the social network of the individual) increases the transmission of HIV in the community. In addition, they examine the effect of changing exogenous incidence and different probabilities of HIV transmission. They conclude that introducing new cases from the outside keeps the epidemic going. While they comment on the characteristics of the sexual network between agents in the model, it is only to note that with relatively low numbers of concurrent partners there is not a single large "spanning tree" or giant connected component of the network. They report that "increasing the number of allowable concurrent partners decreases the dyad frequency and increases the frequency of higher sub-graph structures. (p 10)"

These results show that the model is performing in a plausible way but they add relatively little insight to previous models of the separate components (i.e. marriage markets, sexual network structure, etc). The authors examine neither the differences in

partnership patterns that occur when they introduce non-monogamy, (other than to say that there are more higher-order network structures, meaning that there are more individuals with multiple partnerships). Although they do look at the effect of migration in terms of bringing new infections into the community, they do not examine its effects in terms of sexual network structure or partnering decisions. Additionally, their assumptions about concurrent partners in the model limit conclusions and are particularly problematic. Men may report having more partners than women, yet assuming that dating and married women have no concurrent partners is a strong assumption, and is certainly not valid in a US context (Adimora, et al., 2002). They also maintain the convention of only allowing men to ask women for dates.

All of the models described above are limited in their utility in the broader study of sexual behavior in the United States because they do not allow for multiple partnerships that are either serially monogamous or overlapping in time. This paper describes an agent-based model of sexual decision-making and sexual networks that addresses several of these key limitations by allowing for multiple partnerships over time as well as concurrent partners. The results show that a modified implementation of the Simao and Todd model can produce numbers of lifetime sexual partners, numbers of sexual partners in the past year, rates of concurrency, and relationship durations that are similar to available nationally representative data from the United States on these measures, and generates high levels of correlation in partners' quality values close to what is observed empirically in the context of both marriage and dating in the US. The comparability of these model outputs to real world data suggests that this model may be useful to explore the dynamics of partner selection and sexual decision-making in a

variety of US contexts, including not only broadly nationally representative samples, but also urban areas with widely varying sex ratios and partnership markets.

Implementation of the model

Initial parameters

The model modifies a simplified version of the partnering mechanisms described in Simao and Todd (2002), originally created by Alam et al (2008), shown in Figure 3.1. Agent-level parameters in the model are outlined in Table 3.2, and consist of a set of agent attributes that are assigned at the start of the run. Settable characteristics of the world in which the agents interact are shown in Table 3.3. The descriptive statistics for each of the distributions of agent characteristics are also set in the model, and are also described in Table 3.3. Each agent is assigned several characteristics relating to the partnering mechanism, including quality (a measure of how desirable a given agent is to other agents), aspiration (the level of quality an agent looks for in a partner), courtship duration (how long an agent needs to date another agent before engaging in a sexual relationship), a waiting threshold (how long the agent will go without a partner before decreasing his/her aspiration level), and the ideal number of partners for the agent (how many partners the agent believes he/she should have in a single year). The values of these parameters are assigned randomly from distributions, so there is not a specific default value for each agent. The quality and aspiration values are drawn from either normal (the default) or skewed distributions, the courtship duration is drawn from a normal distribution, and the waiting times are drawn from a uniform distribution. The ideal number of partners is drawn from a gamma distribution, defined differently for male and female agents using sex-specific lambda and alpha parameters.

The quality and aspiration values assigned to the agents are single values drawn from distributions. Although French and Kus (2008) propose that an array of quality attributes, a separate array of preferences, and limited information about new potential partners more accurately represent the evaluation of dating prospects than single values that are revealed to all potential partners, their parameter-heavy modification to the model does not seem to substantially improve model output relative to empirical data. Though additional parameters defining quality and preferences are intuitively appealing, it is not clear that sufficient data is available to determine reasonable parameter values.

Within the model, the number of agents as well as the sex ratio of male to female agents can be set at runtime. The maximum number of network connections can also be varied.

Model setup

In each run of the model, the agents start with a community of contacts or friends from which to draw sexual partners. This friend network is created before the run starts, as described by Alam et al (2008). First, a random network is formed: (number of possible pairs * R_0) pairs of vertices are chosen uniformly at random from the network to meet. (Note: The R_0 used here is the notation implemented by Alam et al, and should not be confused with the epidemiological concept of the basic reproductive number.) If a pair meet who do not have a pre-existing connection, and if neither of them already has the maximum number of connections then a new connection is established between them. Second, friend-of-a-friend connections are made: (degree * degree minus 1 * R_1) vertices are chosen at random, with probabilities proportional to degree times degree minus one. For each vertex chosen one pair of its neighbors is chosen randomly to meet, and establish one new connection between them if they do not have a preexisting connection

and if neither of them already has the maximum number of connections. After the start of the run, at each time step a new random network connection is made, and a new connection is made between an agent and his/her friend-of-a-friend, adding two connections to the overall network at each time step. In addition, at each time step (number of edges * probability of removal) network connections are randomly chosen for removal. This is done by choosing vertices at random, with probabilities proportional to degree. For each vertex chosen, one of its neighbors is chosen uniformly at random and loses the connection to that neighbor. This creates a dynamic community of connections throughout the run of the model, with agents constantly meeting new individuals and losing touch with old contacts.

Model action

The model is a discrete time model in which each step represents one week. At each model step, after the random and friend-of-a-friend meetings have taken place and some friendships are randomly removed, several things happen. The couples in the model are updated, and agents search for partners. In the interest of building a model comparable to existing literature, the starting point for the current model was a simplified partnering model used in an earlier version of the South Africa model by Alam et al (2008). This model implements the mechanism outlined in Simao and Todd (2002), but uses the community network architecture described above. Alam et al (2008) implemented the model in such a way that only male agents make proposals, and in this model a parameter has been added to determine which agents are able to propose a relationship, men, women, or both. The partnering mechanism has also been expanded to include multiple partners.

At each time step, the asking agents get a list of their opposite-sex friends, which includes all connections in the social network to opposite-sex agents. If the asking agent does not already have any partners, then for each friend, he/she determines whether the quality of each friend is higher than the aspiration level of the agent him/herself, and if so, makes that friend a potential date and sends a message to add him/herself to the list of agents proposing to date the friend agent. If the asking agent is already dating other agents, then the perceived quality of the potential date is weighted by the duration of the current relationships as a proportion of the total model run, or 260 time steps.

$$Q_{\text{current dates}} < Q_{\text{potential date}} * (1- D)$$

$Q_{\text{current dates}}$ = average quality of the current date agents
$Q_{\text{potential date}}$ = quality of the potential date
D = [average time dating current partners / 260]

This provided a weight that was small enough to allow partner switching during the course of the model, and would multiply the quality of the potential partners by progressively smaller weights as the current relationships increased in duration. In addition, a set of parameters for valuing monogamy in current and potential partners is included. First, a probability of knowing the concurrency status of one's partner is defined based on the actual concurrency status. Second, if an agent believes (correctly or incorrectly) that a partner has other partners, the agent imposes a penalty for non-monogamy in comparisons with potential partners. In addition, the "tolerance change" parameter allows agents to become more tolerant of concurrency the longer they are unable to find a partner who meets their aspirations.

Several other weighting strategies were implemented at various points of model development (including a fixed cost for being a potential rather than a current partner, as

well as weighting by a measure of number of partners compared to desired number of partners), but none resulted in qualitatively reasonable results.

If the asking agent's quality level is above the aspiration level of the proposed-to agent, and if this agent does not already have any partners, the proposed-to agent adds the asking agent as a potential date. If the proposed-to friend is currently dating other agents, he/she uses the weighted evaluation method, and if the quality measure is high enough, he/she adds the proposer as his/her potential date. If both agents agree, and have each other listed as potential dates, they then become a couple and are dating, moving one another from the potential *date* list to their lists of potential sexual partners. The agent who receives proposals evaluates them in the order in which they arrive. At each step each couple is updated: the number of weeks they have been dating increases by one, and they evaluate the future of their relationship.

In addition to searching for partners within the network of friends, a runtime-settable parameter defines the probability of making the random acquaintance of another agent outside the friendship network. With the defined probability, the agent has the opportunity to evaluate and propose to a random agent outside his/her social network. To allow for comparison with a non-network-based meeting scheme, there is also a parameter which allows agents to meet all of their potential partners randomly, rather than through the friendship network.

In order to update the couples in the model, each couple evaluates the number of weeks they have been dating and determines whether they should break up, remain dating, or become sexual partners. Break-ups occur probabilistically based on the duration of the relationship. In addition to random break-ups, dating relationships can end if an agent meets a new agent who, after weighting, has a higher quality measure than

one of the agents it is currently dating. In that case, the agent ends the relationship with the least desirable partner. Sexual relationships can end if a new dating relationship reaches the end of the courtship period and is a better match than one of the current sexual partners, in which case the relationship with the least desirable sexual partner ends. These removal procedures are only necessary in the context where the number of dates an agent may have is limited or when the agent already has his/her maximum number of sexual partners. Couples decide to become sexual partners if they have been dating long enough to pass the courtship duration for each partner, and if neither partner already has his/her maximum number of partners.

Model behavior across parameter values

The model was run under a wide range of parameter settings to determine not only the sensitivity to change in the parameters, but also to identify a parameterization that would generate the most realistic descriptive statistics of sexual behavior in the agent population compared with empirical data analysis. Full descriptions of the parameter sweeps and numerical results are given in the online supplemental materials. The reported values for number of partners in the past year, lifetime partners, rates of concurrency, and partner quality correlation are averages based on 50 model runs each. The averages were calculated using data from the final time step of the model, attempting to most closely approximate survey data which is cross-sectional. These particular measures were chosen because they are commonly used measures of sexual behavior and are available in many of the nationally representative US surveys.

The model is set to run for 260 time steps, with each time step representing one week. The 5-year duration of a single run was chosen because it was hypothesized that partner selection as a young adult (approximately ages 20-25) would be relatively age-

independent in this interval and that the mechanisms of partner selection would be more likely to be constant than over a longer time frame (Darroch, Landry, & Oslak, 1999). The number of agents is set to 250, which represents the potential dating network of the agents.

Lifetime partners

The changes in the number of lifetime partners (over the 5-year model run) observed as parameter values were varied are shown in Table 3.4. Only those parameters that caused a greater than one standard deviation change in the number of lifetime partners between the highest and lowest parameter values are listed.

Parameters that determined the availability of partners had the expected results: increases in the number of desired partners on the part of female agents (who on average desired fewer partners than male agents) and in the sex ratio (more men available) increased the number of lifetime partners for female agents, while increasing the sex ratio decreased the number of lifetime partners for male agents. Similarly, drawing quality values from skewed (Chi-squared) distributions, or having male and female agents draw from different distributions decreased the number of lifetime partners because fewer high quality partners were available.

Varying those parameters which defined the search process also gave expected outcomes for the most part. Increasing the number of dates an individual could consider at one time increased the number of lifetime partners, while increasing the courtship period decreased the number of lifetime partners. Notably, when agents used the weighted mechanism to consider new partners (and thus gave more weight to those partners of longer duration), they increased the number of lifetime partners, though it is unclear why this would be the case.

It is interesting to note that when agents have a higher probability of suspecting and punishing concurrency (whether they are correct that their partner has outside partners or not) they ultimately have a higher number of lifetime partners. For female agents, the increase in the number of partners occurred between having no probability of punishing concurrency and 0.20 probability, with little change when the probability of punishing was increased further.

Partners in the last year

The results of varying parameters on the number of partners in the past year (measured at the end of the run) is shown in Table 3.5, with only those parameters that caused a change in the number of partners larger than one standard deviation between the lowest and highest parameter values listed. These results show short term effects of variation in parameter values, and in many respects are similar to the results for lifetime partners. For example, increased availability of partners also increases the number of partnerships that occur in a given year. However, contrasting with the trends observed in lifetime partnerships, punishing true concurrency decreases the number of partners that male agents have. Several other parameters also have opposite effects on the number of partners in the past year compared with their effect on the number of lifetime partners: increasing courtship duration and using the friendship network to find partners both increase the number of partners in the past year, but decrease the number of lifetime partners.

Concurrency

Parameters that caused a change in the rate of concurrency larger than one standard deviation (between the highest and lowest parameter values) are listed in Table 3.6. Punishing concurrency decreases its frequency, as expected. Decreasing the

availability of partners (as evidenced by the effects of decreasing the average number of potential dates, drawing male and female quality values from different distributions, and increasing the lambda values for the distributions of the ideal number of partners, a parameter which ultimately decreases the expected value of the distribution by making it more broad) also reduce rates of concurrency. Increases in rates of concurrency suggest that several parameters can be interpreted as increasing tolerance for concurrency: when agent quality values are drawn from a skewed distribution such that high quality partners are relatively scarce, or when courtship duration is long, requiring individuals to wait before engaging in sexual behavior, rates of concurrency increase for men (but do not change for women); when a weighted switching mechanism is used and agents preferentially maintain existing relationships, rates of concurrency increase.

Correlation in partner quality

There are very few parameters that caused a change in the quality correlation larger than one standard deviation between the highest and lowest parameter values, and they are listed in Table 3.7. As expected, increasing the mean number of dates an agent can have at once increases the correlation, as agents can do a better job of comparing available partners. The largest increase in quality correlation, however, occurred between having only a single date at once and having 6 at once, with little change as the number of dates was increased further. When the quality values are drawn from a skewed distribution the correlation also increases, likely because all of the quality values are lower and thus closer together when this distribution is used. Quality correlation decreases substantially, but unsurprisingly, when male and female quality values are drawn from different distributions. It also decreases when only men propose relationships (compared to women proposing relationships, or both being able to

propose), potentially because male agents desire a larger number of partners and find themselves increasingly willing to ask partners who might be below their initial aspirations, and less desirable overall.

Parameter justification

The final parameterization for the model is shown in Table 3.8. This set of parameter values was derived based on a combination of empirical studies in the literature from public health, evolutionary and social psychology, and sexual decision-making, theoretical work from psychology and public health, parameter settings inherited from Alam and colleagues (2008), the authors' hypotheses about the process of partner selection, and calibration of the model to achieve the most realistic outcomes as measured by the number of partners over the lifetime in the 5-year run and the past year, rates of concurrency over the 5 year run, and correlation in partner quality values.

The sex ratio default is set to 0.5 (an equal number of men and women) as an idealized setting for partner search. This ratio is approximately correct in many communities, though differential mortality (at any point before ages 20-25), incarceration, military service, differential college attendance, and other factors may shift the sex ratio in some settings (for example, see Geronimus, Bound, Waidman, Hillemeier, & Burns, 1996).

The parameters for the friendship network were largely drawn from from Alam et al (2008), or set through calibration to achieve distributions of number of partners and rates of concurrency similar to those observed empirically. The parameters that specify network density and clustering (R_0 and R_1) were calibrated by comparing model output to empirical data. However, note that even large changes in friendship network structure do not result in substantial changes in the model results (see supplemental material). The

probability of network edge removal was retained directly from Alam et al. as well. A maximum degree of 10 was determined to represent a qualitatively reasonable set of contacts from which an agent can draw potential partners. The literature shows that most sexual networks are constrained by geography and local dynamics, so the default setting for the model is for agents to find partners through their friendship network. Based on the National Health and Social Life Survey, approximately 20% of partners were the result of meetings that took place in bars or other places outside of regular social networks, and so the probability of randomly meeting a potential partner was set to 20% (Laumann, et al., 1994).

The distributions of aspiration and quality levels were arbitrarily retained from Alam et al (2008). Because these measures are proxies for many unmeasured variables, the specific numbers are not important. A normal distribution was chosen because many of the traits that determine attraction are normally distributed in the population.

The selection of "both" (versus men-only or women-only) having the ability to propose partnerships was based on data demonstrating that the dating market is increasingly egalitarian. In one study of undergraduate students in the Midwest, 84-90% of men had been asked out by a women and 63-85% of women indicated that they had asked a man out on a date (Mongeau, Hale, Johnson, & Hillis, 1993).

The courtship duration, or the amount of time that an agent must wait before entering into a sexual relationship, was estimated based on survey research conducted with undergraduate students reported in a review of human mating strategies by Buss (2006). He reports that at every time point men are more willing to have sex than women, though to limit the number of model parameters this was collapsed into a single distribution for both male and female agents. Based on his figure, the average

undergraduate student is willing to have sex with someone he/she finds attractive after between 4 and 12 weeks of knowing him/her, with both men and women reporting being willing to have sex with someone after 6 months. A normal distribution with mean 10 weeks and standard deviation 2 was chosen to roughly approximate this distribution. The minimum and maximum waiting times (defining a uniform distribution of how long an agent will wait without a proposal being accepted before decreasing his/her aspiration) were calibrated to produce reasonable model output, as no data was available to compare them with empirical measurements. The maximum number of potential partners an agent could date at one time was also calibrated, though 10 was also seen as a qualitatively reasonable mean, with a relatively large standard deviation (5).

The distribution of the ideal number of partners was also estimated from data on the preferences of undergraduate students (Buss, 2006). As the review demonstrates, women report that this number ranges from 1-2 partners over the course of 1 month or a year to approximately 5 partners over the lifetime. Men report desiring many more partners, with Buss's data suggesting men wish to have around 2 partners over the course of a month, 10-12 over 5 years, and nearly 20 over the course of the lifetime. This data is likely to suffer from substantial social desirability bias in reporting, with men feeling social pressure to report desiring more partners and women feeling social pressure to report desiring few, but those same social pressures may also in part influence sexual decision-making, and this data is the best available. No distribution over the population was reported in the literature, and so a gamma distribution was chosen to represent a skewed distribution, where most individuals report desiring some number of partners near the expected value (found by dividing alpha by lambda). Since an exact parameterization was unclear, the model was run with the expected value of the ideal number of lifetime

partners for men ranging from 6-20 and for women from 2-6. The distribution which appeared closest to empirical data from young adults in the US was produced when the expected value for men was 20 (alpha = 20, lambda = 1) and for women was 2 (alpha = 2, lambda = 1). These values fit reasonably with Buss's empirical data, though clearly more data would improve the selection of parameter values in the model.

Parameters determining whether an agent is able to correctly identify concurrency in a partner were estimated based on empirical data. Several studies comparing adolescents' *beliefs* about the concurrent sexual partnerships of their sexual partners with the actual reports from their sexual partners suggest that only 26-42% of individuals whose partners have other concurrent partners know this, and 14-19% of individuals with monogamous partners believed that their partners had concurrent partners (Drumright, Gorbach, & Holmes, 2004; Lenoir, Adler, Borzekowski, Tschann, & Ellen, 2006). The model parameters were set to fall within the ranges observed: if a partner truly has concurrent partners, the penalty for non-monogamy is applied 30% of the time, and if the partner does not have concurrent partners, the penalty for non-monogamy is applied only 15% of the time, reflecting error in individuals' perceptions of their partners' activities.

Very little data has been collected about how individuals compare partners, particularly once they are dating. While the data clearly suggest that individuals prefer higher quality partners (with higher quality measured in a variety of domains including attractiveness, income, education, etc.), it is not clear how much better a potential partner must be to motivate someone to leave a stable relationship, or the extent to which discovering a partners concurrency makes them less attractive. Clearly there is no single estimate of these values, as individuals likely approach each situation in context. To model these decisions, however, it was determined that individuals would weight their

evaluations of potential new partners using the current duration of their relationship (as a fraction of the 5 year model run), and that partners who were believed to have concurrent partners (either correctly or incorrectly) would be penalized 40% of their quality measure.

The probabilities of random break-ups are hard-coded into the model, meaning that there are not currently parameters defined to set them at run time. If a couple has been dating for less than 2 weeks, 2, 5, 7, or more than 7 weeks the probability of break-up is 0.01, 0.015, 0.025, 0.015, and 0.010 respectively. These probabilities were chosen to include an element of stochasticity in the partnership formation process, and were retained from Alam et al (2008). There is no empirical data available to determine how likely a relationship is to end based on the duration of the partnership.

Comparison of model outcomes with survey data

As described above, parameter values were set using empirical data and then the model was calibrated using the remaining parameters to produce patterns of partnership that look very much like empirical sexual behavior data gathered in nationally representative surveys, which is described below. In addition to large survey data sets, data from several smaller studies were used to estimate attribute correlation among dating individuals as well as the average duration of young people's dating and sexual relationships. While empirical data is not available to determine values for every parameter, using several sets of data for parameterization and separate data sets to calibrate, or tune remaining parameters, is likely to produce credible model results.

Empirical data

There are several extant sources for data on the number of sexual partners men and women living in the United States have over the course of a year or the course of a

lifetime, and how often their partnerships overlap in time (concurrent partnerships). These sources were used in combination because each of the data sources represent a different population at a different point in time, and there is no clear single data source that best fits the model population. The first of these is the National Health and Social Life Survey (NHSLS) (Laumann, et al., 1994). Completed in 1992, this data is nearly 20 years old, meaning that these data were collected in the early years of the HIV/AIDS epidemic in the US. The comprehensive nature of the survey, as well as the comparative network modeling described in the literature using these data, however, makes it a useful comparison for this model. NHSLS distributions of numbers of partners over the past twelve months, number of partners in the past 15 years, and number of partners since age 18 are presented in Table 3.9. Based on the population of interest in this model, i.e. young adults, empirical data for individuals aged 18-24 and 25-29 are shown.

The second source of empirical measures of sexual behavior is the National Survey of Family Growth (NSFG) (Chandra, Martinez, Mosher, Abma, & Jones, 2005; Martinez, Chandra, Abma, Jones, & Mosher, 2006). NSFG was designed to describe and explain trends and group differences in birth rates, such as contraception, infertility, sexual activity, and marriage (http://www.cdc.gov/nchs/nsfg/about_nsfg.htm). The first five waves (1973-1995 were conducted only with women, but the most recent available wave of data (Wave 6, 2002) included both men and women. Data on number of partners for this 6th wave are shown in Table 3.10.

The third source of data about sexual behavior in young adults is the National Longitudinal Survey of Adolescent Health (Add Health). Add Health was developed in response to a mandate from the U.S. Congress to fund a study of adolescent health (Harris & Udry, 2008). Waves I and II focus on the forces that may influence

adolescents' health and risk behaviors, including personal traits, families, friendships, romantic relationships, peer groups, schools, neighborhoods, and communities. Wave III was conducted when respondents were between 18 and 26 years old and focuses on adolescent decisions, behavior, and health outcomes in the transition to adulthood. Data on number of sexual partners reported in Wave III are shown in Table 3.11 below.

Of these sources, only NSFG and Add Health estimate rates of concurrency, or the proportion of individuals who have overlapping partnerships over a particular period of time. These estimates are shown in Table 3.12.

The correlation in partner quality measured here is an approximate measure that is a simplification of measures of correlation between partner income, looks, education, and other factors. Hitsch and colleagues (2006) compare the correlation structure of online matches made through an online dating service to that of married couples. They review the literature and report observed correlations by education ($\rho = 0.64$), income ($\rho = 0.13$), height ($\rho = 0.31$-0.63), weight ($\rho = 0.08$-0.32), and looks ($\rho = 0.34$-0.54). For matches made through the online dating service, the correlations are slightly lower, with looks, height, BMI, income, and years of education having correlation coefficients of 0.33, 0.16, 0.13, 0.15, and 0.13 respectively (Hitsch, et al., 2006). The authors suggest that online dating matches are likely to be less correlated as they reflect "first date" partnerships rather than marriage partnerships, and it is reasonable to suppose that correlation for sexual relationships would fall somewhere between first date partnerships and marriages. These data are also shown in Table 2.13.

In addition to the number of partners and correlation in partnership attributes, the average duration of relationships in the model was compared with average duration of sexual relationships reported in the literature. Reported data are available for adolescents

and young adults between 13 and 20 years of age (Howard, Fortenberry, Blythe, Zimet, & Orr, 1999; Manlove, Ryan, & Franzetta, 2007; Sturdevant et al., 2001). These estimates are for populations slightly younger than the model target population of 20-25 years, but nonetheless provide a useful comparative estimate of relationship duration. Using data from the first two waves of the National Longitudinal Study of Adolescent Health (Add Health), Manlove and colleagues (2007) report that the average duration of pre-sexual relationships is approximately 5 months, with the subsequent sexual relationship lasting 5-6 months, for a total relationship duration of approximately 10-11 months. Among women 13-19 years of age enrolled in a prospective HIV study, the average relationship duration was between eleven and twelve months, and this did not differ by HIV status. In both of these studies, the range of relationship durations was substantial; for example, in the Add Health data, sexual relationships lasted between 1 and 42 months. Howard and colleagues (1999) report that among their sample of young women (15-20 years old) using STD clinic services, 76% had had at least one relationship that lasted less than 21 days. Even if this group has a higher frequency of short relationships, it suggests that measures of current partnership duration, or even relationship duration (with the associated connotations), rather than dates of first and last intercourse, may overestimate relationship duration slightly. Measures of variance in these means were not reported.

Comparison with model results

Based on the survey data discussed above, as well as theoretical considerations and the range of model output demonstrated across reasonable ranges of parameters, a set of parameter values was chosen to represent a base model, shown in Table 3.8.

Model output and empirical distributions of the number of lifetime partners and partners over the past year are compared in Tables 3.9, 3.10, and 3.11. To visualize these comparisons, the distribution of number of partners in the model output was divided into bins corresponding with those presented in the survey data and Figures 3.2 and 3.3 show the model distribution of numbers of partners compared to empirical distributions, with the difference between model and empirical proportions on the x-axis. The model data match most closely with those from men and women aged 20-24 from the NSFG (Table 3.10) and men and women aged 18-26 in Add Health (Table 3.11). The most notable deviation from the empirical data is in the number of male agents that report not having any partners in the past year and those having only one partner in the past year: there are more agents without partners than appear in the empirical data, and there are fewer male agents who report having had one partner in the past year than in the empirical data. It seems likely that some portion of this discrepancy is a result of over-reporting of sexual partners in the past year by male respondents on surveys of sexual behavior due to several potential mechanisms. First, social desirability bias, in this case, reporting a higher number of partners than is true to conform to societal perceptions about male sexuality likely contributes to the discrepancy (Fenton, Johnson, McManus, & Erens, 2001). Second, telescoping, in which a respondent recalls a relationship that occurred 13-14 months prior to the survey as having taken place in the past year, is also a likely contributors to an empirical underestimate of the number of young men who have no sexual partners in a given year. Finally, at least one study has suggested that in responding to surveys, more men than women include non-penetrative sex in the definition of "sexual intercourse," which is another source of potential bias (Jeannin, Konings, Dubois-Arber, Landert, & Van Melle, 1998). Overall, however, the model

produces distributions of partners in the last year and over the lifetime that are qualitatively similar to those distributions observed in empirical data.

Rates of concurrency in the United States reported in the literature range from 11-29%, with reporting time frames ranging from 1-5 years (Adimora, et al., 2002; Adimora, et al., 2007; Ford, et al., 2002). The rates of concurrency in the model are slightly higher than those reported in the empirical data, with 41% and 43% respectively for men and women over the 5 year run. It is important to note the time scale over which these were measured, as well as the fact that the model data captures true rates of concurrency in the model, where the survey data are self-reported. In addition, because of the cumulative nature of the model measure (where each instance of concurrent partnership is captured) and the cross-sectional nature of survey data, it would be expected to see slightly higher rates of concurrency in the model output. These are compared in Table 3.12.

The couples produced in the model have an average quality correlation of 0.14. This is much closer to the correlations in partner attributes observed in matches made through an online dating service, though it is not much lower than the correlation observed in marriages (Hitsch, et al., 2006). Correlations from the literature and model output are compared in Table 3.13.

The average relationship duration of agents in the model is 45.9 weeks, which is approximately 11.5 months. This matches estimates reported in the literature (11-12 months), for young adults and includes both the pre-sexual and sexual parts of the relationships (Howard, et al., 1999; Manlove, et al., 2007; Sturdevant, et al., 2001).

Discussion

Based on traditional survey measures of sexual behavior, correlation between partners, and relationship duration, the model produces qualitatively reasonable results

for sexual partnerships. The model is able to generate distributions of partnership counts and other population-level patterns that are similar to empirical data, using simple algorithms for individual decision-making with realistic parameter values. It is notable that all of the deviations of model output from empirical data are in the anticipated directions based on known limitations of surveys of sexual behavior. The model also behaves reasonably when the sex ratio is altered, as well as when the objective "quality" measures of male and female agents come from different distributions. Though these changes make it more difficult for individuals to find partners, they ultimately change their expectations (and sometimes their tolerance for generally undesirable behaviors like partner concurrency) and find partners even in difficult contexts.

The model behaves in reasonable ways when many of the parameter values are varied. As access to available partners increases through a variety of shifts in parameter values, the observed number of partners also increases. In addition, as the probability of discovering concurrency increases, and as the punishment for having concurrent partners increases, rates of concurrency drop. The model will never exactly reproduce the empirically observed data, since it simplifies many aspects of sexual partnership formation, and uses only estimates of other parameter values for which data are not available. In these cases, the value of the model is in its ability to identify critical parameters for which more data is necessary. Variation in model output due to variation in values chosen for the desired number of partners for male and female agents, as well as courtship duration suggest that more detailed descriptive population-level data about these preferences would help to refine the model. In addition, interpretation of the effects of using the social network to find partners is complicated by the lack of empirical data about how these networks function. Similarly, the effect of weighting the algorithm that

agents use to determine when to switch partners confirms that the implementation of the decision-making process is a sensitive parameter, and that additional data about the process of evaluating potential partners against current ones is needed. In spite of these limitations, the reasonableness of both the mechanism and the results validate this model for use in testing hypotheses about sexual partnership patterns and guiding data collection about the processes that shape sexual-decision making.

Table 3.1. Key characteristics of existing models of partner selection

	Todd and Simao	**French and Kus**	**Alam, Meyer and Norling**	**Knittel et al**
Context	General/ Conceptual	General/ Conceptual	Sekhukhune district, Limpopo, South Africa	Young adults, United States
Mate Quality Measure	Single value	Vector of attributes	Single value with endorsements	Single Value
Aspiration	Single value	Weighted vector of attributes	Single value	Single Value
Partner Solicitation	Male-ask-female	Male-ask-female Female-ask-male Both-ask	Male-ask-female	Both-ask
Parameters establishing willingness to change partners	Meeting rate and remaining courtship time	Temperature	Increasing aspiration with partnership duration	Partnership switch weighted by relationship duration
Concurrent Partnerships	No	No	Men only	Yes
Network Architecture	No	No	Yes	Yes
Migration	No	No	Yes	No

Table 3.2. Agent-level Characteristics

Characteristic	**Variable Name**	**Description**
Gender	gender	Male/Female
Quality	baseQuality	Representation of the value of the agent in a sexual relationship
Aspiration	aspirationLevel	Level of quality the agent seeks in a partner
ID	id	ID number
Courtship Duration	courtShipDuration	Minimum duration of dating before engaging in a sexual relationship
Waiting Threshold	waitingThreshold	How long the agent will wait to have a partner before decreasing the aspiration level
Maximum number of partners	maxPartners	How many partners an agent is able to have at one time

Table 3.3. Run-time Settable Model Parameters

Parameter	Variable Name	Description
Number of Time steps	stopT	Number of steps the model runs before stopping
Number of Agents	NumNodes	Number of agents in the simulation
Sex Ratio	sexRatio	Proportion of men in the initial population, ranges from 0-1
Maximum Degree	maxDegree	Maximum number of social connections for each agent
Probability of Edge Removal	removeProb	Probability that a given edge will be removed
R_0	Rsub0	Proportion of possible pairs chosen to make random meetings
R_1	Rsub1	Multiplier to determine the number of nodes chosen to make neighbor meetings
Aspiration Level Mean	meanAspiration	Mean for the normal distribution of aspiration levels assigned to the agents
Aspiration Level SD	sdAspiration	Standard deviation for the distribution of aspiration levels assigned to the agents
Quality Level Mean	meanQuality	Mean for the distribution of quality values assigned to the agents
Quality Level SD	sdQuality	Standard deviation for the distribution of quality values assigned to the agents
Ask Method	Ask	Switch: if "men," only men propose relationships; if "women," only women propose relationships; if "both," all agents propose relationships
Probability of Random Meeting	probRandomPartner	Probability that at a given time step an agent will meet a potential partner randomly (rather than through the friendship network)
Courtship Duration Mean	meanDuration	Mean for the distribution of minimum courtship time before engaging in a sexual partnership
Courtship Duration SD	sdDuration	Standard deviation for the distribution of minimum courtship times
Minimum Waiting Time	minWaiting	Minimum time without a partner before an agent decreases his/her aspiration level
Maximum Waiting Time	maxWaiting	Maximum time without a partner before an agent decreases his/her aspiration level
Maximum Number Dating Mean	meanNumberDating	Mean for the distribution of the maximum number of potential partners an agent can remember and date at one time

Maximum Number Dating SD	sdNumberDating	Standard deviation for the distribution of the maximum number of potential partners an agent can remember and date at one time
Maximum Number of Partners Alpha - Male	alphaM	Shape parameter for the gamma distribution of maximum number of partners for the male agents
Maximum Number of Partners Lambda - Male	lambdaM	Scale parameter for the gamma distribution of maximum number of partners for the male agents
Maximum Number of Partners Alpha - Female	alphaF	Shape parameter for the gamma distribution of maximum number of partners for the female agents
Maximum Number of Partners Lambda - Female	lambdaF	Scale parameter for the gamma distribution of maximum number of partners for the female agents
Network On	networkOn	Switch: if true, agents meet potential partners through the friendship network; if false, agents meet potential partners randomly
Weighted Partner Switch	weightedSwitch	Switch: if true, agents weight partner comparisons by relationship duration; if false, agents compare raw quality measures
Probability of recognizing true concurrency	probRecognizeConcurrentTrue	Probability that an agent will correctly identify a partner with other concurrent partners
Probability of falsely identifying concurrency	probRecognizeConcurrentFalse	Probability that an agent will identify a truly monogamous partner as having other concurrent partners
Concurrency penalty	concurrentPenalty	Fractional adjustment to partner quality applied when concurrency is identified (either true or false)

Table 3.4. Parameter effects on number of lifetime partners.

Increase in parameter value increases number of partners	Increase in parameter value decreases number of partners
Sex Ratio (female only)	Sex Ratio (male only)
Ask Method (men < both < women) (male only)	Female Lambda (female only)
Mean Number of Dates	Friendship Network (true > false)
Probability Punish True Concurrency	Skewed Quality Distribution
Probability Punish False Concurrency	Male/Female Quality Distribution (equal > unequal)
Weighted Switch (false < true)	Courtship Duration
Concurrency Penalty	Male Alpha (female only)
Female Alpha	
Male Lambda	

Table 3.5. Parameter effects on number of partners in the past 12 months.

Increase in parameter value increases number of partners	Increase in parameter value decreases number of partners
Sex Ratio (female only)	Sex Ratio (male only)
Male and Female Alphas	Probability Punish True Concurrency (male only)
Courtship Duration	
Friendship Network	
Mean Number of Dates (female only)	

Table 3.6. Parameter effects on rate of concurrency.

Increase in parameter value increases rate of concurrency	Increase in parameter value decreases rate of concurrency
Courtship Duration (male only)	Sex Ratio (male only)
Male and Female Alphas	Mean Number of Dates (female only)
Friendship Network (true > false)	Male and Female Lambdas
Skewed Quality Distribution (male only)	Probability Punish True Concurrency (male only)
Weighted Switch	Probability Punish False Concurrency (female only)
	Concurrency Penalty
	Male/Female Difference in Quality Distribution (equal > unequal)

Table 3.7. Parameter effects on quality correlation between partners.

Increase in parameter value increases partner quality correlation	Increase in parameter value decreases partner quality correlation
Mean Number of Dates	Ask Method (men > both > women)
Skewed Quality Distribution (skewed > unskewed)	Male/Female Difference in Quality Distribution (equal > unequal)

Table 3.8. Final parameterization of the model and type of parameter sources

Parameter	Final Value	Type of Source
Number of Time steps	260	Theoretical
Number of Agents	250	Theoretical
Sex Ratio	0.5	Empirical/Theoretical
Maximum Degree	10	Calibration
Probability of Edge Removal	0.005	Alam et al
R_0	0.2	Alam et al and Calibration
R_1	2	Alam et al and Calibration
Aspiration Level Mean	50	Alam et al
Aspiration Level SD	25	Alam et al
Quality Level Mean	50	Alam et al
Quality Level SD	25	Alam et al
Ask Method	both	Empirical/Theoretical
Probability of Random Meeting	0.2	Empirical
Courtship Duration Mean	10	Empirical and Calibration
Courtship Duration SD	2	Empirical and Calibration
Minimum Waiting Time	5	Calibration
Maximum Waiting Time	10	Calibration
Maximum Number Dating Mean	10	Calibration
Maximum Number Dating SD	5	Calibration
Maximum Number of Partners Alpha - Male	20	Empirical and Calibration
Maximum Number of Partners Lambda - Male	1	Empirical and Calibration
Maximum Number of Partners Alpha - Female	2	Empirical and Calibration
Maximum Number of Partners Lambda - Female	1	Empirical and Calibration
Network On	true	Empirical
Weighted Switch	true	Empirical and Calibration
Probability of recognizing true concurrency	0.3	Empirical and Calibration
Probability of falsely identifying concurrency	0.15	Empirical and Calibration
Concurrency penalty	0.6	Calibration
Quality Distribution	normal	Theoretical
Equal Male/Female Quality Distributions	true	Theoretical
Tolerance Change	true	Theoretical

Table 3.9. Number of sexual partners over the past 12 months, the past 5 years, and since age 18 reported in the National Health and Social Life Survey (1992) compared with model output.

Social Characteristics	Number of Partners (%)						N
Partners in the past 12 months	*0*	*1*	*2-4*	*5+*	-	-	
Men (all ages)	9.9	66.7	18.3	5.1	-	-	1,407
Women (all ages)	13.6	74.7	10.0	1.7	-	-	1,748
Age 18-24 (men and women combined)	10.8	57.0	23.7	8.6	-	-	502
Age 25-29 (men and women combined)	5.5	72.0	16.8	5.7	-	-	457
Model Output (Male Agents)	**43.9**	**22.3**	**24.1**	**9.6**	**-**	**-**	**125**
Model Output (Female Agents)	**15.6**	**41.7**	**39.4**	**3.3**	-	-	**125**
Partners in the past 5 years	*0*	*1*	*2-4*	*5-10*	*11-20*	*21+*	
Men (all ages)	7.1	45.7	27.7	12.0	4.2	3.3	1,330
Women (all ages)	8.7	59.4	24.3	5.9	1.4	0.4	1,669
Age 18-24 (men and women combined)	11.8	21.5	38.1	18.4	6.0	4.1	483
Age 25-29 (men and women combined)	4.4	38.0	36.6	11.5	6.5	3.0	434
Partners since age 18	*0*	*1*	*2-4*	*5-10*	*11-20*	*21+*	
Men (all ages)	3.4	19.5	20.9	23.3	16.3	16.6	1,394
Women (all ages)	2.5	31.5	36.4	20.4	6.0	3.2	1,732
Age 18-24 (men and women combined)	7.8	32.1	34.1	15.4	7.8	2.8	499
Age 25-29 (men and women combined)	2.2	25.3	31.3	22.2	9.9	9.0	454
Lifetime Partners							
Model Output (Male Agents)	**15.0**	**10.9**	**29.1**	**33.7**	**10.3**	**1.1**	**125**
Model Output (Female Agents)	**10.9**	**14.9**	**33.3**	**27.7**	**12.0**	**1.1**	**125**

Table 3.10. Number of sexual partners over the past 12 months and over the lifetime reported in the National Survey of Family Growth (2002) compared to model output.

Social Characteristics	Number of Partners (%)*									N
Partners in the past 12 months	*0*	*1*	*2*	*3+*	-	-	-	-	-	
Men 18-19	30.5	36.5	16.2	15.4	-	-	-	-	-	4,460
Men 20-24	15.6	49.3	12.7	19.3	-	-	-	-	-	9,883
Men 25-29	11.4	67.1	6.6	12.5	-	-	-	-	-	9,226
Women 18-19	24.8	42.9	13.6	16.8	-	-	-	-	-	4,015
Women 20-24	13.4	60.9	12.6	11.5	-	-	-	-	-	9,840
Women 25-29	6.9	75.9	9.4	5.7	-	-	-	-	-	9,249
Model Output (Male Agents)	**43.9**	**22.3**	**11.3**	**22.4**	-	-	-	-	-	**125**
Model Output (Female Agents)	**15.6**	**41.7**	**23.9**	**18.8**	-	-	-	-	-	**125**
Lifetime partners	*0*	*1*	*2*	*3*	*4*	*5*	*6-9*	*10-19*	*20+*	
Men 15-19	54.0	15.5	6.7	6.9	3.9	3.4	5.3	3.1	1.1	10,208
Men 20-24	12.6	14.8	11.5	10.4	8.4	8.5	14.8	10.1	8.9	9,883
Men 25-29	4.2	12.5	8.0	8.0	9.0	6.7	21.6	14.9	15.1	9,226
Model Output (Male Agents)**	**15.0**	**10.9**	**11.0**	**9.3**	**8.8**	**7.7**	**26.0**	**10.3**	**1.1**	**125**
	0	*1*	*2*	*3*	*4*	*5*	*6-9*	*10+*	-	
Women 15-19	53.2	18.2	6.9	7.4	4.1	2.4	5.2	2.6	-	9,834
Women 20-24	13.3	23.3	13.4	11.0	7.3	7.5	13.1	11.0	-	9,840
Women 25-29	3.4	23.0	13.1	10.4	7.9	8.2	15.0	19.1	-	9,249
Model Output (Female Agents)**	**10.9**	**14.9**	**13.7**	**11.1**	**8.5**	**7.0**	**20.7**	**13.1**	**-**	**125**

*Percentages do not add to 100% if there are individuals who did not respond to this question.
**Highest categories for model output are 6-10, 11-20, and 21+ for male agents, and 6-10, and 10+ for female agents.

Table 3.11. Number of sexual partners over the past 12 months and over the lifetime reported in the National Longitudinal Survey of Adolescent Health.

Social Characteristics	Number of Partners (%)									N
Partners in the past 12 months	*0*	*1*	*2*	*3*	4	5+	-	-	-	
Men 18-26	22.1	41.9	14.7	7.8	3.5	10.0	-	-	-	5092
Women 18-26	19.1	55.4	12.5	5.4	2.0	5.5	-	-	-	5736
Model Output (Male Agents)	**43.9**	**22.3**	**11.3**	**7.8**	**5.0**	**9.6**	-	-	-	**125**
Model Output (Female Agents)	**15.6**	**41.7**	**23.9**	**11.1**	**4.4**	**3.3**	-	-	-	**125**
Lifetime partners	*0*	*1*	*2*	*3*	*4*	*5*	*6-10*	*11-20*	*21+*	
Women 18-26	12.8	18.6	11.6	10.8	8.2	8.5	17.0	7.3	5.2	5092
Men 18-26	14.3	16.7	11.7	8.9	6.8	7.5	16.4	9.3	8.5	5736
Model Output (Male Agents)	**15.0**	**10.9**	**11.0**	**9.3**	**8.8**	**7.7**	**26.0**	**10.3**	**1.1**	**125**
Model Output (Female Agents)	**10.9**	**14.9**	**13.7**	**11.1**	**8.5**	**7.0**	**20.7**	**12.0**	**1.1**	**125**

Table 3.12. Rates of concurrency as reported in the National Survey of Family Growth and National Longitudinal Survey of Adolescent Health compared to model output.

	Respondents reporting concurrent partnerships % (SD)
National Survey of Family Growth (1995) Concurrent partnership in the past 4 years	
All women	12%
Women 18-24	23%
Women 25-29	15%
National Survey of Family Growth (2002) Concurrent partnership in the past year	
All men	11%
Men with at least 1 sexual partner in the past year	12.5%
National Longitudinal Survey of Adolescent Health (2001-2002) Concurrent partnerships ever	
Women 18-26	29%
Men 18-26	24%
Model Output Concurrent partnerships in the past 5 years	
Women	**43% (4.6)**
Men	**41% (4.5)**

Table 3.13. Reported correlation between partners based on selected attributes compared to model output.

	Marriage	Dating	Model Output
Attribute			
Education	0.64	0.13	
Income	0.13	0.15	
Height	0.31-0.63	0.16	
Weight/BMI	0.08-0.32	0.13	
Looks	0.34-0.54	0.33	
"Quality"			**0.16 (0.11)**

Figure 3.1. Schematic of model implementation.

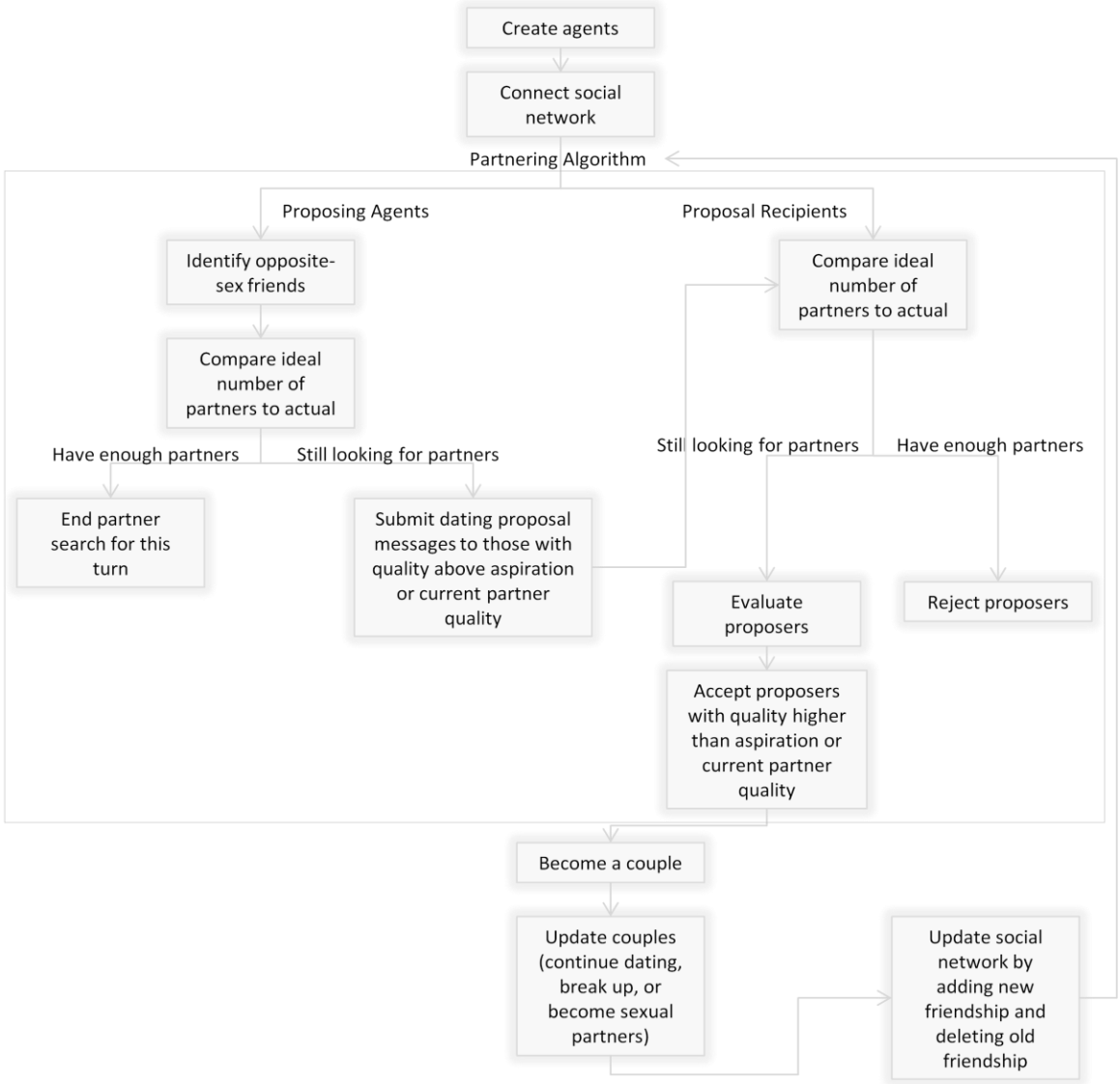


Figure 3.2. Differences in distribution of partners in the past 12 months.

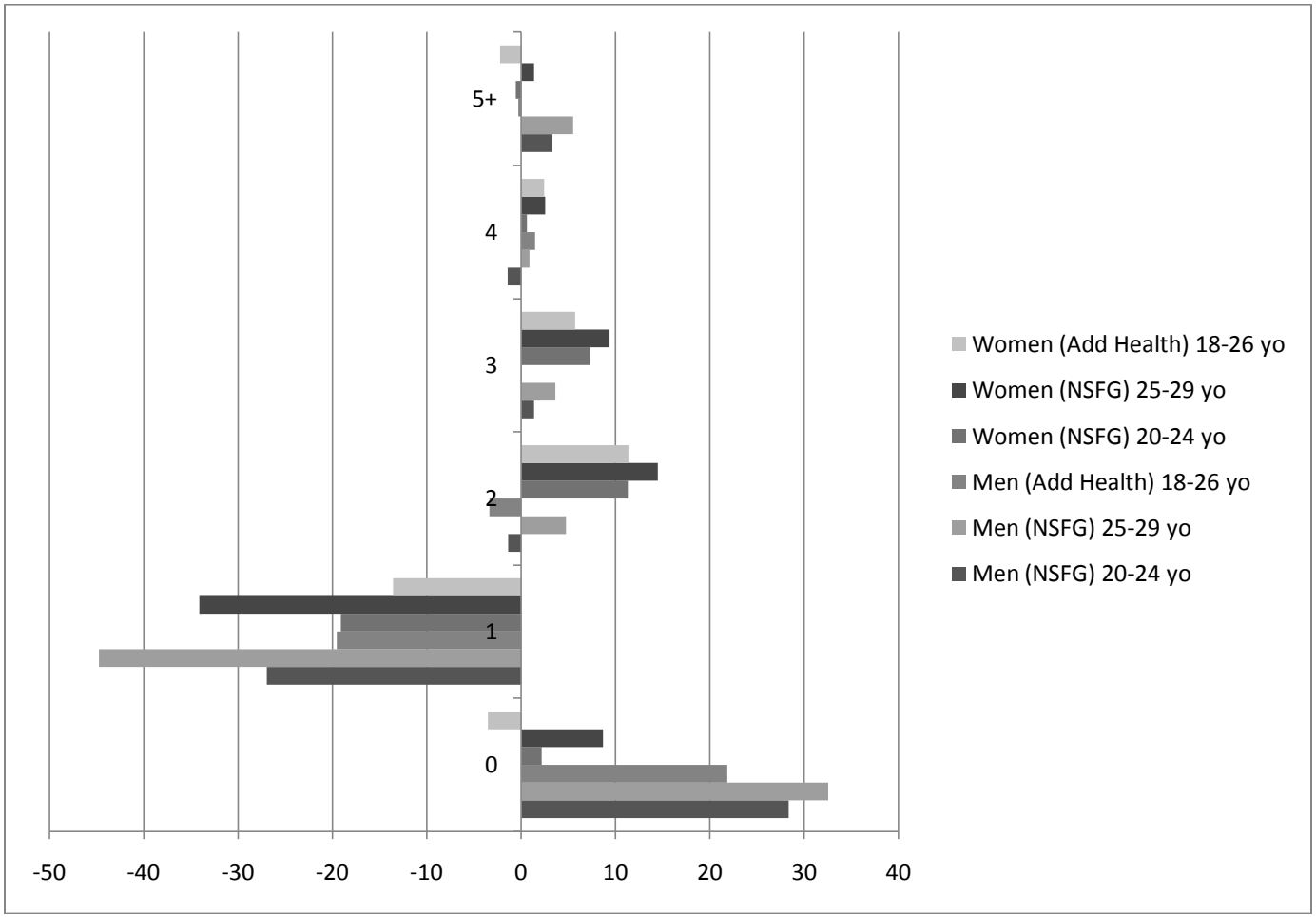
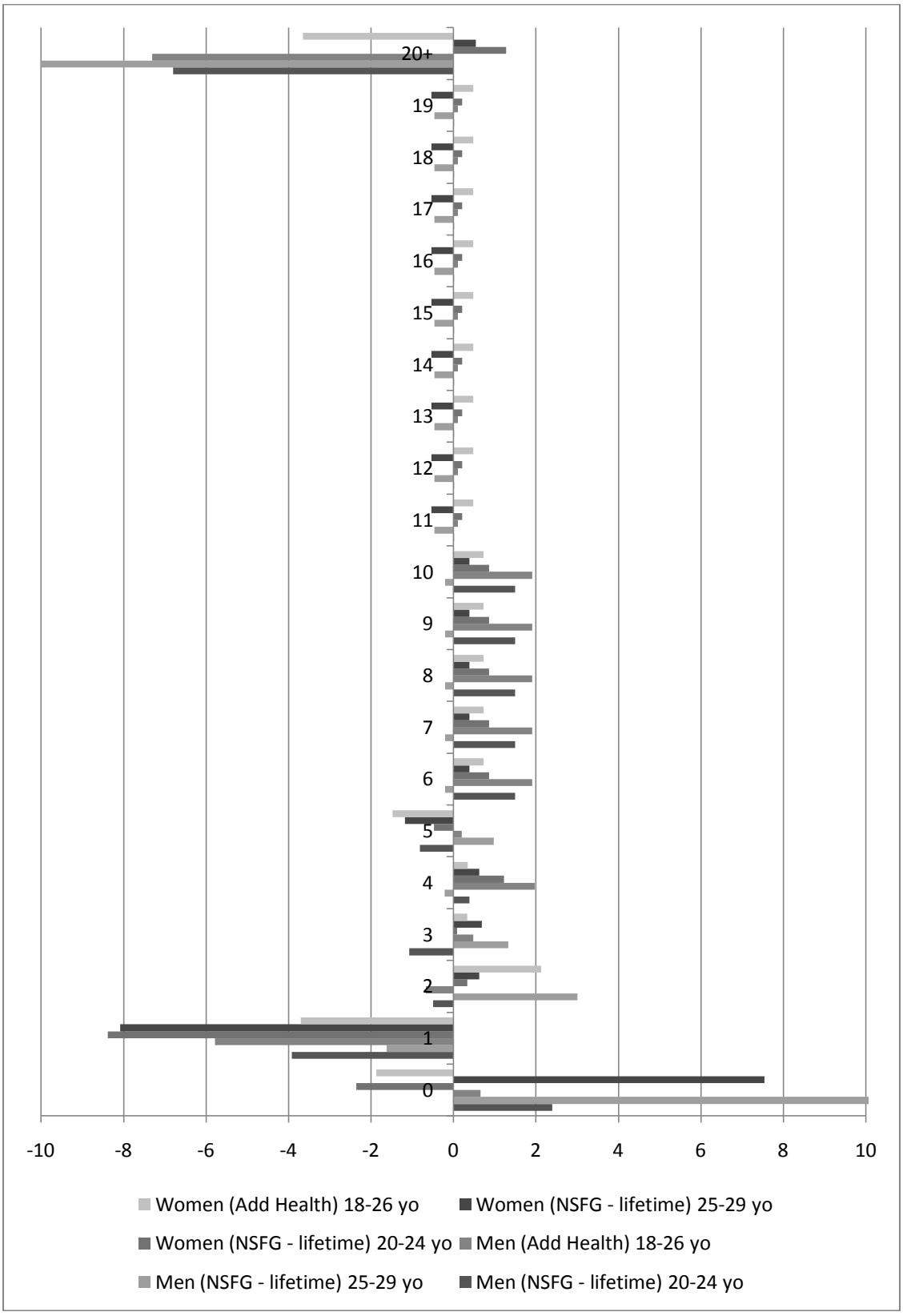


Figure 3.3. Differences in distribution of number of lifetime partners



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Appendix A. Parameter sweep results.

	Partners in the past year		Lifetime partners		% ever concurrent		Quality Correlation
	Male	***Female***	***Male***	***Female***	***Male***	***Female***	
Sex Ratio	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
sR=0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
sR=0.2	4.71 (0.528)	1.568 (0.092)	9.762 (0.957)	3.268 (0.367)	0.71 (0.06)	0.38 (0.043)	0.166 (0.102)
sR=0.4	2.604 (0.27)	1.732 (0.123)	7.416 (0.551)	4.949 (0.407)	0.487 (0.049)	0.421 (0.051)	0.2 (0.092)
sR=0.6	1.611 (0.205)	1.831 (0.145)	5.595 (0.475)	6.396 (0.648)	0.333 (0.047)	0.437 (0.065)	0.153 (0.098)
sR=0.8	0.968 (0.112)	1.843 (0.18)	3.995 (0.331)	7.633 (0.768)	0.182 (0.042)	0.406 (0.07)	0.137 (0.115)
sR=1.0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Ask Method							
aM=both	2.045 (0.23)	1.771 (0.125)	6.421 (0.46)	5.591 (0.52)	0.402 (0.057)	0.428 (0.049)	0.164 (0.091)
aM=men	2.252 (0.258)	1.652 (0.112)	4.486 (0.605)	3.303 (0.422)	0.447 (0.055)	0.394 (0.043)	0.344 (0.102)
aM=women	1.787 (0.331)	1.652 (0.263)	5.6 (0.959)	5.204 (0.91)	0.399 (0.079)	0.404 (0.074)	0.217 (0.116)
Courtship Duration							
mD=0	1.711 (0.244)	1.895 (0.265)	16.347 (1.923)	18.116 (2.262)	0.357 (0.057)	0.464 (0.068)	0.081 (0.09)
mD=10	2.046 (0.232)	1.778 (0.123)	6.331 (0.571)	5.512 (0.325)	0.406 (0.062)	0.428 (0.05)	0.156 (0.085)
mD=20	2.04 (0.228)	1.815 (0.112)	6.083 (0.506)	5.43 (0.409)	0.416 (0.052)	0.438 (0.048)	0.164 (0.087)
mD=30	2.213 (0.23)	1.887 (0.124)	5.917 (0.406)	5.066 (0.403)	0.424 (0.051)	0.43 (0.049)	0.155 (0.092)
mD=40	2.284 (0.28)	1.967 (0.124)	5.367 (0.503)	4.642 (0.385)	0.412 (0.063)	0.432 (0.053)	0.185 (0.106)
mD=50	2.959 (0.315)	2.493 (0.198)	4.919 (0.456)	4.149 (0.335)	0.437 (0.061)	0.435 (0.047)	0.154 (0.094)
Mean Number of Dates							
mDate=1	1.799 (0.301)	1.436 (0.134)	5.42 (0.543)	4.359 (0.401)	0.355 (0.061)	0.331 (0.047)	0.049 (0.095)
mDate=6	1.936 (0.2)	1.698 (0.115)	5.508 (0.435)	4.845 (0.354)	0.397 (0.048)	0.424 (0.046)	0.157 (0.1)
mDate=11	2.069 (0.249)	1.812 (0.139)	6.726 (0.499)	5.916 (0.414)	0.399 (0.052)	0.436 (0.051)	0.163 (0.092)
mDate=16	2.064 (0.204)	1.804 (0.119)	8.959 (0.849)	7.842 (0.586)	0.364 (0.047)	0.425 (0.049)	0.165 (0.089)
mDate=21	1.982 (0.188)	1.729 (0.137)	11.322 (1.103)	9.865 (0.692)	0.318 (0.04)	0.416 (0.051)	0.171 (0.09)

	Partners in the past year		Lifetime partners		% ever concurrent		Quality Correlation
	Male	*Female*	*Male*	*Female*	*Male*	*Female*	
Probability of Punishing True Concurrency							
pTrue=0	2.583 (0.221)	1.823 (0.112)	5.007 (0.386)	3.539 (0.246)	0.483 (0.043)	0.453 (0.049)	0.153 (0.106)
pTrue=0.2	2.027 (0.242)	1.794 (0.1)	6.343 (0.605)	5.636 (0.432)	0.409 (0.047)	0.437 (0.039)	0.158 (0.096)
pTrue=0.4	2.034 (0.206)	1.794 (0.134)	6.501 (0.577)	5.741 (0.409)	0.401 (0.05)	0.438 (0.052)	0.176 (0.088)
pTrue=0.6	2.071 (0.23)	1.795 (0.118)	6.499 (0.445)	5.658 (0.429)	0.4 (0.05)	0.432 (0.049)	0.153 (0.084)
pTrue=0.8	1.969 (0.201)	1.752 (0.105)	6.389 (0.498)	5.706 (0.459)	0.381 (0.043)	0.413 (0.042)	0.157 (0.1)
pTrue=1.0	2.023 (0.251)	1.733 (0.123)	6.489 (0.5)	5.591 (0.48)	0.394 (0.058)	0.418 (0.056)	0.163 (0.114)
Probability of Punishing False Concurrency							
pFalse=0	2.115 (0.233)	1.723 (0.102)	5.229 (0.434)	4.279 (0.363)	0.423 (0.057)	0.436 (0.048)	0.201 (0.107)
pFalse=0.2	2.081 (0.213)	1.765 (0.115)	6.603 (0.495)	5.616 (0.421)	0.405 (0.042)	0.425 (0.04)	0.16 (0.093)
pFalse=0.4	2.057 (0.188)	1.775 (0.128)	6.849 (0.567)	5.911 (0.405)	0.401 (0.049)	0.423 (0.048)	0.197 (0.087)
pFalse=0.6	2.057 (0.21)	1.745 (0.12)	6.954 (0.572)	5.912 (0.433)	0.393 (0.058)	0.409 (0.046)	0.202 (0.096)
pFalse=0.8	2.044 (0.261)	1.692 (0.127)	7.113 (0.608)	5.922 (0.546)	0.382 (0.056)	0.385 (0.055)	0.207 (0.1)
pFalse=1.0	2.022 (0.268)	1.691 (0.118)	7.196 (0.7)	6.048 (0.572)	0.375 (0.057)	0.378 (0.048)	0.215 (0.094)
Probability of Random Meeting	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
pR=0	1.996 (0.337)	1.72 (0.268)	6.368 (1.006)	5.51 (0.932)	0.399 (0.072)	0.42 (0.074)	0.159 (0.099)
pR=0.2	2.029 (0.189)	1.774 (0.126)	6.412 (0.498)	5.627 (0.551)	0.394 (0.044)	0.423 (0.047)	0.15 (0.08)
pR=0.4	2.038 (0.241)	1.794 (0.12)	6.406 (0.574)	5.664 (0.48)	0.408 (0.061)	0.439 (0.05)	0.157 (0.092)
pR=0.6	2.038 (0.275)	1.779 (0.116)	6.183 (0.553)	5.435 (0.521)	0.408 (0.064)	0.436 (0.048)	0.161 (0.088)
pR=0.8	2.074 (0.278)	1.833 (0.128)	6.297 (0.619)	5.59 (0.445)	0.412 (0.059)	0.442 (0.046)	0.162 (0.083)
pR=1.0	2.12 (0.232)	1.846 (0.118)	6.222 (0.54)	5.438 (0.447)	0.423 (0.051)	0.452 (0.049)	0.13 (0.092)

	Partners in the past year		Lifetime partners		% ever concurrent		Quality Correlation
	Male	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*
Maximum Waiting Period							
maxW=10	2.019 (0.211)	1.772 (0.101)	6.345 (0.545)	5.589 (0.463)	0.413 (0.044)	0.426 (0.047)	0.19 (0.102)
maxW=15	1.981 (0.234)	1.755 (0.109)	6.435 (0.491)	5.737 (0.534)	0.399 (0.055)	0.433 (0.037)	0.183 (0.098)
maxW=20	2.054 (0.189)	1.748 (0.125)	6.545 (0.494)	5.584 (0.471)	0.405 (0.053)	0.427 (0.045)	0.159 (0.093)
maxW=25	2.101 (0.223)	1.819 (0.111)	6.547 (0.507)	5.691 (0.433)	0.406 (0.049)	0.453 (0.052)	0.151 (0.094)
Male and Female Lambda							
laF=1-laM=1	2.063 (0.258)	1.786 (0.107)	6.467 (0.57)	5.629 (0.442)	0.412 (0.055)	0.431 (0.048)	0.18 (0.094)
laF=1-laM=2	1.867 (0.184)	1.65 (0.12)	7.255 (0.711)	6.42 (0.581)	0.375 (0.045)	0.439 (0.047)	0.171 (0.08)
laF=1-laM=3	1.658 (0.171)	1.486 (0.094)	7.48 (0.691)	6.715 (0.492)	0.359 (0.043)	0.381 (0.044)	0.22 (0.09)
laF=1-laM=4	1.48 (0.155)	1.36 (0.115)	7.439 (0.726)	6.841 (0.522)	0.338 (0.049)	0.352 (0.035)	0.197 (0.085)
laF=2-laM=1	1.392 (0.197)	1.159 (0.066)	6.325 (0.577)	5.308 (0.44)	0.279 (0.05)	0.151 (0.036)	0.158 (0.105)
laF=2-laM=2	1.288 (0.241)	1.082 (0.169)	6.627 (1.138)	5.595 (0.972)	0.236 (0.056)	0.201 (0.046)	0.154 (0.089)
laF=2-laM=3	1.202 (0.107)	1.023 (0.073)	6.899 (0.564)	5.881 (0.465)	0.245 (0.038)	0.236 (0.03)	0.133 (0.085)
laF=2-laM=4	1.107 (0.136)	0.984 (0.072)	6.543 (0.627)	5.833 (0.493)	0.246 (0.044)	0.247 (0.032)	0.168 (0.078)
Difference in Quality Distribtion							
eQ=false	1.423 (0.31)	1.537 (0.268)	4.003 (0.726)	4.378 (0.913)	0.278 (0.069)	0.365 (0.077)	-0.132 (0.116)
eQ=true	1.985 (0.239)	1.784 (0.142)	6.345 (0.538)	5.723 (0.441)	0.4 (0.056)	0.436 (0.055)	0.187 (0.107)
Maximum Degree							
maxDegree=5	2.043 (0.239)	1.763 (0.112)	6.458 (0.673)	5.59 (0.498)	0.4 (0.049)	0.425 (0.047)	0.168 (0.096)
maxDegree=10	2.006 (0.184)	1.748 (0.118)	6.362 (0.489)	5.552 (0.41)	0.404 (0.048)	0.423 (0.05)	0.18 (0.076)
maxDegree=15	2.086 (0.226)	1.817 (0.125)	6.569 (0.469)	5.745 (0.442)	0.418 (0.047)	0.441 (0.044)	0.177 (0.096)
maxDegree=20	2.012 (0.249)	1.78 (0.121)	6.356 (0.573)	5.643 (0.365)	0.392 (0.051)	0.426 (0.046)	0.157 (0.111)
maxDegree=25	2.073 (0.226)	1.784 (0.107)	6.408 (0.525)	5.532 (0.384)	0.413 (0.058)	0.43 (0.044)	0.19 (0.093)

	Partners in the past year		Lifetime partners		% ever concurrent		Quality Correlation
	Male	***Female***	***Male***	***Female***	***Male***	***Female***	
R0	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
R0=0.005	2.221 (0.242)	1.749 (0.11)	5.744 (0.502)	4.545 (0.429)	0.455 (0.058)	0.421 (0.042)	0.252 (0.124)
R0=0.055	2.05 (0.268)	1.776 (0.131)	6.527 (0.672)	5.679 (0.504)	0.41 (0.061)	0.435 (0.059)	0.147 (0.093)
R0=0.105	2.068 (0.312)	1.798 (0.118)	6.353 (0.567)	5.566 (0.464)	0.41 (0.057)	0.433 (0.055)	0.179 (0.104)
R0=0.155	2.014 (0.238)	1.764 (0.137)	6.399 (0.537)	5.628 (0.461)	0.405 (0.066)	0.424 (0.053)	0.143 (0.091)
R0=0.205	2.057 (0.234)	1.8 (0.124)	6.414 (0.567)	5.629 (0.401)	0.411 (0.054)	0.439 (0.051)	0.173 (0.086)
R0=0.255	2.044 (0.233)	1.76 (0.118)	6.43 (0.513)	5.557 (0.415)	0.413 (0.049)	0.431 (0.048)	0.154 (0.093)
R0=0.305	2.053 (0.243)	1.764 (0.105)	6.527 (0.442)	5.643 (0.45)	0.402 (0.056)	0.427 (0.047)	0.178 (0.108)
R0=0.355	2.067 (0.206)	1.799 (0.113)	6.479 (0.567)	5.651 (0.432)	0.411 (0.052)	0.437 (0.047)	0.158 (0.107)
R0=0.405	2.061 (0.23)	1.782 (0.127)	6.556 (0.543)	5.693 (0.514)	0.408 (0.05)	0.434 (0.049)	0.163 (0.08)
R0=0.455	2.01 (0.22)	1.786 (0.105)	6.365 (0.575)	5.676 (0.488)	0.398 (0.052)	0.437 (0.044)	0.146 (0.083)
R0=0.505	2.051 (0.257)	1.781 (0.134)	6.497 (0.618)	5.672 (0.543)	0.41 (0.054)	0.435 (0.051)	0.171 (0.082)
R1							
R1=1	2.061 (0.19)	1.778 (0.107)	6.362 (0.446)	5.501 (0.378)	0.408 (0.051)	0.432 (0.044)	0.15 (0.099)
R1=2	2.189 (0.239)	1.81 (0.138)	6.749 (0.543)	5.596 (0.433)	0.42 (0.053)	0.444 (0.06)	0.176 (0.089)
R1=3	2.092 (0.219)	1.808 (0.098)	6.527 (0.376)	5.672 (0.472)	0.407 (0.045)	0.434 (0.051)	0.172 (0.087)
R1=4	2.019 (0.229)	1.774 (0.133)	6.478 (0.55)	5.712 (0.478)	0.392 (0.052)	0.434 (0.05)	0.172 (0.089)
R1=5	2.007 (0.229)	1.759 (0.117)	6.349 (0.553)	5.587 (0.453)	0.395 (0.056)	0.425 (0.048)	0.156 (0.078)
R1=6	2.013 (0.217)	1.789 (0.125)	6.367 (0.576)	5.672 (0.446)	0.396 (0.049)	0.427 (0.049)	0.181 (0.11)
R1=7	1.988 (0.214)	1.775 (0.112)	6.398 (0.476)	5.739 (0.494)	0.396 (0.049)	0.437 (0.05)	0.166 (0.095)
R1=8	2.005 (0.212)	1.768 (0.133)	6.437 (0.462)	5.694 (0.445)	0.399 (0.056)	0.431 (0.057)	0.15 (0.093)
R1=9	2.033 (0.25)	1.784 (0.116)	6.389 (0.591)	5.632 (0.498)	0.395 (0.06)	0.425 (0.047)	0.171 (0.089)
R1=10	2.043 (0.223)	1.791 (0.124)	6.402 (0.61)	5.627 (0.446)	0.41 (0.054)	0.434 (0.046)	0.155 (0.099)

	Partners in the past year		Lifetime partners		% ever concurrent		Quality Correlation
	Male	***Female***	***Male***	***Female***	***Male***	***Female***	
Male and Female Alpha	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
alF=2-alM=12	1.927 (0.242)	1.682 (0.099)	7.14 (0.728)	6.251 (0.435)	0.367 (0.058)	0.429 (0.053)	0.167 (0.078)
alF=2-alM=16	2.043 (0.266)	1.759 (0.143)	6.741 (0.67)	5.832 (0.545)	0.397 (0.052)	0.443 (0.042)	0.184 (0.088)
alF=2-alM=20	2.044 (0.216)	1.798 (0.109)	6.452 (0.615)	5.686 (0.418)	0.406 (0.051)	0.436 (0.048)	0.154 (0.094)
alF=2-alM=4	1.382 (0.123)	1.292 (0.108)	6.935 (0.592)	6.492 (0.589)	0.325 (0.047)	0.347 (0.045)	0.174 (0.095)
alF=2-alM=8	1.692 (0.157)	1.551 (0.116)	7.264 (0.516)	6.675 (0.532)	0.351 (0.055)	0.412 (0.045)	0.186 (0.107)
alF=4-alM=12	3.02 (0.324)	2.807 (0.17)	7.637 (0.681)	7.12 (0.557)	0.547 (0.057)	0.714 (0.059)	0.234 (0.102)
alF=4-alM=16	3.319 (0.323)	2.99 (0.145)	7.362 (0.647)	6.646 (0.47)	0.578 (0.049)	0.76 (0.041)	0.203 (0.096)
alF=4-alM=20	3.369 (0.311)	3.013 (0.182)	7.086 (0.511)	6.351 (0.403)	0.573 (0.045)	0.763 (0.042)	0.185 (0.099)
alF=4-alM=4	1.771 (0.18)	1.821 (0.148)	7.459 (0.611)	7.677 (0.531)	0.438 (0.048)	0.437 (0.041)	0.216 (0.081)
alF=4-alM=8	2.557 (0.247)	2.406 (0.17)	8.193 (0.81)	7.715 (0.642)	0.504 (0.048)	0.602 (0.051)	0.189 (0.091)
alF=6-alM=12	3.76 (0.367)	3.746 (0.259)	7.669 (0.716)	7.652 (0.646)	0.646 (0.051)	0.793 (0.046)	0.211 (0.075)
alF=6-alM=16	4.325 (0.479)	4.086 (0.29)	7.76 (0.702)	7.351 (0.571)	0.673 (0.051)	0.844 (0.046)	0.201 (0.097)
alF=6-alM=20	4.56 (0.382)	4.229 (0.258)	7.592 (0.573)	7.058 (0.594)	0.693 (0.047)	0.869 (0.042)	0.193 (0.089)
alF=6-alM=4	2.138 (0.152)	2.209 (0.256)	7.696 (0.619)	7.927 (0.724)	0.533 (0.05)	0.477 (0.055)	0.217 (0.087)
alF=6-alM=8	3.277 (0.305)	3.141 (0.229)	8.202 (0.754)	7.866 (0.628)	0.642 (0.06)	0.677 (0.051)	0.207 (0.087)
alF=8-alM=12	4.559 (0.425)	4.463 (0.257)	8.062 (0.716)	7.917 (0.732)	0.728 (0.053)	0.816 (0.04)	0.245 (0.097)
alF=8-alM=16	5.076 (0.478)	4.968 (0.317)	8.032 (0.643)	7.873 (0.536)	0.743 (0.05)	0.87 (0.035)	0.202 (0.116)
alF=8-alM=20	5.336 (0.423)	5.138 (0.365)	7.9 (0.605)	7.611 (0.578)	0.74 (0.042)	0.891 (0.031)	0.198 (0.099)
alF=8-alM=4	2.432 (0.173)	2.615 (0.204)	7.548 (0.63)	8.114 (0.722)	0.609 (0.048)	0.532 (0.053)	0.211 (0.086)
alF=8-alM=8	3.752 (0.34)	3.766 (0.315)	8.154 (0.723)	8.196 (0.804)	0.713 (0.059)	0.709 (0.059)	0.217 (0.093)
Quality Distribution							
qD=chisquare	2.462 (0.313)	1.596 (0.13)	4.241 (0.522)	2.768 (0.389)	0.512 (0.099)	0.378 (0.068)	0.438 (0.196)
qD=normal	2.074 (0.24)	1.78 (0.125)	6.463 (0.508)	5.57 (0.42)	0.41 (0.053)	0.435 (0.049)	0.159 (0.1)

	Partners in the past year		Lifetime partners		% ever concurrent		Quality Correlation
	Male	*Female*	*Male*	*Female*	*Male*	*Female*	
Concurrency Tolerance Change							
eQ=false-tC=false	1.902 (0.302)	1.49 (0.157)	3.683 (0.418)	2.915 (0.418)	0.378 (0.093)	0.377 (0.081)	-0.139 (0.156)
eQ=false-tC=true	1.879 (0.328)	1.577 (0.146)	3.687 (0.485)	3.136 (0.444)	0.347 (0.072)	0.392 (0.074)	-0.195 (0.134)
eQ=true-tC=false	2.825 (0.304)	1.789 (0.125)	4.985 (0.487)	3.164 (0.258)	0.513 (0.058)	0.463 (0.055)	0.198 (0.13)
eQ=true-tC=true	2.793 (0.306)	1.787 (0.12)	4.923 (0.536)	3.152 (0.24)	0.509 (0.055)	0.446 (0.048)	0.176 (0.109)
Weighted Switch							
wS=false	2.034 (0.307)	1.701 (0.215)	7.354 (0.542)	6.18 (0.558)	0.307 (0.065)	0.31 (0.064)	0.205 (0.096)
wS=true	2.071 (0.182)	1.788 (0.131)	6.502 (0.527)	5.619 (0.448)	0.423 (0.044)	0.436 (0.05)	0.185 (0.113)
Use Friendship Network							
net=false	1.437 (0.347)	1.157 (0.256)	9.251 (0.894)	7.484 (0.878)	0.215 (0.057)	0.237 (0.061)	0.115 (0.101)
net=true	2.087 (0.228)	1.763 (0.114)	6.504 (0.528)	5.506 (0.356)	0.408 (0.055)	0.421 (0.041)	0.2 (0.102)
Concurrent Penalty	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
cP=0	2.978 (0.267)	1.773 (0.122)	4.634 (0.419)	2.76 (0.209)	0.537 (0.062)	0.448 (0.048)	0.234 (0.111)
cP=0.2	2.439 (0.283)	1.79 (0.117)	5.558 (0.557)	4.087 (0.297)	0.45 (0.06)	0.452 (0.044)	0.175 (0.115)
cP=0.4	2.109 (0.266)	1.769 (0.117)	6.175 (0.514)	5.209 (0.448)	0.417 (0.06)	0.433 (0.052)	0.174 (0.105)
cP=0.6	2.03 (0.223)	1.785 (0.131)	6.345 (0.46)	5.609 (0.513)	0.403 (0.054)	0.434 (0.05)	0.199 (0.099)
cP=0.8	2.043 (0.23)	1.8 (0.124)	6.546 (0.601)	5.782 (0.468)	0.418 (0.056)	0.436 (0.055)	0.186 (0.088)
cP=1.0	2.009 (0.251)	1.74 (0.128)	6.715 (0.532)	5.843 (0.456)	0.362 (0.054)	0.388 (0.056)	0.194 (0.099)

Chapter IV

Modeling the effects of incarceration on sexual behavior and sexual partnerships

Introduction

Population and individual level studies have shown associations between rates of incarceration and rates of STDs or HIV, as well as risk factors including numbers of partners and rates of concurrent partners (partnerships that overlap in time) (Adimora, Schoenbach, & Doherty, 2007; Epperson, El-Bassel, Chang, & Gilbert, 2010; Johnson & Raphael, 2005; Khan et al., 2009; Thomas, Levandowski, Isler, Torrone, & Wilson, 2007). Qualitative analyses of the experiences of individuals coming out of prison and jail have also emphasized changed relationship dynamics as a result of incarceration, resulting in changes to sexual networks similar to those identified in quantitative analyses (Bergman, 2008; Braman, 2004; Thomas, et al., 2007).

How incarceration shapes the behavior of sexual partners of incarcerated men is less well studied. Among a sample of men on methadone maintenance therapy and their partners, the incarceration of a female partner was associated with significantly increased odds of having multiple partners in the past six months for men, but the association was not significant for women with incarcerated male partners (Epperson, Khan, El-Bassel, Wu, & Gilbert, 2011). Qualitative work suggests, however, that whether female partners of incarcerated men "go on about [their lives]" while their partners are away or maintain the relationship through visits and calls, they may rely on other relationships for

emotional and financial support, including new sexual partners, during the period of incarceration (Braman, 2004; Comfort, 2008; Thomas, et al., 2007, p. 94).

Clear and colleagues (2003) also hypothesize that incarceration disrupts social networks by damaging familial, economic, and political sources of informal social control, the agreed-upon norms and day-to-day interaction that result in a natural kind of supervision within communities, and it has been suggested that this may also translate into a shift in social norms governing sexuality (Thomas, 2006). They suggest that "coercive mobility" may create a threshold affect, where low levels of incarceration successfully decrease crime (and maintain sexual norms that limit disease spread), but once incarceration rates reach the threshold, crime increases (and risky partnerships increase).

These studies provide compelling evidence for effects of incarceration on sexual behavior and sexual decision-making, and provide theoretical underpinnings for an examination of the effects of incarceration at a community- or population-level, but the shortcomings of empirical data analysis limit our understanding of the mechanisms and magnitude of these effects. The cross-sectional nature of many studies make causal inference impossible, and even where longitudinal data are available, loss of participants over time and the challenge of controlling for important confounding variables complicates the analysis and interpretation of most empirical studies. Experimental designs in this context would be unethical, leaving only well-designed statistical approaches for observational data to estimate the effects of incarceration. In addition to the limitations of observational studies, it is difficult to design a study that successfully measures both individual behavior and community-level effects of incarcerating men.

Relatively little data is available measuring incarceration at a neighborhood or community level, and gathering the complete sexual network data necessary to understand the interconnected nature of partnerships is very difficult. Distinguishing between the effects of incarceration on existing relationships, the future relationship prospects of incarcerated men, and the interaction of various incarceration effects with other community-level characteristics that determine the availability of partners is complicated.

Computational approaches allow for more abstract approaches to these questions by providing a closed system with which to test hypotheses, and they can suggest important avenues for further data collection. Agent-based modeling (ABM) is a promising method for understanding potential mechanisms through which high rates of incarceration may shape sexual networks in communities because it allows for heterogeneity among individuals in the model, and requires an explicit description of the assumptions used in the modeling process. ABM offers the opportunity to experiment with different community rates of incarceration and to manipulate sexual partnership preferences in a way that would be impossible in a study of an actual network of sexual partnerships. Agent-based modeling allows for heterogeneity of agents in this simulation and enables an analysis of effects on patterns of sexual behavior across a range of demographic conditions.

An agent-based modeling approach also has limitations, but these complement those of empirical analysis. Because agents in the model possess only those partnership motivations that have been programmed, and all aspects of the environment are controlled by a series of parameters, this technique allows testing of very specific

hypotheses about the effects of single variables, as well as interactions between different causal factors known to affect sexual networking. The model used in this study is a validated model of sexual partnership combined with an algorithm that incarcerates men and then releases them back into a hypothetical community. The analysis described here offers a "proof of principle," testing whether or not the community experience of incarceration may explain some important proportion of the observed population-level differences in sexual decision-making and sexual networks between communities with high rates of incarceration and those with relatively low rates of incarceration.

Research Questions

1. Could male incarceration, in part, explain observed population-level differences in sexual decision-making and sexual networks?
2. How does male incarceration interact with other factors, such as the sex ratio and availability of high quality partners?

Research Hypotheses

1. Higher community levels of male incarceration will lead to higher numbers of partners for each agent not only among incarcerated individuals, but also across the entire community.
2. Higher community levels of male incarceration will lead to higher rates of concurrency among women in the community.
3. The effects of higher community levels of male incarceration will be exacerbated by low sex ratios (fewer available men) and skewed quality distributions for male agents.

Model Description

Computational models of mate choice for first marriage, which use courtship as a period for comparing potential partners, have matched empirical correlations between partner qualities and the distribution of marriage timing, though it is unclear how detailed measures of mate quality must be, and how best to reflect social norms in the models (Alam, Meyer, & Norling, 2008; French & Kus, 2008; Simao & Todd, 2002). These models help to shape insight about sexual decision-making, but they suffer several substantial limitations. Although they are described broadly as "partnership" models, they assume that partnering is for life, and that each individual can have only one partner. (The Alam, Meyer, and Norling model is an exception here, as it allows for multiple partnerships for men only, though none of the models allow for multiple partnerships for women.) It is clear from empirical data that many individuals have more than one sex partner over the life course, and that substantial numbers of individuals have concurrent partners, or relationships that overlap in time (Adimora et al., 2002; Adimora, et al., 2007). The model used in this study builds on existing models to more accurately reflect sexual partnerships over a 5-year period, rather than simply first marriage.

The model was parameterized to approximate sexual decision-making processes among young (20-25yo) urban residents in the United States. The final parameter values were chosen using a combination of empirical studies in the literature from public health, evolutionary and social psychology, and decision-making; theoretical work from psychology and public health; parameter settings inherited from Alam and colleagues; hypotheses about the process of partner selection; and calibration of the model to achieve the most realistic outcomes. These are summarized in Table 4.1, along with the method(s) used to determine the parameter value. The reported values for each measure in the

model (number of partners in the past year, lifetime partners, rates of concurrency, partner quality correlation, and relationship duration) are averages based on 10 model runs each. All of the measures were calculated at the end of the run, with the number of partners in the last year reflecting the last 52 weeks of the model run (to facilitate comparison with cross-sectional survey data).

The model is implemented using RepastJ, a Java-based simulation package. The model is set to run for 260 time steps, with each time step representing one week. The 5-year duration of a single run was chosen because it was hypothesized that partner selection as a young adult (approximately age 20-25) would be relatively age-independent in this interval, and that the mechanisms of partner selection would be more likely to be constant.

At the start of each model run, each agent is assigned partner search characteristics (quality, aspiration, courtship duration, a waiting threshold, and the ideal number of partners for the agent). The number of agents as well as the sex ratio of male to female agents can be set at runtime. The density and clustering of the friendship network connections can also be varied.

In each run of the model, the agents start with a community of contacts or friends from which to draw sexual partners. At each model step after random and friend-of-a-friend meetings have taken place, and some friendships are randomly removed, several things happen. The agents search for partners, couples are updated, and the agents are updated. Partner search takes place through a friendship network and with some probability each agent also meets a random other agent. Based on an algorithm using the potential partner's quality, the aspiration level, the duration of current partnerships, as

well as whether or not partners are believed to be non-monogamous, the agents form partnerships. Also at each time step, couples evaluate the number of weeks they have been dating and determine whether they should break up, remain dating, or become sexual partners. If the agents are unable to find partners after a period of time (individually defined for each agent as the "waiting period"), they become less selective so their aspiration levels slowly drop, and they become more tolerant of non-monogamy and punish concurrency less harshly.

Based on both traditional survey measures of sexual behavior and measures of correlation between partners, the model produces qualitatively reasonable results for sexual partnerships. The model generates distributions of partnership counts and other population-level patterns that are similar to empirical data, using simple algorithms for individual decision-making with realistic parameter values. Although the model will never exactly reproduce the empirically observed data, since it simplifies many aspects of sexual partnership formation, and uses only estimates of other parameter values for which data are not available, the reasonableness of both the mechanism and the results validate this model for use in testing hypotheses about sexual decision-making.

Incarceration in the model

Incarceration of the agents was defined with the following parameters: probability of male incarceration at each time step, and the mean and standard deviation of a distribution of sentence lengths (in weeks). Female incarceration was not considered due to its rarity. When an agent was incarcerated, the probability of relationship break-up changed, the probability of starting a new relationship changed, and the agent decreased his quality measure as a penalty for incarceration. The probability of partnership during

incarceration (pIP) defines how likely it is that a new relationship could begin during incarceration. With the probability (1 - pIP), the agent is rejected automatically because of his incarceration status, but with probability pIP he is considered using the same algorithm as any other agent. The reverse is true of the probability of break-up due to incarceration (pIB). With probability pIB, the relationship ends due to incarceration, but with probability (1 - pIB), the relationship is evaluated using the same criteria as every other partnership in the model. The incarceration penalty is implemented as the proportion of total quality lost due to incarceration, such that if the incarceration penalty is set to 0.5, an incarcerated man loses 50% of his quality value due to his incarceration at each time step that he is incarcerated.

Absent empirical data to guide parameter value selection, a base model was tested to determine the potential effects of incarceration using qualitative evidence that many partnerships end as a result of incarceration, some new partnerships do begin during incarceration, and that men are generally perceived as less desirable partners after incarceration (Braman, 2004; Comfort, 2008). The probability of initiating a new partnership while incarcerated set to 0.5 and the probability of breaking up as a result of incarceration set to 0.5. These values were chosen to reflect a fairly optimistic outlook for incarceration, where only half of the relationships men have when they are incarcerated end due to that incarceration, and they have a the same probability of starting new relationships while incarcerated. The penalty for incarceration was set to 0.1, so an agent loses 10% of his quality value for each week that he is incarcerated. The mean sentence length was 12 weeks with a standard deviation of 4 weeks, based on rounded estimates from the National Longitudinal Study of Adolescent Health.

This model was run with the probability of incarceration at each time step ranging between zero and 0.003, at intervals of 0.0005 (resulting in a 5 year cumulative probability of incarceration of 0-72%, at intervals of 12%). Results for incarcerated agents are only shown at the highest rate of incarceration in order to have a sufficiently large number of agents in this group.

For sensitivity analyses, the penalty for incarceration, probability of starting a new relationship while incarcerated, and the probability of having a relationship end while incarcerated were each included in a multiplicative sweep with incarceration rate, with the former three measures ranging from 0-1 and incarceration probability at each time step ranging from 0.001 to 0.003 (resulting in a 5 year cumulative probability of incarceration of 24-72%). These parameters reflect the range of mechanisms and magnitudes of the social costs of incarceration to incarcerated individuals and their partners as implemented in the model, and allow for examination of the effects of incarceration in a variety of contexts.

Model results for incarcerated agents are reported only for a probability of incarceration of 0.003/time step, the highest examined here, in order to have sufficiently high numbers of agents in this group.

Additional Experimental Variables

Sex Ratio: A multiplicative sweep was run to determine whether an imbalanced sex ratio would interact with the incarceration rate, where the sex ratio was varied between 0.1 and 0.9 (at intervals of 0.1) at each incarceration rate between 0.001 and 0.003 at each time step (at intervals of 0.001 for the incarceration rate).

Male Agent Quality Distribution: To examine a scenario posed in the literature by Adimora and Schoenbach (2005) in which relatively few educated and employed men are available in urban African American communities compared to the number of educated and employed women, the incarceration rate was varied between 0.001 and 0.003 per time step (at intervals of 0.001) in two different scenarios. In the first, both male and female agent quality values were drawn from a normal distribution centered at 50. In the second, female agent quality values were also drawn from a normal distribution centered at 50, but male agent quality values were drawn from a skewed (Chi-squared) distribution with a mean of only 25 (one standard deviation below the mean of the normal distribution).

Experimental Protocol

The model was run for 260 time steps (260 weeks = 5 years) with 250 agents with the parameterization described above. The reported values for number of partners in the past year, lifetime partners, rates of concurrency, and partner quality correlation are averages based on 10 model runs each, and were calculated using data from the final time step of the model, attempting to most closely approximate survey data which is cross-sectional.

To determine whether incarceration could explain observed population level differences the effects of varying incarceration rates and other incarceration parameters were evaluated among those agents who were incarcerated, and the effects of varying these parameters were also examined looking at the behavior of the entire model population, which includes male agents who have been incarcerated as well as all other agents.

Results

First, the effects of incarceration on measures of sexual behavior are examined to address the first two research hypotheses. Second, in order to understand how incarceration in the model is working, and to determine the sensitivity of the results to changes in uncertain parameter values, the individual parameters that determine how incarceration affects agents are varied. These include sentence length, how likely agents are to start new partnerships while incarcerated and the rate at which partnerships end due to incarceration, as well as the "penalty" for incarceration, the drop in quality an agent experiences due to incarceration. Third, the results of experiments testing interactions between incarceration and the parameters affecting the availability of potential partners are described, testing the third and final research hypothesis.

Base model

Within the population of the model the number of partners in the past year increases slightly with the increase in incarceration rate up to an incarceration rate of approximately 0.002/time step (a cumulative probability of incarceration of 0.48), after which point it plateaus, as is illustrated in Figure 4.1. This increase occurs for both male and female agents, as shown in Table 4.2. There does not appear to be an appreciable effect on number of partners over the lifetime (Table 4.2). Given that no agents are incarcerated at the start of model run, we would expect changes averaged over the full 5 years to be less substantial than those in the final year of the run, when many more men have been incarcerated. Male agents who have been incarcerated during the model run look very similar to those who have not, though the rates of concurrency are very low in this group. Model results for ever incarcerated agents are shown in Table 4.3.

Rates of concurrency among the whole population, shown in Table 4.2, stay relatively constant, and may even drop slightly as incarceration increases. The quality correlation in the overall population drops as incarceration increases (Table 4.2).

Sensitivity Analysis

Among ever incarcerated male agents, increasing the average sentence length had a uniformly negative effect on the number of partners in the past year. The number of lifetime partners increased slightly as sentence length increased, and concurrency was unaffected. Among the full population, however, there was not a substantial effect of increasing the average sentence length: there were no measurable effects on on the number of partners over the past year, lifetime partners, or rates of concurrency among male or female agents. That is, increasing the length of the sentence for male agents who were incarcerated did not change the effect of incarceration on community-level measures of sexual behavior. The quality correlation between partners decreased more rapidly with longer sentence lengths. These results are shown in Table 4.4.

For male agents who had been incarcerated, increasing the probability of new partnership formation while incarcerated was associated with a decrease in the number of lifetime partners, and a slight decrease in concurrency, but did not affect the number of partners in the past year. There was not a substantial change in the effect of incarceration on the number of partners or rates of concurrency in the full population when the probability of new partnership formation while incarcerated was varied, as shown in Table 4.5. The quality correlation between partners decreased as incarceration increased, with a positive or zero correlation at an incarceration rate of 0.001/time step and a negative correlation at 0.003/time step. Increasing the probability of forming new

relationships during incarceration flattened this curve (so that the correlation at all points was closer to zero).

Increasing the probability that existing partnerships were ended as a result of incarceration increased the number of lifetime partners for ever incarcerated agents, while the number of partners in the past year and rates of concurrency were unaffected. Among all agents, the effect of incarceration on the number of partners in the past year was greatest when the probability of breaking off a partnership due to incarceration was intermediate (pIB = 0.4), as shown in Table 4.6. There was no effect on the number of lifetime partners. Rates of concurrency were not correlated with the probability of breaking up during incarceration for male agents who had been incarcerated, but for both male and female agents, a low probability of breaking up increased the rates of concurrency, though these increases were very small.

Among male agents who had been incarcerated, increasing the penalty for incarceration resulted in a decrease in the number of partners over the past year but a slight increase in the number of lifetime partners. For all members of the community, male and female, and incarcerated and non-incarcerated alike, increasing the penalty for incarceration results in increased numbers of partners (both in the past year and over the lifetime); this effect is more pronounced at lower rates of incarceration than higher rates, as shown in Table 4.7. When the penalty for incarceration is low, there is little effect on the quality correlation, but when it is high, increasing incarceration rates dramatically decreases the quality correlation (with a positive correlation at an incarceration rate of 0.001/time step and a negative correlation at 0.003/time step).

Interactions with non-incarceration parameters

When the sex ratio (expressed in the model as the proportion of men in the population) varies, the effect of incarceration is altered. At very high sex ratios (where men are over-represented), the effect of incarceration is pronounced, and there is a substantial increase in the number of partners in the last year, while the effect of incarceration on the number of lifetime partners remains minimal. At the lowest sex ratio (where women make up 90% of the population), the effect of incarceration is diminished. The effect of incarceration has the greatest magnitude at sex ratios that are between the extremes and the balance point, when the proportion of men in the population is either 0.3 or 0.7, as shown in Table 4.8. Though rates of concurrency are sensitive to the sex ratio (in that when there are many more women than men, rates of concurrency are higher for men, and when there are many more men than women, rates of concurrency are higher for women), the effect of incarceration on concurrency remains unremarkable at all sex ratios.

Drawing men's quality measures from a different distribution from women's quality measures was tested to examine how sex differences in education and labor market opportunities might influence the effect of incarceration on measures of sexual behavior. When men's quality measures were drawn from a distribution skewed to lower quality values, both men and women have fewer partners both in the last year and over the lifetime, and lower rates of concurrency compared to drawing the quality measures from the same normal distribution. However, when the values are drawn from different distributions, the magnitude of the effect of incarceration is increased, though the overall effect remains small. These results are shown in Table 4.9.

Discussion

The results from these model experiments suggest that incarceration as implemented in the model can cause an increase in the number of partners at the community level even when cumulative rates of incarceration over the model run are as low as 12% (i.e., a very low probability of incarceration at each step, resulting in a 12% probability of incarceration over the entire model run). The results of these experiments suggest that the disruptive effects of incarceration, as well as the loss in quality men are likely to experience after incarceration, may result in increased numbers of partners for both inmates and for those in their communities. These results are relatively robust to variations in parameters that determined partnership dynamics during incarceration and in sentence length.

These findings extend previous work on the effects of "coercive mobility" which has provided preliminary documentation of an increase in crime with increasing incarceration after a threshold incarceration rate, and offers support to ecological studies linking rates of incarceration with increased rates of STDs and HIV (Clear, et al., 2003; Johnson & Raphael, 2005; Thomas, 2006; Thomas, et al., 2007). At cumulative incarceration rates above 12% in the model, the number of partners in the last year (measured at the end of the model run) for male agents plateaus, but for female agents the number continues to increase. For male agents, above a threshold of 12% there is not a substantial additional effect of incarceration. For female agents in the community, however, additional incarceration seems to represent additional meaningful change in the context of sexual partnership and the number of partners continues to rise. This dose-response relationship among female agents suggests that modest decreases in the incarceration rate may have a more immediate effect on female patterns of partnership,

perhaps by limiting the loss of "high quality" partners that are available, or by maintaining existing relationships.

The incarceration rates in these computational experiments were selected to represent relatively high incarceration rates, but are similar to those reported in African American men. The Bureau of Justice Statistics reports that in 2001, 16.6% of adult black males in the US had ever gone to prison and when the sample is restricted to men below 45 years of age, 22% of black males had been confined in State or Federal prison (Bonczar, 2003). They also report that if incarceration rates remain unchanged, 32.2% of black men born in 2001 will go to prison during their lifetimes (Bonczar, 2003). Pettit and Western (2004) report that black men born 1965-1969 had a 20.5% cumulative risk of incarceration by age 34, and for black men with less than a high school education in this same time period, the cumulative risk is 58.9%. These high rates of incarceration at relatively young ages (before individuals are 34 years old) suggest that lifetime risk of incarceration is concentrated in young adulthood, the time frame represented in the model, and that the cumulative rates of incarceration for the model are reasonable for qualitative comparison with empirical lifetime rates of incarceration.

The potential contribution of high rates of incarceration to the imbalance between numbers of available men and available women in urban African American communities, and the potentially inequitable partnership market this may create, has been presented in the literature previously, (see for example, Adimora & Schoenbach, 2005), and this model presents a unique opportunity to test this framework.

The effects of changing the penalty for incarceration can be conceptualized in terms of the availability of high quality partners. When the penalty is high, fewer men

who have been incarcerated are attractive partners, which both increases the likelihood that their partners will seek and find different, more attractive partners and that those men who have not been incarcerated will have a more substantial advantage in competing for partners, resulting in a situation in which the effective sex ratio leaves available women outnumbering attractive available men by a large margin.

Reducing the stigma of incarceration, as well as reducing the effective "loss of quality," through job training and placement, maintaining community connections, and other during- and post-incarceration interventions would potentially increase the likelihood that existing partnerships would be long-lasting, and would ameliorate the effect of incarceration where it decreases the effective sex ratio (the ratio of attractive male partners to attractive female partners) even more than it decreases the actual sex ratio (the ratio of all men to all women), though clearly reducing incarceration is the best way to eliminate these community-level effects.

These results also offer some support to arguments that a more open criminal justice system, i.e. one that enables the maintenance of inmate's relationships with partners and family, would reduce the instability of partnerships for men who have been incarcerated. Our findings suggest it may also reduce the number of partners observed in communities with high rates of incarceration.

Increasing the average sentence length for male agents who were incarcerated did appear to decrease their number of partners in the past year, but it actually increased the number of lifetime partners. The effect of changing this parameter on the overall population was small in comparison to the effect of adding any incarceration compared to no incarceration; at both the shortest and longest average sentence lengths incarceration

caused a slight increase in the number of partners in the past year. These results suggest that simply removing incarcerated men for a longer period does not improve the sexual risk profile of the individual incarcerated men or the communities from which they come, and that harsher sentences are not the answer to the problems that incarceration brings for communities, as has been suggested by much of the qualitative work on family and partnership dynamics in the context of incarceration (Braman, 2004; Comfort, 2008).

In spite of the potential moderating factors relating to the sentence length and the potential to maintain relationships during incarceration, these model results ultimately show that incarceration, through disruption of partnerships and reducing the capability of formerly incarcerated men to find partners, can shift the larger population toward sexual behavior that enables HIV and other STD transmission. Although the parameter sweeps suggest that this effect could be limited through interventions with incarcerated men, they also show that it could not easily be reduced without substantially reducing rates of incarceration. This series of computational experiments demonstrate a proof of principle: high rates of incarceration can cause shifts in sexual behavior patterns at the community level.

These changes at the community level are small in magnitude, but at population levels even small changes have the propensity to substantially change the landscape of HIV risk. For example, among the small community of agents in this simulation, an average increase of 0.1 partners in the past year multiplied across the population represents an additional 25 partnerships among these 250 agents. Increasing the number of connections between a fixed number of individuals increases network density creating

more opportunities for transmission, and thus increasing risk (Doherty, Padian, Marlow, & Aral, 2005).

In addition, the effects of the sex ratio and the availability of high quality partners as investigated in this model support further exploration. The effect of incarceration has the greatest magnitude at sex ratios that are between the extremes and the balance point, suggesting that in urban African American communities where, due to differentially high male mortality, men make up less than 50% of the population, the effect of incarceration may be more substantial than in communities where the population is balanced between men and women (Geronimus, Bound, Waidman, Hillemeier, & Burns, 1996).

The most notable observation from the interactions between non-incarceration parameters and incarceration rates, however, is that incarceration seems to have a more dramatic effect when men and women have quality measures coming from different distributions (where men's quality values are on average lower than women's). Though the absolute number of partners is overall lower in this situation (likely due to the drastically different distributions chosen to examine this situation), the increases in the number of partners with incarceration are much larger, particularly in partners within the last year. This suggests that incarceration affects most substantially those communities where male unemployment and low education are already high compared to female achievement in the labor market and education. Given the current distribution of incarceration in the United States, it is fair to stay that the system punishes those communities who are most at risk.

This model does have some substantial limitations. It does not take into account any of the potential modifications in approach to sexual decision-making, and qualitative

and theoretical discussions of expressions of masculinity that suggest that men may be more likely to seek out increased numbers of partners after incarceration, potentially exacerbating the effect observed in the model (Thomas, et al., 2007; Whitehead, Peterson, & Kaljee, 1994). As such, many of the mechanisms that Clear et al (2003) propose underlying "coercive mobility" are not included and the model, and it likely underestimates the effect of incarceration on sexual networks in communities where rates of incarceration are high. In addition, the model is not a perfect replica of sexual decision-making. Though the in-depth process of validating the model increases confidence in the model output, it is still possible that it does not capture those aspects of partnership dynamics that are important in incarceration. Finally, there is relatively little empirical data available to empirically validate the implementation of incarceration in the model. The sensitivity analysis suggests that substantial changes in the effects of incarceration in the model would not substantially change the conclusions, but this limitation points to the strong need for data about how sexual relationships change during and after incarceration.

Despite its limitations, however, the model strongly suggests that incarceration may play a role in community-level sexual behavior among groups with high levels of incarceration. The results provide proof of principle that incarceration could explain part of the differences observed between African-American and White sexual networks and patterns of sexual behavior. Though incarceration is likely only one of many factors that determine sexual decision-making, it is improbable that incarceration at current rates does not have substantial effects on community HIV risk.

Table 4.1. Parameterization of the model

Parameter	Final Value	Type of Source
Number of Time steps	260	Theoretical
Number of Agents	250	Theoretical
Sex Ratio	0.5	Empirical/Theoretical
Maximum Degree	10	Calibration
Probability of Edge Removal	0.005	Alam et al
R_0	0.2	Alam et al and Calibration
R_1	2	Alam et al and Calibration
Aspiration Level Mean	50	Alam et al
Aspiration Level SD	25	Alam et al
Quality Level Mean	50	Alam et al
Quality Level SD	25	Alam et al
Ask Method	both	Empirical/Theoretical
Probability of Random Meeting	0.2	Empirical
Courtship Duration Mean	10	Empirical and Calibration
Courtship Duration SD	2	Empirical and Calibration
Minimum Waiting Time	5	Calibration
Maximum Waiting Time	10	Calibration
Maximum Number Dating Mean	10	Calibration
Maximum Number Dating SD	5	Calibration
Maximum Number of Partners Alpha - Male	20	Empirical and Calibration
Maximum Number of Partners Lambda - Male	1	Empirical and Calibration
Maximum Number of Partners Alpha - Female	2	Empirical and Calibration
Maximum Number of Partners Lambda - Female	1	Empirical and Calibration
Network On	true	Empirical
Weighted Switch	true	Empirical and Calibration
Probability of recognizing true concurrency	0.3	Empirical and Calibration
Probability of falsely identifying concurrency	0.15	Empirical and Calibration
Concurrency penalty	0.6	Calibration
Quality Distribution	normal	Theoretical
Equal Male/Female Quality Distributions	true	Theoretical
Tolerance Change	true	Theoretical

Table 4.2. Base model results.

	Partners in the Past Year		Lifetime Partners		Ever Concurrent		Quality Correlation
pIM	Male Avg (SD)	Female Avg (SD)	Male Avg (SD)	Female Avg (SD)	Male Avg (SD)	Female Avg (SD)	Mean (SD)
0	2.015 (0.215)	1.759 (0.13)	6.389 (0.44)	5.596 (0.45)	0.396 (0.048)	0.424 (0.052)	0.19 (0.078)
0.0005	2.107 (0.263)	1.803 (0.125)	6.487 (0.587)	5.58 (0.489)	0.413 (0.063)	0.421 (0.05)	0.142 (0.078)
0.001	2.144 (0.228)	1.833 (0.092)	6.465 (0.557)	5.543 (0.407)	0.405 (0.052)	0.428 (0.037)	0.116 (0.074)
0.0015	2.089 (0.212)	1.836 (0.15)	6.402 (0.497)	5.637 (0.454)	0.392 (0.045)	0.419 (0.053)	0.064 (0.089)
0.002	2.158 (0.251)	1.856 (0.148)	6.406 (0.562)	5.524 (0.399)	0.406 (0.055)	0.428 (0.055)	0.072 (0.079)
0.0025	2.135 (0.228)	1.861 (0.138)	6.408 (0.482)	5.603 (0.413)	0.409 (0.045)	0.418 (0.047)	0.011 (0.081)
0.003	2.126 (0.227)	1.85 (0.136)	6.394 (0.475)	5.585 (0.499)	0.388 (0.056)	0.406 (0.054)	-0.014 (0.089)

Table 4.3. Model output for ever incarcerated agents.

		Concurrency	Partners in the past year	Lifetime partners	N (ever incarcerated)
		Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Base	0.003	0.003 (0.007)	2.088 (0.437)	6.329 (1.088)	66.34 (12.195)
pIP	0	0.005 (0.009)	2.04 (0.449)	6.465 (0.755)	67.6 (7.954)
	0.2	0.003 (0.008)	2.025 (0.423)	6.17 (1.137)	67.04 (11.877)
	0.4	0.004 (0.008)	2.123 (0.32)	6.354 (0.628)	66.86 (5.689)
	0.6	0.003 (0.006)	2.106 (0.35)	6.319 (0.685)	69.92 (5.976)
	0.8	0.003 (0.007)	2.019 (0.347)	6.51 (0.685)	67.04 (7.126)
	1	0.002 (0.007)	2.037 (0.325)	6.209 (0.602)	67.08 (6.875)
pIB	0	0.003 (0.007)	2.174 (0.527)	6.161 (1.125)	67.42 (12.187)
	0.2	0.003 (0.007)	2.004 (0.301)	6.229 (0.585)	68.68 (7.514)
	0.4	0.002 (0.006)	2.184 (0.29)	6.588 (0.631)	68.06 (7.541)
	0.6	0.004 (0.008)	2.025 (0.322)	6.377 (0.7)	68.32 (7.787)
	0.8	0.003 (0.008)	2.092 (0.386)	6.371 (0.86)	67.36 (7.907)
	1	0.003 (0.007)	2.143 (0.309)	6.459 (0.616)	67.4 (7.166)
iP	0	0.002 (0.006)	2.117 (0.334)	6.285 (0.661)	66.86 (7.519)
	0.2	0.004 (0.008)	2.041 (0.263)	6.232 (0.623)	68.64 (6.401)
	0.4	0.006 (0.009)	2.109 (0.333)	6.204 (0.684)	67.2 (6.633)
	0.6	0.004 (0.008)	2.041 (0.38)	6.323 (0.691)	67.58 (7.276)
	0.8	0.002 (0.007)	2.032 (0.324)	6.306 (0.673)	69.02 (7.504)
	1	0.002 (0.005)	1.987 (0.32)	6.34 (0.741)	67.94 (7.841)
mT	4	0.003 (0.006)	2.109 (0.358)	6.226 (0.732)	66.14 (6.863)
	8	0.004 (0.008)	2.058 (0.39)	6.184 (0.721)	66.22 (6.544)
	12	0.004 (0.008)	2.032 (0.323)	6.363 (0.697)	67.58 (6.328)
	16	0.002 (0.006)	2.102 (0.316)	6.404 (0.598)	68.62 (6.791)
	20	0.002 (0.006)	2.048 (0.386)	6.403 (0.799)	67.14 (7.239)
	24	0.003 (0.007)	2.009 (0.364)	6.163 (0.699)	68.92 (7.488)
	28	0.003 (0.008)	2.055 (0.384)	6.378 (0.631)	66.84 (7.02)
	32	0.004 (0.008)	2.024 (0.354)	6.394 (0.79)	67.76 (7.466)
sR	0.1	0.034 (0.037)	5.988 (1.658)	7.976 (2.038)	13.46 (3.626)
	0.3	0.01 (0.016)	3.95 (0.7)	6.471 (0.927)	40.44 (5.556)
	0.5	0.001 (0.005)	2.667 (0.501)	4.985 (0.642)	67.18 (6.527)
	0.7	0.002 (0.007)	1.782 (0.295)	3.808 (0.495)	94.78 (6.774)
	0.9	0.001 (0.006)	1.177 (0.298)	2.625 (0.596)	121.24 (9.104)
eQ	FALSE	0.003 (0.009)	1.86 (0.33)	3.195 (0.413)	67.58 (8.013)
	TRUE	0.003 (0.008)	2.61 (0.533)	4.857 (1.005)	65.34 (12.011)

Table 4.4. Variation in sentence length.

mT	4	8	12	16	20	24	28	32
pIM		Partners in the past year (male)						
0.001	2.114 (0.245)	2.104 (0.229)	2.123 (0.272)	2.07 (0.2)	2.151 (0.306)	2.102 (0.239)	2.058 (0.379)	2.109 (0.232)
0.002	2.094 (0.257)	2.053 (0.243)	2.082 (0.225)	2.151 (0.282)	2.183 (0.287)	2.078 (0.385)	2.179 (0.285)	2.148 (0.28)
0.003	2.089 (0.262)	2.125 (0.265)	2.191 (0.393)	2.141 (0.248)	2.154 (0.24)	2.083 (0.269)	2.134 (0.266)	2.097 (0.28)
		Partners in the past year (female)						
0.001	1.786 (0.122)	1.817 (0.088)	1.824 (0.128)	1.804 (0.114)	1.834 (0.137)	1.829 (0.135)	1.778 (0.299)	1.858 (0.105)
0.002	1.812 (0.137)	1.83 (0.102)	1.856 (0.123)	1.831 (0.127)	1.868 (0.115)	1.85 (0.305)	1.882 (0.137)	1.86 (0.143)
0.003	1.835 (0.125)	1.845 (0.125)	1.859 (0.298)	1.848 (0.152)	1.87 (0.17)	1.862 (0.123)	1.876 (0.145)	1.865 (0.122)
		Lifetime partners (male)						
0.001	6.569 (0.6)	6.436 (0.538)	6.524 (0.555)	6.461 (0.55)	6.463 (0.636)	6.494 (0.548)	6.38 (1.031)	6.45 (0.527)
0.002	6.366 (0.525)	6.29 (0.537)	6.361 (0.562)	6.496 (0.635)	6.469 (0.602)	6.319 (1.087)	6.482 (0.56)	6.41 (0.597)
0.003	6.349 (0.471)	6.375 (0.629)	6.36 (1.074)	6.507 (0.478)	6.372 (0.408)	6.281 (0.537)	6.459 (0.504)	6.279 (0.541)
		Lifetime partners (female)						
0.001	5.573 (0.506)	5.578 (0.39)	5.64 (0.535)	5.639 (0.382)	5.544 (0.478)	5.669 (0.422)	5.527 (0.906)	5.704 (0.43)
0.002	5.528 (0.372)	5.636 (0.471)	5.686 (0.449)	5.557 (0.475)	5.569 (0.486)	5.643 (0.957)	5.627 (0.391)	5.584 (0.547)
0.003	5.618 (0.504)	5.553 (0.444)	5.408 (0.888)	5.639 (0.442)	5.55 (0.465)	5.647 (0.441)	5.701 (0.391)	5.616 (0.458)
		Ever concurrent (male)						
0.001	0.413 (0.044)	0.407 (0.057)	0.405 (0.061)	0.395 (0.049)	0.406 (0.054)	0.4 (0.045)	0.393 (0.074)	0.397 (0.048)
0.002	0.395 (0.054)	0.39 (0.057)	0.384 (0.039)	0.401 (0.057)	0.409 (0.061)	0.392 (0.083)	0.388 (0.052)	0.399 (0.062)
0.003	0.392 (0.046)	0.386 (0.057)	0.398 (0.078)	0.384 (0.058)	0.39 (0.042)	0.365 (0.061)	0.388 (0.053)	0.386 (0.057)
		Ever concurrent (female)						
0.001	0.425 (0.045)	0.421 (0.05)	0.425 (0.049)	0.418 (0.04)	0.423 (0.047)	0.415 (0.054)	0.413 (0.077)	0.429 (0.052)
0.002	0.408 (0.042)	0.421 (0.047)	0.414 (0.036)	0.408 (0.042)	0.418 (0.047)	0.415 (0.082)	0.419 (0.051)	0.429 (0.061)
0.003	0.418 (0.049)	0.414 (0.051)	0.406 (0.079)	0.402 (0.051)	0.404 (0.046)	0.395 (0.045)	0.41 (0.053)	0.404 (0.047)
		Quality Correlation						
0.001	0.145 (0.107)	0.127 (0.074)	0.104 (0.086)	0.108 (0.067)	0.104 (0.065)	0.087 (0.081)	0.089 (0.085)	0.068 (0.087)
0.002	0.13 (0.099)	0.11 (0.075)	0.062 (0.083)	0.027 (0.072)	0.039 (0.077)	0.042 (0.071)	0.028 (0.094)	-0.002 (0.09)
0.003	0.103 (0.094)	0.036 (0.066)	-0.029 (0.075)	-0.033 (0.085)	-0.048 (0.08)	-0.072 (0.097)	-0.059 (0.073)	-0.085 (0.077)

Table 4.5. Variation in the probability of initiating new partnerships while incarcerated.

pIP	0	0.2	0.4	0.6	0.8	1
	Mean (SD)					
pIM	Partners in the last year - male					
0.001	2.085 (0.247)	2.143 (0.245)	2.112 (0.221)	2.117 (0.255)	2.095 (0.223)	2.026 (0.262)
0.002	2.135 (0.247)	2.118 (0.259)	2.081 (0.235)	2.145 (0.23)	2.124 (0.261)	2.144 (0.221)
0.003	2.139 (0.266)	2.184 (0.261)	2.15 (0.209)	2.072 (0.377)	2.216 (0.289)	2.179 (0.24)
	Partners in the last year (female)					
0.001	1.826 (0.114)	1.835 (0.149)	1.839 (0.118)	1.831 (0.136)	1.825 (0.131)	1.775 (0.123)
0.002	1.816 (0.115)	1.827 (0.146)	1.852 (0.125)	1.819 (0.133)	1.837 (0.137)	1.848 (0.142)
0.003	1.842 (0.114)	1.867 (0.117)	1.871 (0.155)	1.818 (0.286)	1.862 (0.106)	1.861 (0.14)
	Lifetime partners (male)					
0.001	6.53 (0.631)	6.492 (0.49)	6.429 (0.469)	6.474 (0.503)	6.453 (0.595)	6.384 (0.553)
0.002	6.578 (0.545)	6.36 (0.486)	6.347 (0.515)	6.621 (0.534)	6.409 (0.575)	6.541 (0.5)
0.003	6.493 (0.6)	6.604 (0.497)	6.412 (0.464)	6.193 (1.115)	6.457 (0.533)	6.425 (0.507)
	Lifetime partners (female)					
0.001	5.749 (0.565)	5.578 (0.453)	5.621 (0.453)	5.623 (0.417)	5.636 (0.489)	5.623 (0.462)
0.002	5.626 (0.515)	5.514 (0.484)	5.668 (0.422)	5.637 (0.533)	5.565 (0.471)	5.648 (0.411)
0.003	5.615 (0.449)	5.675 (0.441)	5.593 (0.486)	5.441 (0.891)	5.468 (0.503)	5.5 (0.368)
	Ever concurrent (male)					
0.001	0.402 (0.05)	0.411 (0.056)	0.405 (0.052)	0.404 (0.053)	0.407 (0.052)	0.395 (0.067)
0.002	0.409 (0.055)	0.399 (0.055)	0.405 (0.059)	0.409 (0.049)	0.392 (0.062)	0.397 (0.055)
0.003	0.391 (0.057)	0.405 (0.059)	0.398 (0.045)	0.38 (0.076)	0.405 (0.065)	0.401 (0.061)
	Ever concurrent (female)					
0.001	0.429 (0.045)	0.433 (0.052)	0.424 (0.049)	0.43 (0.052)	0.424 (0.044)	0.418 (0.052)
0.002	0.416 (0.045)	0.413 (0.053)	0.416 (0.043)	0.414 (0.046)	0.409 (0.049)	0.424 (0.047)
0.003	0.404 (0.053)	0.417 (0.041)	0.408 (0.044)	0.396 (0.068)	0.416 (0.054)	0.403 (0.049)
	Quality correlation					
0.001	0.119 (0.088)	0.107 (0.083)	0.121 (0.076)	0.116 (0.066)	0.124 (0.061)	0.098 (0.065)
0.002	0.075 (0.076)	0.059 (0.086)	0.041 (0.066)	0.043 (0.083)	0.061 (0.088)	0.057 (0.085)
0.003	0 (0.082)	-0.022 (0.092)	-0.004 (0.082)	0.01 (0.075)	-0.013 (0.089)	-0.017 (0.09)

Table 4.6. Variation in the probability of partnership break-up while incarcerated.

pIB	0	0.2	0.4	0.6	0.8	1
pIM		Partners in the past year (male)				
0.001	2.116 (0.208)	2.119 (0.267)	2.083 (0.261)	2.097 (0.238)	2.119 (0.26)	2.119 (0.224)
0.002	2.212 (0.244)	2.084 (0.283)	2.149 (0.272)	2.099 (0.181)	2.115 (0.253)	2.035 (0.371)
0.003	2.146 (0.275)	2.184 (0.255)	2.192 (0.268)	2.131 (0.23)	2.112 (0.27)	2.102 (0.373)
		Partners in the past year (female)				
0.001	1.828 (0.135)	1.837 (0.118)	1.792 (0.115)	1.842 (0.155)	1.815 (0.156)	1.832 (0.133)
0.002	1.917 (0.135)	1.832 (0.124)	1.852 (0.145)	1.855 (0.149)	1.857 (0.131)	1.792 (0.284)
0.003	1.922 (0.15)	1.888 (0.131)	1.889 (0.141)	1.857 (0.127)	1.864 (0.116)	1.802 (0.289)
		Lifetime partners (male)				
0.001	6.399 (0.482)	6.43 (0.563)	6.447 (0.563)	6.401 (0.541)	6.525 (0.544)	6.397 (0.46)
0.002	6.533 (0.506)	6.328 (0.555)	6.512 (0.601)	6.438 (0.504)	6.402 (0.562)	6.206 (1.025)
0.003	6.416 (0.499)	6.372 (0.477)	6.47 (0.569)	6.425 (0.505)	6.35 (0.532)	6.314 (1.06)
		Lifetime partners (female)				
0.001	5.545 (0.458)	5.602 (0.459)	5.577 (0.444)	5.636 (0.45)	5.608 (0.421)	5.554 (0.457)
0.002	5.675 (0.367)	5.599 (0.495)	5.632 (0.433)	5.694 (0.442)	5.647 (0.469)	5.487 (0.918)
0.003	5.779 (0.526)	5.534 (0.452)	5.603 (0.496)	5.617 (0.446)	5.638 (0.494)	5.425 (0.881)
		Ever concurrent (male)				
0.001	0.407 (0.046)	0.41 (0.065)	0.398 (0.057)	0.399 (0.054)	0.403 (0.049)	0.401 (0.051)
0.002	0.422 (0.056)	0.397 (0.059)	0.403 (0.055)	0.39 (0.045)	0.389 (0.054)	0.397 (0.082)
0.003	0.399 (0.049)	0.409 (0.062)	0.393 (0.055)	0.383 (0.045)	0.39 (0.058)	0.388 (0.084)
		Ever concurrent (female)				
0.001	0.439 (0.057)	0.436 (0.049)	0.409 (0.047)	0.428 (0.059)	0.412 (0.048)	0.419 (0.05)
0.002	0.436 (0.042)	0.417 (0.047)	0.418 (0.047)	0.418 (0.046)	0.42 (0.056)	0.409 (0.075)
0.003	0.418 (0.048)	0.418 (0.036)	0.419 (0.042)	0.407 (0.048)	0.408 (0.04)	0.4 (0.078)
		Qualtiy correlation				
0.001	0.107 (0.082)	0.116 (0.082)	0.113 (0.075)	0.125 (0.07)	0.108 (0.094)	0.105 (0.088)
0.002	0.024 (0.085)	0.022 (0.077)	0.045 (0.086)	0.065 (0.083)	0.074 (0.087)	0.052 (0.078)
0.003	-0.014 (0.093)	-0.017 (0.086)	-0.021 (0.086)	-0.023 (0.086)	-0.008 (0.087)	-0.004 (0.088)

Table 4.7. Variation in the penalty for incarceration.

iP	0	0.2	0.4	0.6	0.8	1
pIM		Partners in the past year (male)				
0.001	2.067 (0.219)	2.142 (0.248)	2.095 (0.218)	2.105 (0.239)	2.12 (0.263)	2.131 (0.317)
0.002	2.052 (0.235)	2.15 (0.23)	2.172 (0.254)	2.202 (0.24)	2.172 (0.253)	2.101 (0.263)
0.003	2.097 (0.255)	2.178 (0.25)	2.131 (0.392)	2.151 (0.23)	2.11 (0.274)	2.155 (0.247)
		Partners in the past year (female)				
0.001	1.777 (0.121)	1.849 (0.134)	1.858 (0.13)	1.86 (0.128)	1.88 (0.155)	1.851 (0.139)
0.002	1.766 (0.13)	1.879 (0.164)	1.879 (0.129)	1.86 (0.124)	1.862 (0.126)	1.865 (0.128)
0.003	1.784 (0.132)	1.914 (0.146)	1.841 (0.29)	1.873 (0.118)	1.834 (0.127)	1.864 (0.138)
		Lifetime partners (male)				
0.001	6.408 (0.461)	6.569 (0.537)	6.438 (0.569)	6.476 (0.527)	6.34 (0.54)	6.504 (0.565)
0.002	6.42 (0.542)	6.42 (0.463)	6.534 (0.545)	6.562 (0.534)	6.524 (0.57)	6.441 (0.47)
0.003	6.354 (0.662)	6.376 (0.547)	6.381 (1.059)	6.407 (0.533)	6.343 (0.576)	6.482 (0.508)
		Lifetime partners (female)				
0.001	5.527 (0.411)	5.698 (0.51)	5.719 (0.426)	5.745 (0.478)	5.642 (0.46)	5.689 (0.397)
0.002	5.546 (0.479)	5.623 (0.455)	5.668 (0.364)	5.562 (0.42)	5.613 (0.44)	5.76 (0.549)
0.003	5.423 (0.477)	5.622 (0.437)	5.533 (0.905)	5.602 (0.483)	5.543 (0.485)	5.632 (0.496)
		Ever concurrent (male)				
0.001	0.403 (0.061)	0.412 (0.058)	0.397 (0.057)	0.384 (0.05)	0.405 (0.051)	0.399 (0.067)
0.002	0.412 (0.05)	0.392 (0.059)	0.398 (0.055)	0.399 (0.049)	0.401 (0.055)	0.39 (0.046)
0.003	0.409 (0.054)	0.392 (0.056)	0.385 (0.079)	0.389 (0.053)	0.383 (0.049)	0.384 (0.036)
		Ever concurrent (female)				
0.001	0.425 (0.046)	0.432 (0.053)	0.424 (0.041)	0.42 (0.046)	0.426 (0.052)	0.43 (0.059)
0.002	0.422 (0.045)	0.411 (0.061)	0.416 (0.049)	0.408 (0.052)	0.412 (0.046)	0.416 (0.05)
0.003	0.419 (0.053)	0.406 (0.052)	0.402 (0.08)	0.404 (0.044)	0.397 (0.044)	0.406 (0.053)
		Quality correlation				
0.001	0.16 (0.071)	0.097 (0.078)	0.094 (0.057)	0.064 (0.074)	0.083 (0.077)	0.062 (0.086)
0.002	0.171 (0.099)	0.015 (0.09)	-0.009 (0.082)	-0.01 (0.082)	0.009 (0.067)	-0.005 (0.09)
0.003	0.169 (0.083)	-0.062 (0.081)	-0.071 (0.086)	-0.103 (0.069)	-0.068 (0.08)	-0.076 (0.078)

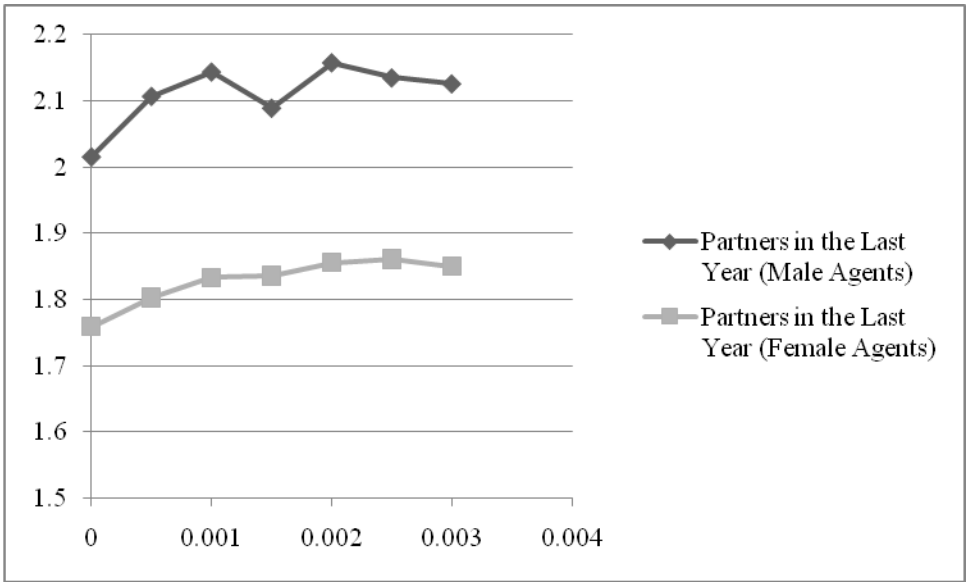
Table 4.8. Interaction between the sex ratio and incarceration rates.

sR	0.1	0.3	0.5	0.7	0.9
pIM		Partners in the past year (male)			
0	6.808 (1.025)	3.474 (0.363)	2.097 (0.259)	1.221 (0.126)	0.776 (0.115)
0.001	6.64 (0.933)	3.573 (0.452)	2.076 (0.272)	1.251 (0.22)	0.823 (0.134)
0.002	6.396 (1.398)	3.534 (0.463)	2.126 (0.268)	1.273 (0.151)	0.865 (0.141)
0.003	6.703 (0.935)	3.627 (0.375)	2.098 (0.38)	1.327 (0.197)	0.913 (0.168)
		Partners in the past year (female)			
0	1.398 (0.109)	1.65 (0.096)	1.77 (0.123)	1.824 (0.131)	1.911 (0.27)
0.001	1.398 (0.095)	1.675 (0.099)	1.835 (0.127)	1.917 (0.318)	2.014 (0.303)
0.002	1.382 (0.232)	1.693 (0.102)	1.838 (0.147)	1.981 (0.209)	2.271 (0.378)
0.003	1.402 (0.108)	1.715 (0.097)	1.818 (0.296)	2.031 (0.275)	2.318 (0.394)
		Lifetime partners (male)			
0	0.861 (1.511)	8.536 (0.795)	6.487 (0.509)	4.806 (0.347)	3.348 (0.402)
0.001	0.865 (1.498)	8.495 (0.679)	6.424 (0.622)	4.614 (0.772)	3.401 (0.416)
0.002	0.49 (2.278)	8.345 (0.662)	6.398 (0.593)	4.649 (0.462)	3.19 (0.553)
0.003	0.733 (1.377)	8.674 (0.756)	6.322 (1.049)	4.739 (0.454)	3.254 (0.395)
		Lifetime partners (female)			
0	2.244 (0.283)	4.062 (0.298)	5.507 (0.467)	7.212 (0.673)	8.279 (1.227)
0.001	2.294 (0.233)	4.005 (0.284)	5.71 (0.487)	7.09 (1.215)	8.324 (0.855)
0.002	2.278 (0.452)	4.025 (0.34)	5.549 (0.434)	7.238 (0.634)	8.343 (1.251)
0.003	2.26 (0.289)	4.117 (0.372)	5.494 (0.905)	7.255 (0.629)	8.265 (0.9)
		Ever concurrent (male)			
0	0.857 (0.083)	0.591 (0.068)	0.415 (0.066)	0.237 (0.039)	0.116 (0.043)
0.001	0.837 (0.067)	0.599 (0.061)	0.4 (0.06)	0.242 (0.056)	0.108 (0.044)
0.002	0.798 (0.151)	0.581 (0.074)	0.393 (0.058)	0.239 (0.044)	0.105 (0.044)
0.003	0.833 (0.09)	0.591 (0.058)	0.39 (0.07)	0.238 (0.044)	0.106 (0.039)
		Ever concurrent (female)			
0	0.314 (0.056)	0.403 (0.04)	0.422 (0.04)	0.43 (0.062)	0.392 (0.107)
0.001	0.309 (0.045)	0.399 (0.031)	0.427 (0.047)	0.421 (0.08)	0.377 (0.086)
0.002	0.296 (0.061)	0.393 (0.053)	0.42 (0.056)	0.409 (0.06)	0.366 (0.105)
0.003	0.295 (0.058)	0.392 (0.045)	0.402 (0.077)	0.414 (0.066)	0.341 (0.102)
		Quality correlation			
0	0.129 (0.121)	0.185 (0.108)	0.151 (0.112)	0.13 (0.1)	0.073 (0.143)
0.001	-0.008 (0.152)	0.069 (0.089)	0.125 (0.084)	0.105 (0.076)	0.099 (0.109)
0.002	-0.165 (0.155)	-0.032 (0.117)	0.071 (0.081)	0.103 (0.079)	0.098 (0.103)
0.003	-0.234 (0.183)	-0.123 (0.098)	-0.009 (0.089)	0.05 (0.08)	0.082 (0.099)

Table 4.9. Interaction between the quality distribution and incarceration rate.

eQ	FALSE	TRUE
pIM	Partners in the last year (male)	
0	1.393 (0.243)	2.079 (0.267)
0.001	1.514 (0.278)	2.073 (0.184)
0.002	1.609 (0.246)	2.221 (0.26)
0.003	1.554 (0.326)	2.146 (0.275)
	Partners in the last year (female)	
0	1.541 (0.137)	1.778 (0.114)
0.001	1.583 (0.132)	1.792 (0.099)
0.002	1.682 (0.143)	1.874 (0.124)
0.003	1.628 (0.287)	1.844 (0.156)
	Lifetime partners (male)	
0	4.21 (0.455)	6.545 (0.553)
0.001	3.913 (0.476)	6.441 (0.533)
0.002	3.97 (0.392)	6.658 (0.607)
0.003	3.767 (0.678)	6.376 (0.587)
	Lifetime partners (female)	
0	4.749 (0.821)	5.631 (0.473)
0.001	4.177 (0.731)	5.578 (0.446)
0.002	4.21 (0.641)	5.637 (0.438)
0.003	3.997 (0.84)	5.499 (0.428)
	Ever concurrent (male)	
0	0.275 (0.062)	0.409 (0.058)
0.001	0.285 (0.063)	0.402 (0.046)
0.002	0.276 (0.063)	0.417 (0.06)
0.003	0.269 (0.063)	0.403 (0.055)
	Ever concurrent (female)	
0	0.368 (0.07)	0.43 (0.049)
0.001	0.332 (0.061)	0.424 (0.041)
0.002	0.319 (0.054)	0.426 (0.052)
0.003	0.299 (0.062)	0.407 (0.046)
	Quality correlation	
0	-0.149 (0.1)	0.185 (0.118)
0.001	-0.331 (0.11)	0.127 (0.09)
0.002	-0.436 (0.107)	0.045 (0.072)
0.003	-0.433 (0.106)	0.013 (0.094)

Figure 4.1. Base model results for partners in the last year.



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Chapter V

Conclusion

The important original contributions of this dissertation are: documenting increased risky sexual partnerships among young men who have been incarcerated compared to their never-incarcerated peers, and demonstrating that these differences were not present before incarceration; developing and validating an agent-based model of sexual behavior for use in hypothesis testing and to guide data collection; and providing a "proof of principle" series of model experiments that demonstrate that high rates of community incarceration may contribute to differences in sexual networks and patterns of sexual behavior. These core findings are elaborated and interpreted here in the context of the research limitations, highlighting the next research steps that are warranted.

Conclusions

The analysis of Add Health focuses on the effects of incarceration on the young adult male who has been incarcerated and his partners. Although all of the men in the sample started out with similar sexual histories prior to incarceration in terms of numbers of partners and rates of concurrency, those men who were later incarcerated went on to have significantly higher numbers of partners than those men who were never incarcerated. In addition, the partners of those men who were incarcerated were more likely to have concurrent partners than the partners of never incarcerated men. Not only were men's sexual lives affected by incarceration, perhaps because of relationship disruption due to incarceration, differences in the perception of the men as potential

partners, or changes in how they approached romantic and sexual relationships after incarceration, but the sexual lives of their partners were also changed.

The computational model experiments extend the findings from the first paper to examine the effect of male incarceration on community-level patterns of sexual behavior. Varying the incarceration rate in an agent-based model of sexual partnership showed that at rates of incarceration similar to those documented in many urban African American communities, the numbers of partners and rates of concurrency were increased in the whole community compared to an identical community without incarceration. Incarceration in this simulation disrupted many of the partnerships of men who were incarcerated (though not all), and also changed the desirability of formerly incarcerated men as potential partners. It did not, however, change the strategies of either incarcerated men or their partners when forming relationships, which suggests that the true effect of incarceration may be even more substantial.

In addition to contributions to the literature on the effects of incarceration on sexual behavior, this dissertation makes a substantial methodological contribution. Initially, the extension of models of first marriage markets to broader considerations of sexual partnerships seemed simple. Allowing agents to have multiple relationships proved to be a deceptively simple undertaking, prompting consideration of the algorithms individuals use to decide when to leave sexual relationships for new partners, and parameters defining preferences for monogamy as well as determining how often agents would correctly assess whether their partners were monogamous. The resulting model, validated using nationally representative measures of sexual behavior as well as many smaller studies, allows for exploration of individual and external factors that shape sexual

decision-making. Demonstrating the feasibility of producing nationally representative patterns of sexual behavior is an important extension of the modeling literature. Once the code is made publically available, other researchers will be able to extend and modify the model to address a wide range of research questions about sexual behavior.

Implications

Incarceration causes shifts in sexual behavior among those individuals who have been incarcerated and their partners, and is likely to contribute to changes in sexual behavior patterns at the community level as well. These results fit well with documented associations between incarceration and higher numbers of sexual partners, higher rates of concurrency, and risky sexual behavior, despite the finding of increased concurrency among *partners* of incarcerated men rather than among the men themselves (Adimora, Schoenbach, & Doherty, 2007; Epperson, El-Bassel, Chang, & Gilbert, 2010; Epperson, El-Bassel, Gilbert, Orellana, & Chang, 2008; Khan et al., 2009; Seal et al., 2007). The age of respondents in the data set and the time frame of the study are likely to have contributed to discrepancies between these findings and those already reported in the literature. The lack of significant differences between men who would be incarcerated later and their never incarcerated peers suggests a particular temporal relationship between risky sexual behavior and incarceration, that men who are incarcerated are only different from never incarcerated men after their incarceration, and supports a causal relationship between incarceration and sexual behavior.

The theoretical grounding of this dissertation in complex systems theory emphasizes the importance of interactions between individuals to translate changes at the individual level up to the community and population level (Simon & Koopman, 2005).

Many of the changes documented in this dissertation are not only significant, but substantial in magnitude, and even very small changes at a population-level have the propensity to change the landscape of HIV risk. In light of the negative effects of incarceration on both individual and community sexual behavior, the most obvious response is to decrease rates of incarceration. Alternatives to incarceration, for example drug courts, have the potential to maintain existing relationships and family structures and seem likely to reduce the disruptive effects of incarceration.

In addition, the community-level results support a more open criminal justice system for those who are incarcerated, that supports the maintenance of inmates' relationships with partners and family in order to reduce the instability of partnerships for men who have been incarcerated. Interventions such as job training and placement might also minimize the "loss of quality" that occurs due to incarceration, and keep young men on the same sexual behavior trajectory as their never incarcerated peers.

The studies presented in this dissertation make substantial contributions to the literature, and document pervasive effects of incarceration on patterns of sexual behavior, but the results do not distinguish between potential mechanisms through which incarceration shapes sexual decision-making and sexual behavior. The finding of significant differences in partners' behavior suggests ramifications of incarceration beyond the individual, and the model results show that even without changes in preferences about sexual partnerships, incarceration can cause changes in sexual behavior patterns at the community level. Clear and colleagues (2003) hypothesis that incarceration disrupts social networks by damaging familial, economic, and political sources of informal social control, the agreed-upon norms and day-to-day interaction that

result in a natural kind of supervision within families and communities seems born out in these modeling results, with incarceration causing complex results in community sexual networks, rather than simply removing men from the community. As currently implemented, however, the model cannot address the potential effects of community norms about masculinity, sexual decision-making and partnerships, or other aspects of men's sexual lives that may be affected by incarceration.

Similarly, the data used to document the individual effects of incarceration contain little in the way of measures of masculinity, or other measures that might explain the connection between incarceration and sexual behavior. Qualitative work illustrating the disruptive effect of incarceration on relationships and families and even the potential for recently incarcerated men to seek out new multiple new partners to make up for lost time points toward complicated mechanisms that require a nuanced analytic approach to tease out (Bergman, 2008; Braman, 2004; Thomas, Levandowski, Isler, Torrone, & Wilson, 2007). These qualitative studies and the quantitative and modeling work presented here implore further investigation of complex interplay between Whitehead's concept of respectable versus reputational masculinity (1994), the construction of resistant, but locally dominant or hegemonic, masculinities as described by Courtenay (2000) and the particular structural challenges faced by men who have been incarcerated (Nandi, 2002; Rios, 2009; Western, 2006).

Future Work

The gaps left untested in the conceptual model highlight many potential avenues for future research, including additional investigation into the sexual decision-making processes of formerly incarcerated men, more in depth examination of how the partners

of individuals who are incarcerated respond to this change, further exploration of community responses to incarceration, and assessment of programs that divert men from incarceration to determine whether and how their effects on the sexual lives of these men differ substantially from those of incarceration. The results of the dissertation also provide a strong case for advocacy work toward reducing the burden of incarceration.

Ascertaining the specific mechanisms through which incarceration acts, by examining how men who have been incarcerated and their partners see themselves and their sexual lives has the potential to not only illuminate the processes that shape patterns of sexual behavior, but also to define promising avenues for intervention with incarcerated men and their partners. A mixed methods approach aimed at teasing apart how self-concept and masculinity, the reality of imbalanced sex ratios in many communities (with men underrepresented), and changes in economic opportunity and social networks as a result of incarceration shape sexual decision-making would be useful in developing policy and programmatic interventions to reduce HIV and STD risk for men who have been incarcerated and their partners.

In the immediate future, working with available data and collaborating with researchers asking similar questions will move this research program forward. A supplement to the third wave of Add Health data includes a survey of the primary partners of a subset of Add Health respondents; exploring the sexual behavior of these partners is like to shed light on the mechanisms through which incarceration might shape their behavior. In addition, Thomas and colleagues (2007) report briefly on qualitative data from interviews with partners and formerly incarcerated individuals that they have not subsequently published; collaboration with this group may allow for secondary

analysis of this data with a focus on masculinity and the sexual strategies of men who have been incarcerated, as well as those of their partners. Finally, Blankenship et al (2010) recently reported on preliminary findings of a pilot study of men recently released from prison and men on probation and their partners; collaboration on the larger project, which includes both quantitative and qualitative approaches, is another approach to answering these larger questions.

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