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Modeling the community-level effects of male incarceration on the sexual partnerships of men and women

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Abstract

Men who have been incarcerated experience substantial changes in their sexual behavior after release from jail and prison, and high rates of incarceration may change sexual relationship patterns at a community level. Few studies, however, address how rates of incarceration affect community patterns of sexual behavior, and the implications of those patterns for HIV and STD risk. We describe a “proof of principle” computational model that tests whether rates of male incarceration could, in part, explain observed population-level differences in patterns of sexual behavior between communities with high rates of incarceration and those without. This validated agent-based model of sexual partnership among 20–25 year old heterosexual urban residents in the United States uses an algorithm that incarcerates male agents and then releases them back into the agent community. The results from these model experiments suggest that at rates of incarceration similar to those observed for urban African American men, incarceration can cause an increase in the number of partners at the community level. The results suggest that reducing incarceration and creating a more open criminal justice system that supports the maintenance of inmates’ relationships to reduce instability of partnerships for men who are incarcerated may have important sexual health and public health implications. Incarceration is one of many social forces

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that affect sexual decision-making, and incarceration rates may have substantial effects on community-level HIV and STD risks.

Keywords

Incarceration; HIV/AIDS; Sexual risk; Agent-based model

Introduction

Population and individual level studies show associations between rates of incarceration and higher rates of STDs and/or HIV; these studies also find a relationship between population rates of incarceration or individual history of incarceration and increased risk factors associated with HIV and STD acquisition and transmission, including higher rates of concurrent sexual partnerships and a greater number of sexual partners (Adimora, Schoenbach, & Doherty, 2007; Epperson, El-Bassel, Chang, & Gilbert, 2010; Johnson & Raphael, 2005; M. R. Khan et al., 2009; Knittel, Snow, Griffith, & Morenoff, 2013; J. C. Thomas, Levandowski, Isler, Torrone, & Wilson, 2007). Although incarceration among women is increasing, because men are incarcerated at a rate many times higher than that of women (954 per 100,000 U.S. residents compared to 68 per 100,000 U.S. residents, respectively, in 2009), most analyses focus on sexual risks to men that result from incarceration and the effects on women of having an incarcerated partner (Carson & Golinelli, 2013; Epperson, Khan, El-Bassel, Wu, & Gilbert, 2011; West, 2010). Qualitative and quantitative analyses emphasize increased rates of partnership dissolution due to physical and emotional distance, as well as a desire for an increased number of sexual partners to “make up for lost time” (Bergman, 2008; Braman, 2004; Maria R. Khan, Behrend, et al., 2011; J. C. Thomas, et al., 2007). The literature also suggests that whether female partners of incarcerated men “go on about [their lives]” while their partners are away or maintain their relationships through visits and calls, these women may rely on other relationships, including new sexual partners, for emotional and financial support (Braman, 2004; Comfort, 2008; J. C. Thomas, et al., 2007, p. 94).

Clear and colleagues (2003) define “coercive mobility” as the disruption of social networks, community structure, and social norms that occurs as a result of high community rates of incarceration, and results in an increase, rather than a decrease, in crime rates with high rates of incarceration. Thomas (2006) extrapolated that this may also translate into a shift in social norms governing sexuality that facilitates HIV and/or STD transmission. These authors hypothesize a threshold effect, wherein low levels of incarceration are associated with less crime and maintain sexual norms that limit disease spread, but once incarceration rates reach a threshold, crime increases and risky partnerships increase, leading to increased disease transmission.

Discussion of incarceration in the United States must include the context of racial disparities in criminal justice involvement. The complex historic interaction between racialized fears of and responses to crime, increasing economic disparity, the influx of crack cocaine into already struggling urban neighborhoods, and political responses to the drug “epidemic”

fueled a “prison boom” starting in the 1980s which resulted in disproportionate incarceration of young African American men, particularly poor men with little education (Kent & Jacobs, 2005; Stolzenberg, D’Alessio, & Eitle, 2004; Western, 2006). Persistent disparities in economic disadvantage, differential policing, and conscious and unconscious bias in the criminal justice system have reinforced these differential rates of incarceration even as the absolute number of men incarcerated in the US has plateaued in recent years (Carson & Golinelli, 2013; Ousey & Lee, 2008; Rodriguez, 2011; Walker, Spohn, & DeLone, 1996).

Conceptual models postulating the relationships between criminal justice involvement and sexual decision-making appropriately situate it in relation to other social forces that shape sexual relationships and community-level risk for HIV and other STDs (Adimora & Schoenbach, 2005; J. C. Thomas, 2006; J. C. Thomas & Thomas, 1999). Individuals are constrained by geography and biography, and sexual and social networks form through introductions that take place in the contexts of work and school, still remarkably segregated in most of the United States due to decades of discriminatory lending policies and federal and state housing policy (Frey & Meyers, 2005; Laumann, Gagnon, Michael, & Michaels, 1994; Massey, 1990). Economic policy, concentrated unemployment and disadvantage, sex differences in mortality and migration, and residential segregation all contribute to the racial disparities in the prevalence of incarceration, and also decrease the relative availability of desirable male partners compared with female partners (Geronimus, Bound, Waidman, Hillemeier, & Burns, 1996; Massey, 1990). Green and colleagues (2012) also empirically demonstrate a frequently postulated association between low sex ratios (where men are underrepresented) and increased risk for unprotected sex and having multiple sex partners.

These studies together provide compelling evidence for a relationship between male incarceration, sexual behavior, and sexual decision-making, and they provide theoretical underpinnings for an examination of the effects of incarceration at a community level. The shortcomings of observational, often cross-sectional, studies limit our understanding of these effects, however, in a context in which experimental design would be unethical.

Computational approaches provide a closed system in which to test hypotheses, and, as such, can suggest important avenues for policy and research. Agent-based modeling (ABM) is a promising method for understanding potential mechanisms through which high rates of incarceration shape sexual networks in communities because it allows for heterogeneity between individuals in the model. In addition, ABM requires an explicit description of the assumptions used in the modeling process. ABM offers the opportunity to experiment with rates of incarceration and sexual partnership preferences in a transparent way that would be impossible in a study of an actual network of sexual partnerships.

Previous work using ABM to examine patterns of sexual partnership focused on preferences and decision-making strategies involved in spousal selection as well as implications of patterns of sexual partnership (and particularly non-monogamy) on HIV transmission (Alam, Meyer, & Norling, 2008; French & Kus, 2008; Simao & Todd, 2003). These earlier models emphasized decision-making around first marriage and non-monogamy in male partners, but not applicable to a context in which individuals have more than one partner over the course of their lives, and where both men and women are relatively likely to engage in non-monogamous partnerships at some point in their lives. These limitations prompted

the development of a model of sexual partnership in the United States that would reproduce patterns of partnerships demonstrated in nationally representative data sets, and would provide a model world in which to test hypotheses about sexual decision-making (Knittel et al., 2011).

We present here an extension of that model, a “proof of principle,” model testing whether men’s incarceration may provide an explanation for 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, separate from sexual behavior that occurs inside criminal justice institutions. We also test whether incarceration might interact with other social forces, such as the sex ratio and the availability of high quality partners.

Methods

Model Description

This study builds on an agent-based model of sexual partnerships over a 5-year period, implemented in Repast J, adding parameters and analyses to address the question of male incarceration. Full details on the parameters, design, and evaluation of the core model have been described previously (Knittel et al., 2011). In brief, when the model is run without incarceration, individuals (called “agents”) are assigned measures indicating how desirable they are to other agents (“quality”), the level of quality they look for in a partner (“aspiration”), how long they need to date another agent before engaging in a sexual relationship, how long they will go without a partner before decreasing their aspirations, and the number of partners they believe they should have in a year. As the model runs, agents meet and decide whether to form a partnership. At each time-step, existing couples can choose to remain in a non-sexual partnership, become sexual partners, or break up. The flow of this portion of the model is illustrated in Figure 1. Parameter values for this portion of the model were chosen from a combination of empirical data, previous parameter values described in the literature, and theoretical considerations (Knittel et al., 2011). Where no data or theory were available to guide the selection of parameter values, a range of values were tried until the model was calibrated to produce qualitatively reasonable results based on available partnership data. It was ultimately parameterized to approximate sexual decision-making processes among 20-25 year-old urban residents in the United States, and the values that produced these distributions are used here.

The community simulated in the model consists of 250 agents, half of whom are male and half are female. This was chosen to represent a potential dating network, though there is no empirical data available to define the number of people an individual may encounter as potential partners. During the development of the model, results were similar with 250 or 500 agent communities (Knittel et al., 2011).

Incarceration in the Model (Core Model)

We limit our model and analyses to male incarceration as women comprise only a small proportion of the jail and prison population, and acknowledging that there are likely to be

different theoretical considerations surrounding female incarceration (Braithwaite, Treadwell, & Jacob Arriola, 2005; Glaze & Kaeble, 2014). Incarceration of the male agents was defined with the following parameters: probability of incarceration at each time step, and the mean and standard deviation of a distribution of sentence lengths (in weeks). As shown in Figure 1, when a male agent is incarcerated, he is assigned a new probability of relationship break-up at the time of incarceration, a new probability of starting a new relationship while he is incarcerated, and his quality measure decreases as a penalty for incarceration.

The probability of partnership during incarceration (pIP) defines how likely it is that a new partnership would begin during incarceration. With probability (1 - pIP), the agent is rejected automatically as a potential partner because of his incarceration status, and with probability pIP he is considered using the same algorithm as any other agent. The definition of the probability of break-up due to incarceration (pIB) is similar. 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 at each time step that he is incarcerated. Parameter values for these probabilities were chosen using the limited data that exists on the fate of relationships when one partner is incarcerated, and suggest that approximately 40% of relationships dissolve at the time of incarceration (Maria R. Khan, Behrend, et al., 2011).

There is also qualitative evidence that many partnerships end as a result of incarceration, some new partnerships 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 was set to 0.5 and the probability of breaking up as a result of incarceration set to 0.5. 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 (12 weeks) and standard deviation (4 weeks) were set based on estimates generated 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%).

Sensitivity Analyses

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 the incarceration rate 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 they allow for examination of the effects of incarceration in a variety of contexts.

Additional Experimental Variables

Sex Ratio—The sex ratio is defined in the model as the proportion of men in the population. Using data from African American residents of 270 metropolitan areas defined in the 1980 US Census, and restricting the sample to men in the labor force and non-institutionalized women, Fossett and Kiecolt (1993) found that the median proportion of men in the population was 0.37 and the tenth and ninetieth percentile proportions were 0.33 and 0.45 (Fossett & Kiecolt, 1993). In the model, a multiplicative sweep was run to determine whether an imbalanced sex ratio would interact with the incarceration rate. The sex ratio was varied between 0.3 and 0.7 (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—Adimora and Schoenbach (2005) describe a scenario in which relatively few educated and employed men are available in urban African American communities compared to the number of educated and employed women, and suggest that this “effective sex ratio” may exacerbate the effects of incarceration on partnership dynamics in these communities to a greater extent than the actual sex ratio. To test this hypothesis, 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 weeks (five years) with 250 agents (125 male and 125 female). The reported values for number of partners in the past year, lifetime partners, rates of concurrency, and partner quality correlation are averages based on ten model runs each and were calculated using data from the final time step of the model to most closely approximate cross-sectional survey data.

Results for the core model and the examination of the effects of the sex ratio and quality distribution are reported as a baseline value without incarceration, and then as the change in the measure at each rate of incarceration, separated into male and female agents. The results for the sensitivity analyses are reported as means and standard deviations of the measures. All of these results are drawn from the entire community in the model, which includes both formerly and currently incarcerated agents as well as the rest of the male and female agents. Results for incarcerated male agents are drawn from experiments where the incarceration rate was set to the highest parameter value (0.03 per time-step) in order to have enough currently or previously incarcerated agents to present average values at the end of the model run.

Results

Core Model

With the addition of incarceration, the number of sexual partners that male and female members of the model community have within the past year increases. These results are shown in Table 1 and Figure 2. For the community of agents, this is an additional 9-17 partnerships for male agents in the past year, and an additional 5-12 partnerships for female agents in the past year. The average increase per male agent is between 0.07 and 0.14 additional partners in the past year, and the average increase per female agent is between 0.04 and 0.1 additional partners compared with the model without incarceration. For male agents, the increase in the number of partners appears roughly equivalent regardless of the level of incarceration, though for female agents, the number of additional partners increases with increasing rates of incarceration.

For male agents, the average number of lifetime partners increases very slightly with incarceration, though the degree of that increase diminishes with increasing rates of incarceration. There is not a clear trend for the number of lifetime partners for female agents. There is also no substantial change in rates of concurrency in the model community with incarceration. The quality correlation between partners in the community drops with increasing rates of incarceration.

The results for male agents who have been incarcerated during the model run are shown in Table 2. 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.

Sensitivity Analysis

Among the model community, there was not a substantial effect of increasing the average sentence length: there were no measurable effects on the increases in the number of partners over the past year, lifetime partners, or rates of concurrency among male or female agents with increasing rates of incarceration. The results for the number of partners in the past year are shown in Figure 3. 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. Among ever incarcerated male agents, increasing the average sentence length does have a uniformly negative effect on the number of partners within the past year, however the number of lifetime partners increases slightly as sentence length increased, and concurrency is unaffected. Numerical results of the sensitivity analyses are available in the supplemental materials.

For male agents who had been incarcerated, increasing the probability of new partnership formation while incarcerated did not have an appreciable effect. There was not a substantial change in the effect of incarceration on the number of partners or rates of concurrency in the model community with change in the probability of new partnership formation while incarcerated. Increasing the probability of forming new relationships during periods of incarceration brought the quality correlation between partners closer to zero at all levels of incarceration.

Increasing the probability that existing partnerships ended as a result of incarceration increases the number of lifetime partners for agents who had ever been incarcerated, while the number of partners in the past year and rates of concurrency were unaffected. Among all agents, both male and female in the model community, 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 ($p_{IB} = 0.4$). There was no effect on the number of lifetime partners for either male or female agents. Rates of concurrency did not change with the probability of breaking up during incarceration for male agents who had been incarcerated, and were low at all levels. For both male and female agents in the model community, however, a low probability of breaking up increased very slightly the rates of concurrency. This reflects the fact that some female agents whose relationships continued while their male partner was incarcerated (and thus had a lower probability of forming a new, concurrent relationship), nonetheless form new relationships during that time, albeit at a slightly lower rate than if their relationship had ended.

Among male agents who had been incarcerated, increasing the penalty for incarceration results in a decrease in the number of partners over the past year but a slight increase in the number of lifetime partners. Across the entire model community, 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 at higher rates. This occurs because, as the quality of male agents drops with incarceration, their relationships are more likely to end because their partners have found a more desirable partner. The net effect of an increased penalty of incarceration in terms of quality, then, is of increased instability in relationships, which leads to a higher number of partners. 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.

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. Where men are over-represented, the effect of incarceration is more pronounced, and there is a substantial rise in degree of increase in the number of partners in the last year across the model community, while the effect of incarceration on the number of lifetime partners remains minimal. The effect of incarceration has the greatest magnitude when the proportion of men in the population is either 0.3 or 0.7, as shown in Table 3. Rates of concurrency are certainly sensitive to the sex ratio; when there are many more women than men, rates of concurrent partnerships are higher for men, and the converse is also true. Nonetheless, the effect of incarceration on concurrency remains unremarkable at all sex ratios.

When men's quality measures are 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.

Discussion

The results from these model experiments suggest that incarceration can cause an increase in the number of sexual partnerships at the community level over five years with rates of incarceration as low as 12%. The results of these experiments suggest that the disruptive effects of incarceration, as well as the loss in quality that men are likely to experience after they are incarcerated, may result in increased numbers of partners for both male former inmates and for men and women in their communities. These results are relatively robust to variations in parameters that determine partnership dynamics during incarceration and in sentence length. It is important to note, however, that although the model results show a causal relationship, because all of the other variables can be held constant, it remains to be examined how directly this can be best applied to actual incarcerated populations. Instead, the results of the model should be interpreted as suggesting that, as implemented in the model, incarceration may explain some portion of the differences in numbers of sexual partners observed in communities with high rates of incarceration.

These findings offer support to ecological studies linking rates of incarceration with increased rates of STDs and HIV and extend previous work on the social effects of high rates of incarceration (Clear, et al., 2003; Johnson & Raphael, 2005; J. C. Thomas, 2006; J. C. Thomas, et al., 2007). Few studies have examined the sexual behavior of both men and women in the setting of male incarceration. In our model, at cumulative incarceration rates above 12% in the model, there is not a substantial additional effect of incarceration on male agents, whereas for female agents in the community, 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 few studies that have looked at relationship dissolution and changes in sexual partnership patterns around the time of incarceration have not described different effects by sex; Khan and colleagues (2011) showed that loss of a partner during incarceration was associated with approximately three times the prevalence of having two or more new sexual partners in the four weeks prior to the study. The difference in effects of incarceration on male and female agents in the model may have resulted from several possible pathways. It is possible that because the male partners are incarcerated they have decreased access to partners both during the time of incarceration and due to their decreased desirability after release, they are not able to accrue new partners at the same rate as their female counterparts. In addition, sexual partnerships which occur during incarceration are likely underreported because they may not be considered relationships, may be coercive, and may include stigmatized same-sex sexual experiences. The model is also notable for its exclusion of changes in partnership preferences based on incarceration. Although limited qualitative data has suggested that some recently released men may seek out an increased number of sexual partners to make up for lost time, and that women with incarcerated partners may be more likely to pursue concurrent partnerships (J. C. Thomas, et al., 2007), there was not sufficient evidence for these mechanism to be included in the model. It is also possible that

there are other changes in behavior that are related to mechanisms not captured in the model, which may also account for the differences observed between male and female agents.

These model results ultimately suggest that incarceration, through disruption of partnerships and reducing the capability of formerly incarcerated men to find partners, could shift the larger population toward sexual behavior that enables transmission of HIV and other STDs. Although the sensitivity analysis suggests 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.

The changes at the individual level in the model are small in magnitude, but at community, and ultimately at the population levels even small changes have the propensity to substantially change the landscape of HIV and other STD 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, thus increasing risk (Doherty, Padian, Marlow, & Aral, 2005). Further work is needed to determine whether these sorts of changes in network structure are observed in social groups that include incarcerated individuals, and their impact on disease spread.

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. 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, the cumulative risk was 58.9% (Pettit & Western, 2004). In 2001, 16.6% of adult black males, and 22% of those below at 45 in the US had ever gone to prison (Bonczar, 2003). If incarceration rates remain unchanged, 32.2% of black men born in 2001 will go to prison during their lifetimes (Bonczar, 2003). These high rates of incarceration at relatively young ages suggest that lifetime risk of incarceration is concentrated in young adulthood, and that the rates of incarceration and timeframe for the model are reasonable.

This study also suggests that the effect of incarceration has the greatest magnitude at sex ratios that are unbalanced. 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, et al., 1996).

Incarceration also seems to have a more dramatic effect when men's quality values are on average lower than women's. This suggests that incarceration affects most substantially those communities where male unemployment and low education are already pronounced compared to female achievement in the labor market and education. Given the current distribution of incarceration in the United States, these results suggest that the system punishes those communities that are most at risk.

This model is not without limitations. It does not take into account potential modifications in approach to sexual decision-making; men may be more likely to seek out increased numbers of partners after incarceration, and women more likely to seek new partners while their partners are incarcerated, potentially exacerbating the effect observed in the model (Braman, 2004; Maria R. Khan, Behrend, et al., 2011; J. C. Thomas, et al., 2007; Whitehead, Peterson, & Kaljee, 1994). Some of the mechanisms that Clear et al (2003) and Thomas et al (2005) propose underlying “coercive mobility” are also not included in the model, such as community-wide changes in social mores that make risky partnerships more likely. Whitehead and colleagues (1997), for example, describe a particular urban, African American masculine gender identity arising in the context of unemployment, residential segregation, and an imbalanced sex ratio, which is in part defined by having multiple sex partners as a means of establishing masculinity where economic prowess is unavailable. For these reasons, the model likely underestimates the effect of incarceration.

In addition, the transmission of HIV and other STDs is not explicitly included in the model. Instead, the model was selected to represent a small enough community where the prevalence and incidence of a particular infection could be presumed to be relatively constant, and changes in sexual behavior and sexual networks could be examined. Effects on disease transmission were extrapolated from current understandings about the relationships between sexual network structure and HIV and STD transmission.

Finally, there is scant empirical data available to 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 additional data about how sexual relationships change during and after incarceration.

Implications for Policy

Agent-based models offer the unique opportunity to evaluate both the individual and community effects of potential policy interventions, sometimes yielding surprising or counterintuitive results. When the penalty for incarceration is set high, one might predict a decreased number of relationships when, in fact, incarcerated men in the model are *less* attractive and their partners are *more* likely to seek different, more attractive partners, resulting in a community-level increase in the number of partnerships. Policy strategies to decrease this effect might include reducing the stigma of incarceration, as well as job training and placement, maintaining community connections, and other during- and post-incarceration interventions. Khan et al (2011) reported that the loss of a partner during incarceration was associated with nearly three times the prevalence of having two or more new partners. A criminal justice system that enabled the maintenance of inmate’s relationships with partners and family might also reduce the instability of partnerships for men who have been incarcerated.

Grinstead and colleagues (2001) documented the monetary costs of maintaining relationships during incarceration. They found that women in relationships with incarcerated African American men in a large state prison spent \$292/month maintaining contact, which

represented approximately 26% of total income for those women in the lowest income category, and 9% for women in the highest income category. These simple data alone suggest that interventions to decrease the cost of relationships maintenance might be useful in decreasing relationship instability related to incarceration.

The demonstrated success at decreasing HIV risk behavior of programs such as Project Start, an individual HIV risk reduction program which includes not only education about the prevention of HIV transmission, but also skills training, housing, employment, and other referrals support the idea that mitigating the other social consequences of incarceration might minimize the effects of incarceration on HIV and other STD risk. Another example of a promising program is the “Healthy Relationships” program run by Centerforce, a non-profit organization based in San Quentin, California, aims to equip HIV positive inmates for post-release relationships by developing skills, decreasing stress, building self-confidence, creating realistic expectations and improving decision making regarding disclosure of the HIV status to potential partners, family and friends.

Increasing the average sentence length for incarcerated male agents in the model also had a paradoxical effect, increasing their number of lifetime partners, and had relatively little effect at the community level. Simply removing incarcerated men for a longer period does not improve the sexual risk profile of the incarcerated individuals or the communities from which they come, and suggests that harsher sentences are not the answer to the problems that incarceration brings for communities, consistent with much of the qualitative work on family and partnership dynamics in the context of incarceration (Braman, 2004; Comfort, 2008).

Despite its limitations, 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 in HIV and other STD infection rates observed in urban African-American communities compared with communities with lower incarceration, and suggests that harsher or longer penalties might exacerbate this problem. Though incarceration is likely only one of many factors that determine sexual decision-making, incarceration at current rates almost certainly influences community HIV risk.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

References

- *. Knittel AK, Riolo RL, Snow RC. Development and evaluation of an agent-based model of sexual partnership. *Adaptive Behavior*. 2011; 19(6):425–450.
- Adimora AA, Schoenbach VJ. Social Context, Sexual Networks, and Racial Disparities in Rates of Sexually Transmitted Infections. *Journal of Infectious Diseases*. 2005; 191(S):S115–S122. [PubMed: 15627221]
- Adimora AA, Schoenbach VJ, Doherty IA. Concurrent sexual partnerships among men in the United States. *American Journal of Public Health*. 2007; 97(12):2230–2237. [PubMed: 17971556]

- Alam, SJ.; Meyer, R.; Norling, E. A Model for HIV Spread in a South African Village (Vol. Unpublished Manuscript). Centre for Policy Modelling, Manchester Metropolitan University Business School; 2008.
- Bergman, L. *Getting Ghost: Two Young Lives and the Struggle for the Soul of an American City*. New Press; New York: 2008.
- Bonczar, T. Bureau of Justice Statistics Special Report. Washington DC: 2003. Prevalence of Imprisonment in the U.S. Population, 1974-2001.
- Braithwaite RL, Treadwell HM, Jacob Arriola KR. Health disparities and incarcerated women: a population ignored. *American Journal of Public Health*. 2005; 95(10):1679–1681. [PubMed: 16186446]
- Braman, D. *Doing Time on the Outside*. University of Michigan Press; Ann Arbor: 2004.
- Carson, EA.; Golinelli, D. *Prisoners in 2012*. 2013.
- Clear TR, Rose DR, Waring E, Scully K. Coercive Mobility and Crime: A Preliminary Examination of Concentrated Incarceration and Social Disorganization. *Justice Quarterly*. 2003; 20(1):33–62.
- Comfort, M. *Doing Time Together: Love and Family in the Shadow of the Prison*. The University of Chicago Press; Chicago: 2008.
- Doherty IA, Padian NS, Marlow C, Aral SO. Determinants and Consequences of Sexual Networks as They Affect the Spread of Sexually Transmitted Infections. *Journal of Infectious Diseases*. 2005; 191(S1):S42–S54. [PubMed: 15627230]
- Epperson MW, El-Bassel N, Chang M, Gilbert L. Examining the Temporal Relationship Between Criminal Justice Involvement and Sexual Risk Behaviors among Drug-Involved Men. [empirical]. *Journal of Urban Health*. 2010; 87(2):324–336. [PubMed: 20143270]
- Epperson MW, Khan MR, El-Bassel N, Wu E, Gilbert L. A Longitudinal Study of Incarceration and HIV Risk Among Methadone Maintained Men and Their Primary Female Partners. *AIDS Behavior*. 2011; 15(2):347–355. [PubMed: 20063053]
- Fossett MA, Kiecolt KJ. Mate Availability and Family Structure among African Americans in US Metropolitan Areas. *Journal of Marriage and the Family*. 1993; 55(2):288–302.
- French RM, Kus ET. KAMA: A Temperature-Driven Model of Mate Choice Using Dynamic Partner Representations. *Adaptive Behavior*. 2008; 16(1):71–95.
- Frey, WH.; Meyers, D. *Racial Segregation in US Metropolitan Areas and Cities, 1990-2000: Patterns, Trends, and Explanations* (Vol. Population Studies Center Research Report 05-573). Population Studies Center, University of Michigan; Ann Arbor, MI: 2005.
- Geronimus AT, Bound J, Waidman TA, Hillemeier MM, Burns PB. Excess Mortality Among Blacks and Whites in the United States. *The New England Journal of Medicine*. 1996; 335(1552):1558.
- Glaze, LE.; Kaeble, D. *Correctional Populations in the United States*. 2014. 2013.
- Green TC, Pouget ER, Harrington M, Taxman FS, Rhodes AG, O'Connell D, Friedmann PD. Limiting Options. *Sexually Transmitted Diseases*. 2012; 39(6):424–430. doi: 10.1097/OLQ.0b013e318254c81a. [PubMed: 22592827]
- Grinstead O, Faigles B, Bancroft C, Zack B. The Financial Cost of Maintaining Relationships with Incarcerated African American Men: A Survey of Women Prison Visitors. *Journal of African American Men*. 2001; 6(1):59–69.
- Johnson, RC.; Raphael, S. *The Effects of Male Incarceration Dynamics on AIDS Infection Rates among African- American Women and Men* (Vol. Working Paper). University of California; Berkeley: 2005.
- Kent SL, Jacobs D. Minority Threat and Polic Strength from 1980 to 2000: A Fixed-Effects Analysis of Nonlinear and Interactive Effects in Large US Cities. *Criminology*. 2005; 43(3):731–760.
- Khan MR, Behrend L, Adimora AA, Weir SS, White BL, Wohl DA. Dissolution of Primary Intimate Relationships during Incarceration and Implications for Post-release HIV Transmission. *Journal of Urban Health*. 2011; 88(2):365–375. doi: 10.1007/s11524-010-9538-1. [PubMed: 21286825]
- Khan MR, Doherty IA, Schoenbach VJ, Taylor EM, Epperson MW, Adimora AA. Incarceration and High-Risk Sex Partnerships among Men in the United States. *Journal of Urban Health: Bulletin of the New York Academy of Medicine*. 2009; 86(4):584–601. [PubMed: 19459050]

- Khan, MR.; Epperson, MW.; Mateu-Gelabert, P.; Bolyard, M.; Sandoval, M.; Friedman, SR. American Journal of Public Health. Vol. 101. A Social Network Perspective; Brooklyn, NY: 2011.
- Incarceration, Sex With an STI- or HIV-Infected Partner, and Infection With an STI or HIV in Bushwick; p. 1110-1117.doi: 10.2105/ajph.2009.184721
- Knittel AK, Snow RC, Griffith DM, Morenoff J. Incarceration and Sexual Risk: Examining the Relationship Between Men's Involvement in the Criminal Justice System and Risky Sexual Behavior. *AIDS and Behavior*. 2013; 17(8):2703–2714. doi: 10.1007/s10461-013-0421-4. [PubMed: 23392910]
- Laumann, EO.; Gagnon, JH.; Michael, RT.; Michaels, S. The Social Organization of Sexuality. The University of Chicago Press; Chicago: 1994.
- Massey D. American Apartheid: Segregation and the Making of the Underclass. *American Journal of Sociology*. 1990; 96(2):329–357.
- Ousey GC, Lee MR. Racial Disparity in Formal Social Control: An Investigation of Alternative Explanations of Arrest Rate Inequality. *Journal of Research in Crime and Delinquency*. 2008; 45(3):322–355.
- Pettit B, Western B. Mass Imprisonment and the Life Course: Race and Class Inequality in U.S. Incarceration. *American Sociological Review*. 2004; 69:151–169. Journal Article.
- Rodriguez N. Concentrated Disadvantage and the Incarceration of Youth: Examining How Context Affects Juvenile Justice. *Journal of Research in Crime and Delinquency*. 2011; 50(2):189–215. doi: 10.1177/0022427811425538.
- Simao J, Todd PM. Emergent Patterns of Mate Choice in Human Populations. *Artificial Life*. 2003; 9:403–417. Journal Article. [PubMed: 14761259]
- Stolzenberg L, D'Alessio SJ, Eitle D. A Multilevel Test of Racial Threat Theory. *Criminology*. 2004; 42(3):673–698.
- Thomas JC. From Slavery to Incarceration: Social Forces Affecting the Epidemiology of Sexually Transmitted Diseases in the Rural South. *Sexually Transmitted Diseases*. 2006; 33(7):S6–S10. [PubMed: 16794556]
- Thomas JC, Levandowski BA, Isler MR, Torrone E, Wilson G. Incarceration and Sexually Transmitted Infections: A Neighborhood Perspective. *Journal of Urban Health: Bulletin of the New York Academy of Medicine*. 2007; 85(1):90–99. [PubMed: 18046653]
- Thomas JC, Sampson LA. High Rates of Incarceration as a Social Force Associated with Community Rates of Sexually Transmitted Infection. [empirical]. *Journal of Infectious Diseases*. 2005; 191(Supplement 1):S55–S60. [PubMed: 15627231]
- Thomas JC, Thomas K. Things ain't what they ought to be: social forces underlying racial disparities in rates of sexually transmitted diseases in a rural North Carolina county. *Social Science & Medicine*. 1999; 49:1075–1084. [PubMed: 10475671]
- Walker, S.; Spohn, C.; DeLone, M. The Color of Justice: Race, Ethnicity, and Crime in America. Wadsworth Publishing Company; Detroit: 1996.
- West, HC. Prison Inmates at Midyear 2009–Statistical Tables. Washington DC: 2010.
- Western, B. Punishment and Inequality in America. Russell Sage Foundation; New York: 2006.
- Whitehead TL. Urban Low-Income African American Men, HIV/AIDS, and Gender Identity. *Medical Anthropology Quarterly*. 1997; 11(4):411–447. [PubMed: 9408898]
- Whitehead TL, Peterson J, Kaljee L. The “Hustle”: Socioeconomic Deprivation, Urban Drug Trafficking, and Low-Income, African-American Male Gender Identity. *Pediatrics*. 1994; 93:1050–1054. Journal Article. [PubMed: 8197006]

Highlights

- An agent-based model simulates sexual partnerships in communities with and without incarceration
- Incarceration in the model increases the number of sexual partners for both male and female agents
- Harsher or longer penalties might exacerbate the effect of incarceration
- High levels of incarceration likely play a role in community-level sexual behavior

Figure 1.
Model schematic.

Figure 2.
Change in number of partners in the community over the past year compared with no incarceration

Figure 3.

Number of partners in the past year, by probability of incarceration and sentence length in months

Table 1

Change in partnership dynamics reported as the baseline value (without incarceration) and the average change observed in the measure at each incarceration rate.

Partners in the Past Year	Male Individual	Male Community	Female Individual	Female Community
<i>Without incarceration</i>	2.015	251.875	1.759	219.875
Probability of incarceration at each time step				
0.0005	+ 0.09	+ 11.50	+ 0.04	+ 5.50
0.001	+ 0.13	+ 16.13	+ 0.07	+ 9.25
0.0015	+ 0.07	+ 9.25	+ 0.08	+ 9.63
0.002	+ 0.14	+ 17.88	+ 0.10	+ 12.13
0.0025	+ 0.12	+ 15.00	+ 0.10	+ 12.75
0.003	+ 0.11	+ 13.88	+ 0.09	+ 11.38

Lifetime Partners	Male Individual	Male Community	Female Individual	Female Community
<i>Without incarceration</i>	6.389	798.625	5.596	699.5
Probability of incarceration at each time step				
0.0005	+ 0.10	+ 12.25	– 0.02	– 2.00
0.001	+ 0.08	+ 9.50	– 0.05	– 6.62
0.0015	+ 0.01	+ 1.62	+ 0.04	+ 5.12
0.002	+ 0.02	+ 2.12	– 0.07	– 9.00
0.0025	+ 0.02	+ 2.38	+ 0.01	+ 0.87
0.003	+ 0.00	+ 0.62	– 0.01	– 1.38

Ever in a Concurrent Partnership	Male Rate	Male Community	Female Rate	Female Community
<i>Without incarceration</i>	0.396	49.5	0.424	53
Probability of incarceration at each time step				
0.0005	+ 0.02	+ 2.13	– 0.00	– 0.38
0.001	+ 0.01	+ 1.13	+ 0.00	+ 0.50
0.0015	– 0.00	– 0.50	– 0.01	– 0.63
0.002	+ 0.01	+ 1.25	+ 0.00	+ 0.50
0.0025	+ 0.01	+ 1.62	– 0.01	– 0.75
0.003	– 0.01	– 1.00	– 0.02	– 2.25

Quality Correlation	Mean
<i>Without incarceration</i>	0.19
Probability of incarceration at each time	

Quality Correlation	Mean
step	
0.0005	– 0.05
0.001	– 0.07
0.0015	– 0.13
0.002	– 0.12
0.0025	– 0.18
0.003	– 0.20

Table 2

Model output for ever incarcerated agents.

	Past year partners		Lifetime partners		Concurrency		Ever incarcerated Mean
	Individual	Group	Individual	Group	Individual	Group	
<i>Baseline model with high rates of incarceration</i>	<i>2.09</i>	<i>138.52</i>	<i>6.33</i>	<i>419.87</i>	<i>0.00</i>	<i>0.20</i>	<i>66.34</i>
Probability of starting a new partnership while incarcerated							
0	− 0.05	− 3.24	+ 0.14	+ 9.19	+ 0.00	+ 0.14	67.6
0.2	− 0.06	− 4.22	− 0.16	− 10.66	+ 0.00	+ 0.00	67.04
0.4	+ 0.04	+ 2.34	+ 0.03	+ 1.67	+ 0.00	+ 0.07	66.86
0.6	+ 0.02	+ 1.26	− 0.01	− 0.70	+ 0.00	+ 0.00	69.92
0.8	− 0.07	− 4.63	+ 0.18	+ 12.13	+ 0.00	+ 0.00	67.04
1	− 0.05	− 3.42	− 0.12	− 8.05	− 0.00	− 0.07	67.08
Probability of breaking up due to incarceration							
0	+ 0.09	+ 5.80	− 0.17	− 11.33	+ 0.00	+ 0.00	67.42
0.2	− 0.08	− 5.77	− 0.10	− 6.87	+ 0.00	+ 0.00	68.68
0.4	+ 0.10	+ 6.53	+ 0.26	+ 17.63	− 0.00	− 0.07	68.06
0.6	− 0.06	− 4.30	+ 0.05	+ 3.28	+ 0.00	+ 0.07	68.32
0.8	+ 0.00	+ 0.27	+ 0.04	+ 2.83	+ 0.00	+ 0.00	67.36
1	+ 0.05	+ 3.71	+ 0.13	+ 8.76	+ 0.00	+ 0.00	67.4
Incarceration penalty							
0	+ 0.03	+ 1.94	− 0.04	− 2.94	− 0.00	− 0.07	66.86
0.2	− 0.05	− 3.23	− 0.10	− 6.66	+ 0.00	+ 0.07	68.64
0.4	+ 0.02	+ 1.41	− 0.13	− 8.40	+ 0.00	+ 0.20	67.2
0.6	− 0.05	− 3.18	− 0.01	− 0.41	+ 0.00	+ 0.07	67.58
0.8	− 0.06	− 3.87	− 0.02	− 1.59	− 0.00	− 0.07	69.02
1	− 0.10	− 6.86	+ 0.01	+ 0.75	− 0.00	− 0.07	67.94
Sex ratio							
0.1	+ 3.90	+ 52.49	+ 1.65	+ 22.17	+ 0.03	+ 0.42	13.46
0.3	+ 1.86	+ 75.30	+ 0.14	+ 5.74	+ 0.01	+ 0.28	40.44
0.5	+ 0.58	+ 38.90	− 1.34	− 90.29	− 0.00	− 0.13	67.18

	Past year partners		Lifetime partners		Concurrency		Ever incarcerated
	Individual	Group	Individual	Group	Individual	Group	Mean
<i>Baseline model with high rates of incarceration</i>	<i>2.09</i>	<i>138.52</i>	<i>6.33</i>	<i>419.87</i>	<i>0.00</i>	<i>0.20</i>	<i>66.34</i>
0.7	− 0.31	− 29.00	− 2.52	− 238.94	− 0.00	− 0.09	94.78
0.9	− 0.91	− 110.45	− 3.70	− 449.07	− 0.00	− 0.24	121.24
Quality distribution							
Skewed male distribution	+ 0.52	+ 34.11	− 1.47	− 96.18	+ 0.00	+ 0.00	65.34
Sentence length							
12	− 0.06	− 3.78	+ 0.03	+ 2.30	+ 0.00	+ 0.07	67.58
16	+ 0.01	+ 0.96	+ 0.08	+ 5.15	− 0.00	− 0.07	68.62
20	− 0.04	− 2.69	+ 0.07	+ 4.97	− 0.00	− 0.07	67.14
24	− 0.08	− 5.44	− 0.17	− 11.44	+ 0.00	+ 0.00	68.92
28	− 0.03	− 2.21	+ 0.05	+ 3.28	+ 0.00	+ 0.00	66.84
32	− 0.06	− 4.34	+ 0.07	+ 4.40	+ 0.00	+ 0.07	67.76
4	+ 0.02	+ 1.39	− 0.10	− 6.81	+ 0.00	+ 0.00	66.14
8	− 0.03	− 1.99	− 0.15	− 9.60	+ 0.00	+ 0.07	66.22

Table 3

Interaction between the sex ratio and incarceration rates.

Probability of incarceration at each time-step	Individual 0.3	Community	Individual 0.5	Community	Individual 0.7	Community
Partners in the past year (male)						
0	3.474	434.25	2.097	262.125	1.221	152.625
0.001	+ 0.10	+ 12.38	− 0.02	− 2.62	+ 0.03	+ 3.75
0.002	+ 0.06	+ 7.50	+ 0.03	+ 3.62	+ 0.05	+ 6.50
0.003	+ 0.15	+ 19.12	+ 0.00	+ 0.12	+ 0.11	+ 13.25
Partners in the past year (female)						
0	1.65	206.25	1.77	221.25	1.824	228
0.001	+ 0.03	+ 3.13	+ 0.06	+ 8.12	+ 0.09	+ 11.63
0.002	+ 0.04	+ 5.38	+ 0.07	+ 8.50	+ 0.16	+ 19.63
0.003	+ 0.07	+ 8.13	+ 0.05	+ 6.00	+ 0.21	+ 25.88
Lifetime partners (male)						
0	8.536	1067	6.487	810.875	4.806	600.75
0.001	− 0.04	− 5.13	− 0.06	− 7.87	− 0.19	− 24.00
0.002	− 0.19	− 23.87	− 0.09	− 11.13	− 0.16	− 19.63
0.003	+ 0.14	+ 17.25	− 0.17	− 20.63	− 0.07	− 8.38
Lifetime partners (female)						
0	4.062	507.75	5.507	688.375	7.212	901.5
0.001	− 0.06	− 7.13	+ 0.20	+ 25.38	− 0.12	− 15.25
0.002	− 0.04	− 4.62	+ 0.04	+ 5.25	+ 0.03	+ 3.25
0.003	+ 0.05	+ 6.87	− 0.01	− 1.62	+ 0.04	+ 5.38
Ever concurrent (male)						
0	0.591	73.875	0.415	51.875	0.237	29.625
0.001	+ 0.01	+ 1.00	− 0.02	− 1.87	+ 0.01	+ 0.63
0.002	− 0.01	− 1.25	− 0.02	− 2.75	+ 0.00	+ 0.25
0.003	+ 0.00	+ 0.00	− 0.03	− 3.13	+ 0.00	+ 0.13

Probability of incarceration at each time-step	Individual 0.3	Community	Individual 0.5	Community	Individual 0.7	Community
Ever concurrent (female)						
0	0.403	50.375	0.422	52.75	0.43	53.75
0.001	- 0.00	- 0.50	+ 0.01	+ 0.63	- 0.01	- 1.13
0.002	- 0.01	- 1.25	- 0.00	- 0.25	- 0.02	- 2.63
0.003	- 0.01	- 1.38	- 0.02	- 2.50	- 0.02	- 2.00
Quality correlation						
0		0.185		0.151		0.13
0.001		- 0.27		- 0.03		- 0.03
0.002		- 0.22		- 0.08		- 0.03
0.003		- 0.31		- 0.16		- 0.08

Table 4

Interaction between the quality distribution and incarceration rate.

	Equal distributions		Unequal distributions	
	Individual	Community	Individual	Community
Partners in the last year (male)				
<i>Without incarceration</i>	2.079	259.875	1.393	174.125
Probability of incarceration at each time step				
0.001	− 0.01	− 0.75	+ 0.12	+ 15.13
0.002	+ 0.14	+ 17.75	+ 0.22	+ 27.00
0.003	+ 0.07	+ 8.37	+ 0.16	+ 20.13
Partners in the last year (female)				
<i>Without incarceration</i>	1.778	222.25	1.541	192.625
Probability of incarceration at each time step				
0.001	+ 0.01	+ 1.75	+ 0.04	+ 5.25
0.002	+ 0.10	+ 12.00	+ 0.14	+ 17.63
0.003	+ 0.07	+ 8.25	+ 0.09	+ 10.88
Lifetime partners (male)				
<i>Without incarceration</i>	6.545	818.125	4.21	526.25
Probability of incarceration at each time step				
0.001	− 0.10	− 13.00	− 0.30	− 37.13
0.002	+ 0.11	+ 14.13	− 0.24	− 30.00
0.003	− 0.17	− 21.13	− 0.44	− 55.38
Lifetime partners (female)				
<i>Without incarceration</i>	5.631	703.875	4.749	593.625
Probability of incarceration at each time step				
0.001	− 0.05	− 6.62	− 0.57	− 71.50
0.002	+ 0.01	+ 0.75	− 0.54	− 67.38
0.003	− 0.13	− 16.50	− 0.75	− 94.00
Ever concurrent (male)				
<i>Without incarceration</i>	0.409	51.125	0.275	34.375

	Equal distributions		Unequal distributions	
	Individual	Community	Individual	Community
Probability of incarceration at each time step				
0.001	− 0.01	− 0.87	+ 0.01	+ 1.25
0.002	+ 0.01	+ 1.00	+ 0.00	+ 0.13
0.003	− 0.01	− 0.75	− 0.01	− 0.75
Ever concurrent (female)				
<i>Without incarceration</i>	<i>0.43</i>	<i>53.75</i>	<i>0.368</i>	<i>46</i>
Probability of incarceration at each time step				
0.001	− 0.01	− 0.75	− 0.04	− 4.50
0.002	− 0.00	− 0.50	− 0.05	− 6.13
0.003	− 0.02	− 2.88	− 0.07	− 8.63
Quality correlation				
<i>Without incarceration</i>		<i>0.185</i>		<i>− 0.149</i>
Probability of incarceration at each time step				
0.001		− 0.06		− 0.18
0.002		− 0.14		− 0.29
0.003		− 0.17		− 0.28