THE MICRO-SOCIAL RISK ENVIRONMENT FOR INJECTION DRUG USE: AN EVENT SPECIFIC MULTILEVEL ANALYSIS OF INJECTION RISK BEHAVIOR

By

Patrick Janulis

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Psychology - Doctor of Philosophy

2014

ABSTRACT

THE MICRO-SOCIAL RISK ENVIRONMENT FOR INJECTION DRUG USE: AN EVENT SPECIFIC MULTILEVEL ANALYSIS OF INJECTION RISK BEHAVIOR

By

Patrick Janulis

Injection drug use continues to contribute to new incidence of HIV and remains the primary risk factor for hepatitis C virus in the United States. Accordingly, understanding the social processes associated with injection risk behavior remains an important goal for public health research in effort to inform interventions to reduce the frequency these behaviors. However, previous research has largely focused on *who* is most likely to engage in injection risk behavior rather than examining *when, where,* and *with whom* individuals may be at heighted risk. The current study uses event specific data from the Sexual Acquisition and Transmission of HIV Cooperative Agreement to examine dyadic, network, and situational characteristics associated with injection risk behavior. Data on multiple observations nested within participants (participant n = 784, injection episodes n = 1778) is used to examine both within and between person variation in injection risk behavior via multilevel structural equation modeling. Results are interpreted using Tseng and Seidman's (2007) theory of social settings.

Results indicated that injection risk behavior was lower when injecting with new partners. While having an injection partner that is also a sexual partner was associated with greater risk for both males and females, sexual partnership was significantly more positively associated with injection risk for females as compared to males. Furthermore, females were at greater risk when injecting with other females but the gender of their injection partner was not associated with any difference in risk among males. For network characteristics, the number of injectors in the participant's network was not significantly associated with risk behavior. Finally,

for situational characteristics no significant relationship with injection risk behavior was found for the location of the injection episode (e.g., if the participant injected at home) but injection risk behavior was higher when more non-injectors were present during the injection episode.

These results suggest that differences in social norms or resource availability may create unique risk factors for female injectors as compared to males. Future studies could provide further insight by explicitly measuring mediating social setting variables such as the availability and control of injection resources (e.g., syringes or drugs) as well as setting level norms. Furthermore, the results indicate that intervention and evaluations studies should continue to develop HIV/HCV preventive interventions tailored toward sexual partners and explore the potential for gender specific programming. While the current study provides initial insight into a more complex view of injection risk behavior and associated dyadic, network, and situational variables, significant within-person variability persisted after including all model variables. This suggests that additional dyadic and situational characteristics must be identified to better predict this unexplained variation in injection risk behavior across injection episodes. Accordingly, future work is required to develop a more thorough understanding of social setting mechanisms that may enhance protective behaviors and inhibit risk behavior within injection settings.

ACKNOWLEDGMENTS

As a researcher who focuses on the social context of behavior, it is abundantly clear to me that this work was only completed due to the mentorship, guidance, patience, and support of many individuals prior to and during my graduate studies. I am incredibly indebted to Dr. Benjamin Hidalgo who first introduced me to community psychology and provided invaluable advice in the early years of my graduate career. Similarly, I would certainly not be on my current career trajectory without the mentorship provided by Dr. Greg Scott and all those who I worked with at DePaul University's Social Science Research Center. I would also like to say thanks to Dr. Robin L. Miller for providing many opportunities to expand my knowledge, experience, and expertise in HIV research and Dr. James C. Anthony for introducing me to the field of epidemiology and providing exceptional mentorship in the transition from my role as a graduate student into an early career scholar. Finally, I am incredibly appreciative to Dr. Jennifer Watling Neal for her flexibility in allowing me to pursue my substantive interests, eagerness to pass on her insight and enthusiasms for social network analysis, and unwavering support for me and my fellow graduate students.

I must also thank my family for their assistance throughout my postgraduate years. Of particular noteworthiness, to my parents who have facilitated and encouraged my intellectual curiosity for many years and, of course, to my partner Molly who has been instrumental to my success through her loving support. Molly has shown endless patience during these busy and stressful years, she has continued to encourage me to pursue my interests despite their inconvenience to her (thanks for moving to Lansing with me!), and she has provided much

needed insight and perspective that has frequently liberated me from the tunnel vision of graduate school.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

Most internationally regulated drugs have multiple modes of administration (e.g., intranasal vs. intravenous) and the mode of administration is strongly associated with the negative health effects of using these drugs such as risk for developing drug use disorders (Gossop, Griffiths, Powis, & Strang, 1992) and the spread of disease associated with the these drugs (Latkin, Knowlton, & Sherman, 2001). Of primary interest in the current study is the elevated viral transmission risk caused by the injection of drugs for extra-medical purposes (e.g., to get "high"). For example, injection drug use was associated with 11% of new HIV infections in 2011 within the United States (CDC, 2013). Given that 1% of the US population is estimated to use injection drugs each year (Brady et al., 2008; Mathers et al., 2008; USDHHS, 2013b), this suggests that injection drug users (IDUs)[1] continue to contribute disproportionally to the new incidence of HIV in the United States. Furthermore, IDUs remain at high risk for contracting hepatitis C virus (HCV). For example, prevalence of HCV among IDUs in the United States was estimated at 73.4% in 2004 (Nelson et al., 2011) and injection drug use continues to be the greatest risk factor for contracting HCV (Alter, 2007).

Both HIV and HCV can be spread through the sharing and reuse of needles, syringes, and other non-syringe injection paraphernalia including cookers, cottons, and rinse water (Gillies et al., 2010; Mathei et al., 2006; J. Page et al., 2006). These behaviors spread HIV/HCV when blood residue from a first injector is left on these objects and is subsequently exposed to an open wound of another injector. While syringe sharing has been recognized as an HIV/HCV risk behavior since the early days of the US HIV epidemic (Zibbell, 2012), non-syringe related

[1] The use of "IDUs" in this document will refer exclusively to individuals that are injecting for non-medical drug use, such as to get "high", and will not include individuals engage in self-injections for medical purposes such as insulin injections.

paraphernalia sharing has increasingly been the focus of viral transmission, particularly for HCV (Gillies et al., 2010; Mathei et al., 2006; Needle et al., 1998; J. Page et al., 2006). Despite progress, many of these risk behaviors continue to be common among IDUs (Thiede et al., 2007; USDHHS, 2013a). For example, 21.8% of IDUs reported using a syringe previously used by another IDU during their most recent injection episode in 2012 (USDHHS, 2013a). Accordingly, research to understand these HIV/HCV risk behaviors and interventions to prevent the spread of these diseases among IDUs remains an urgent public health concern.

While the research examining injection risk behavior continues to focus on studies examining individual level characteristics (e.g., age, length of injecting, gender; Rhodes, 2009), a growing number of studies have begun to document the environmental correlates of risk behavior such as neighborhoods, networks, and norms (Latkin, German, et al., 2013; Rhodes, 2009). Given that any single IDU may inject in a variety of circumstances over time (e.g., with difference partners or at different physical locations), the circumstances of specific injection episodes may increase or decrease the level of injection risk behavior. However, few studies have examined the characteristics of settings (e.g., physical or social) for specific injection episodes and how these characteristics may impact injection risk behavior (Latkin, German, et al., 2013). Accordingly, understanding the situational and social circumstances of specific injection episodes will move analysis beyond identifying *who* is at heighted risk to also examine *when*, *where*, and *with whom* they are at risk. Those studies that have examined situational factors associated with injection risk behavior have largely been unable to directly compare the relative impact of individual and environmental factors because most studies either collect data on a single injection episode or measure individual's generalized risk behavior (e.g., risk behavior during the last 30 days) rather than risk behavior associated with a specific injection

episodes. Therefore, these studies have not compared risk behavior by participants in multiple settings and/or with different injection partners.

Accordingly, this study attempts to further unpack the "micro-social" risk environment of injection drug use (Latkin & Knowlton, 2005) by leveraging data on multiple injection episodes nested within individuals. By analyzing this data using multilevel structural equation modeling, this study will provide novel insight toward the associations of individual and situational characteristics on injection risk behavior. Furthermore, this study will utilize social setting theory (Tseng & Seidman, 2007) in attempt to model and interpret the micro-social risk environment in a holistic manner. This theory conceptualizes setting outcomes as being derived from setting resources, distribution of resources, and social processes. In the case of injection drug use settings, *resources* include the amount of time available and physical resource requirements (e.g., drugs and paraphernalia) for injecting drugs, *the distribution of resources* describe who may have greater or lesser amount of these resources in a specific setting, and *social processes* would include paraphernalia sharing norms, participation in activities (e.g., syringe exchange program), and relationships that lead to the setting outcome such as injection risk behavior. While many of these theoretical components cannot be directly assessed in the current study, social setting theory will be used to guide the understanding of the mechanisms underlying the hypothesized associations between study variables.

The current study will explore the following research questions: 1) what characteristics of injection partners and social/physical environment explain within person variation in injection risk behavior, and 2) what network and individual characteristics explain between person variation in injection risk behavior and 3) what individual characteristics explain variation in the association between situational and dyadic characteristics and injection risk behavior? This study

would expand upon previous research in this area by including event specific data on multiple injection episodes in a manner that allows for the simultaneous comparison of within and between individual variation in injection risk behavior. By answering these research questions and providing a more nuanced understanding of injection risk behavior, this study should directly inform future research and interventions intended to understand and prevent HIV risk behavior among injection drug users. For example, event specific analysis of risk behavior has been successfully used in designing policies and interventions to promote healthier behavior during peak risk events for engaging in alcohol (Neighbors et al., 2007) and sexual (Crosby, 2013) risk behaviors. In this vein, a more comprehensive understanding of injection episode characteristics that place IDUs at heightened risk would allow for interventions specifically tailored to empower IDUs to avoid or prepare for these high risk events.

Literature Review

The literature review will begin by examining the current trends in HIV/HCV and correlates of HIV/HCV seroconversion. The review will then examine the individual, dyadic, network, and environmental correlates as well as interventions to reduce injection risk behavior. Finally, the limitations of the existing literature will be discussed before discussing the theoretical frame and describing the current study.

Current Trends in HIV among IDUs

HIV continues to pose a serious health challenge to IDUs through associated morbidity and mortality (Mathers et al., 2013). The estimated prevalence of HIV was 9% in 2009 among a large sample (n = 10,073) of IDUs in 20 metropolitan statistical areas and 45% of HIV-positive IDUs were unaware of their HIV status (Wejnert et al., 2012). However, given that metropolitan regions were the quickest to implement HIV preventive interventions, these estimates may not accurately reflect the true prevalence of HIV among IDUs. The most recent prevalence estimates of HIV among all IDUs in the United States vary from 15.5% in 2003 (Mathers et al., 2008) to 2-3% in 2009 (Broz et al., 2014).

Despite the continued health burden of HIV among IDUs, significant progress has been made since the early years of the US HIV epidemic (Des Jarlais & Semaan, 2008). For example, the incidence of HIV among IDUs, as measured per person years, has decreased by roughly 80% since the mid 1980s (Hall et al., 2008). For example, New York City experienced a decline from 13 cases per 100 person-years in the late 1970s to mid-1980s (Des Jarlais et al., 2000) to 1 to 4 cases per 100 person-years by the mid 2000s (Des Jarlais & Semaan, 2008). Likewise, incidence dropped from 5.5 cases per 100 person-years in 1988-1989 to 0.0 cases per 100 person-years by the 2005-2008 among cohorts of injectors in Baltimore (Mehta et al., 2011) and similar declines

in incidence have been witnessed throughout the United States (Hall et al., 2008; Prejean et al., 2011; Tempalski et al., 2009). Furthermore, prevalence of HIV decreased in 88.5% of US metropolitan areas between 1992 and 2002 (Tempalski et al., 2009). These declines have mainly been attributed to the proliferation of syringe exchange programs and other interventions and policy changes that have increased access to sterile syringes (Des Jarlais & Semaan, 2008; Hall et al., 2008). Nonetheless, given the continued health burden and disproportionate representation of IDUs among new HIV infections, HIV remains an important concern for injection drug research and intervention.

Correlates of HIV Serostatus and HIV Seroconversion. Sharing injection paraphernalia, particularly syringes (Kaplan & Heimer, 1992), is a strong and consistent predictor of HIV serostatus and HIV seroconversion among IDUs (Chaisson, Moss, Onishi, Osmond, & Carlson, 1987; Chitwood et al., 1995; Friedman, Jose, Deren, Des Jarlais, & Neaigus, 1995; Moss et al., 1994; David Vlahov et al., 1990) and was the primary focus of research and intervention throughout the first two decades of HIV prevention research among IDUs (Zibbell, 2012). For example, a study in Miami found that individuals who shared syringes were four times more likely to seroconvert after controlling for other confounding factors (Chitwood et al., 1995). However, aside from sharing injection paraphernalia, the most common risk factors associated with HIV seroconversion are frequency of injection (Kozlov et al., 2006; Spittal et al., 2002; Strathdee et al., 2001) and injecting or use of cocaine or other stimulants (Bruneau et al., 2011; Chaisson et al., 1989; Craib et al., 2003; Kozlov et al., 2006; Patterson et al., 2008; Spittal et al., 2002; Tavitian-Exley, Boily, & Vickerman, 2013; Tyndall et al., 2003). These risk factors are likely associated with HIV because they mirror the level of actual exposure to viral transmission risk (Thorpe et al., 2002). That is, frequent injectors have higher cumulative

exposure to HIV because more frequent injections leads to a greater number of total opportunities for the IDU to come into contact with blood residue from other injectors with HIV, even after controlling for the risk observed at any specific injection event. Alternatively, injection frequency could also be associated with seroconversion because more frequent injections require a greater amount of injection resources (e.g., syringes) and therefore IDUs may rely on sharing injection paraphernalia if they are unable to obtain these resources (Remis, Bruneau, & Hankins, 1998). Also, cocaine injectors tend to inject more frequently than other injectors (Colón et al., 2001) and the frequency of injection may explain some of the increased exposure risk. Still, in several of these studies cocaine injecting remains independently associated with HIV seroconversion after controlling for frequency of injecting suggesting a higher seroconversion risk is observed among these injectors in excess of the risk associated with increased injection frequency. While the mechanism explaining this excess risk is still unclear, it is hypothesized that cocaine injecting tends to be more common among individuals who have a general higher profile of risk across drug and sexual risk behaviors (e.g., more frequent "binge" drug use) and this confounding effect may explain the excess risk of seroconversion witnessed among cocaine injectors (De, Jolly, Cox, & Boivin, 2006; Tyndall et al., 2003).

Other studies (Craib et al., 2003; Spittal et al., 2002; Strathdee et al., 2001) have identified separate seroconversion risk factors for males and females suggesting moderation of seroconversion risk factors by sex. For example, a study of Vancouver IDUs found that females who needed help injecting experienced higher risk of seroconversion while this factor was not significant for males (Spittal et al., 2002).[2] Similarly, in a study of mostly African American Baltimore IDUs, Strathdee et al. (2001) found that males who attended "shooting galleries" (i.e.,

[2] While another study (O'Connell et al., 2005) found 'needing help injecting' as a significant predictor across males and females, this study did not perform a stratified analysis or test for an interaction effect.

sites where IDUs congregate to inject together) and those who had a lower level of education had higher risk for seroconversion while neither of these factors were significant predictors of seroconversion among females. Although, the most consistent seroconversion risk factors (i.e., frequency of injecting) are present among both males and females (Spittal et al., 2002; Strathdee et al., 2001). Yet, the difference risk factors observed in sex stratified analysis suggest that different social processes may lead to seroconversion risk for males and females; these processes will be further discussed in the later section on injection risk behavior.

Recent evidence also suggests that macro and micro structural characteristics are independently associated with HIV seroconversion. For example, a study of Vancouver IDUs found that location in a high-risk environment (e.g., extreme poverty and high crime rate regions) was independently associated with seroconversion (Maas et al., 2007). Similarly, estimated community HIV viral load significantly predicts HIV seroconversion even after controlling for unsafe sex, paraphernalia sharing, and frequency of injecting (Wood et al., 2009). These studies suggests that the structural characteristics such as the stage of the HIV epidemic and concentration of high-risk behavior in local communities continue to contribute to individual's seroconversion risk regardless of individual risk behavior. For example, individual risk behavior differentially impacts the likelihood of seroconversion depending on the stage of the epidemic in a given region. More specifically, in a study of 50 US cities Friedman et al. (1995) found that in high-prevalence cities using unsterile injection equipment was a strong predictor of seroconversion but was not a significant predictor of seroconversion in low-prevalence cities. This suggests that even risk behaviors that are very efficient at spreading viral diseases can have weak relationships to seroconversion when controlling for the stage and extent of the community epidemic.

Current Trends in HCV among IDUs

Prevalence estimates of HCV among injection drug users in the United States range considerably from 8 to 80% (Aceijas & Rhodes, 2007). However, a systematic review found the midrange estimate of HCV prevalence among IDUs to be 73.4% in 2002-2004 (Nelson et al., 2011), suggesting that HCV still posed a significant health burden in this population. In the early 2000s an estimated 60% of previously acquired and 68% of newly acquired infections are attributable to injection drug use (Alter, 2002). In fact, the decline of HCV infections attributed to contaminated medical equipment in developed nations (Alter, 2002) has lead to an increasing percentage of HCV infections being attributed to injection drug use in these countries (Alter, 2007; Averhoff, Glass, & Holtzman, 2012).

While sharing of syringes has long been a focus of HCV transmission, increasing evidence suggests that sharing of non-syringe paraphernalia may also be a significant source of HCV transmission among injection drug users (Finlinson, Colan, Negran, & Robles, 2008; Hagan et al., 2001; Huo, Bailey, Garfein, & Ouellet, 2005; Needle et al., 1998; Pouget, Hagan, & Des Jarlais, 2012; Thorpe et al., 2002). Injection drug use involves a complex number of steps from combining the drugs with water, cooking the solutions, splitting the drugs (i.e., in the case of multiple person use), injecting the drugs, often making multiple punctures, and stopping the flow of blood from the wound. Compared to HIV, HCV can be more easily spread through objects used to cook the drugs (i.e., "cookers"), cottons used to filter the drugs, and objects used to clean wounds. This is because HCV can survive for longer periods outside of the human body than HIV (Paintsil, He, Peters, Lindenbach, & Heimer, 2010), has been shown to be much more transmittable than HIV during needle sticks (Sulkowski, Ray, & Thomas, 2002), and is therefore more easily transmitted on non-syringe paraphernalia (Donoghoe & Wodak, 1998; Mehta et al.,

2011). A recent meta-analysis of 21 international studies (including 9 studies from the United States) between 1989 and 2006 found that sharing syringes, sharing rinse water, sharing cottons, sharing cookers, sharing miscellaneous unspecified non-syringe injecting equipment, and backloading all had a significant pooled associations with HCV seroconversion (Pouget et al., 2012). Accordingly, injection risk behavior for HCV clearly extends beyond direct syringe sharing.

As the incidence and prevalence of HIV among IDUs has continued to decline in many regions, increasing focus has been placed on the spread of HCV in this population (Madden & Cavalieri, 2007; Zibbell, 2012). Despite progress decreasing the sharing of syringe paraphernalia, altering the sharing of cookers, cottons, rinse water, and other non-syringe paraphernalia has been harder to accomplish (Santibanez et al., 2006) likely due to the lower perceived risk of these behaviors (Rhodes, Davis, & Judd, 2004), previous lack of emphasis of reducing these behaviors in safer injecting interventions (Zibbell, 2012), and how deeply engrained these behaviors are for social processes such as drug sharing (Grund et al., 1996). Despite some evidence supporting the effectiveness of harm reduction interventions to reduce the spread of HCV (Hagan, Pouget, & Des Jarlais, 2011), strong evidence for the efficacy of these interventions has yet to be established and important questions still remain such as what level of behavioral change is required to decrease the incidence of HCV among IDUs and to obtain sustained reductions in prevalence (Hagan et al., 2011; Palmateer et al., 2010). Nonetheless, some evidence suggests HCV prevalence may be decreasing among IDUs in the United States. For example, prevalence of HCV in samples of IDUs in four major cities (i.e., Baltimore, Chicago, Los Angeles, and New York) dropped from 65% in 1994 to 35% in 2004 (Amon et al., 2008). However, other recent studies have estimated incidence of HCV among IDUs at ~25 per

1000 person years (Clatts, Colón-López, Giang, & Goldsamt, 2010; K. Page et al., 2009) which suggests incidence remains unchanged from earlier estimates (Hahn et al., 2002). Accordingly, further evidence is required to resolve these contradictions and uncover if there have been changes to incidence and prevalence and, if so, what regions and individuals have experienced these changes.

Increasing use of prescription opioids may also be contributing to a novel source of HCV infection. Recent increases in the incidence of prescription opioids use (Compton & Volkow, 2006) may explain an increase in the incidence of prescription opioid injecting associated with a concurrent increase in incidence of HCV among these opioid injectors (Bruneau, Roy, Arruda, Zang, & Jutras**-** Aswad, 2012). For example, regions in the United States associated with high rates of prescription opioid use have also seen recent increases HCV infection among young IDUs suggesting a possible link between these two trends; accordingly, prescription opioid injecting may be an emerging risk group for HCV infection that has not been the focus of much previous research (Valdiserri et al., 2014).

Correlates of HCV and HCV seroconversion. Beyond sharing injection paraphernalia, the strongest persistently identified predictor of HCV positive status among injection drug users is the number of years injecting (Amon et al., 2008; Crofts et al., 1993; Diaz et al., 2001; Garfein et al., 1998; Havens et al., 2013; Hope et al., 2011; Lorvick, Kral, Seal, Gee, & Edlin, 2001; Thomas et al., 1995). This is likely because injectors face extremely high incidence rates in the first years of injecting (Hagan et al., 2007). For example, one study (Maher et al., 2006) of urban Australia injectors found IDUs had an incidence rate of 51.2 per 100 person years during their first 1-3 years injecting. Similarly, another study (Hagan, Thiede, & Des Jarlais, 2004) of Seattle IDUs found the mean weighted average time to infection at 3.4 years. Therefore, long-term

injectors have faced the largest cumulative risk and are most likely to be HCV seropositive but are also least likely for seroconversion because most are already seropositive (Hagan, Pouget, Des Jarlais, & Lelutiu-Weinberger, 2008). Just as for HIV, frequency of injecting (Amon et al., 2008; Hagan et al., 2010; Hope et al., 2011; Thomas et al., 1995; Thorpe et al., 2002) and cocaine injecting (C. Miller et al., 2002; Thorpe et al., 2002) are both strong predictors of HCV seropositivity and HCV seroconversion because, again, frequency of injecting also closely mirrors the actual level of risk for being exposed to HCV (Thorpe et al., 2002).

Co-infection of HIV and HCV

In addition to the substantial health burden both HIV and HCV independently create among IDUs, this population also faces substantial complications cause by co-infection of HIV and HCV (Alter, 2006; Sulkowski, 2008). Globally in the general population, HCV prevalence rates among HIV positive individuals vary from 25-30% in western Europe and the USA (Alter, 2006) with substantially higher rates (72-95%) being observed among injection drug users (Denis et al., 1997; Roca et al., 2003; Sulkowski & Thomas, 2003). Just as in the general population, injection drug user is a strong predictor of HCV among HIV positive individuals. For example, one study found injection drug use as the sole significant predictor of HCV infection besides aspartate aminotransferase (i.e., an indicator of liver damage) among a sample of HIV positive individuals (Staples, Rimland, & Dudas, 1999).

HIV can complicate the treatment and clearance of HCV. For example, lower rates of spontaneous clearance have been observed among those who also have HIV (Grebely et al., 2007). Comorbidity of HIV and HCV also increases the risk of liver damage due to highly active antiretroviral therapy (Rockstroh & Spengler, 2004). However, the impact of HCV co-infection among HIV positive individuals remains unclear. One study observed similar survival rates

among HIV/HCV co-morbid patients compared to HIV alone (Staples et al., 1999; Wright et al., 1994) while another found decreased mortality rates among co-infected participants (El-Serag, Giordano, Kramer, Richardson, & Souchek, 2005). However, others have found similar HIV related mortality among co-morbid individuals but increased overall mortality due to greater liver associated mortality (Bonacini, Louie, Bzowej, & Wohl, 2004). Contrastingly, patients with HCV related liver disease and co-infections of HIV appear to have considerably higher rates of mortality as compared to those with HCV alone (Pineda et al., 2005).

Clearly, HIV and HCV contribute to substantial morbidity and mortality among IDUs. The prime focus of most research and interventions has been to reduce the frequency of injection risk behavior among IDUs in effort to reduce the incidence of both diseases. Accordingly, next we will examine these risk behaviors and the individual, dyadic, network, and environmental correlates engaging in these behaviors.

Injection Risk Behavior

Since the early days of the HIV/AIDS epidemic, the majority of research on behavioral risk factors for the spread of viral diseases among IDUs has focused on the sharing of syringes and needles (Scott, 2011) as this behavior provided the most efficient route for the spread of HIV among IDUs. As discussed, increasing focus has been placed on the sharing of non-syringe paraphernalia as emphasis of research and intervention has shifted from HIV to both HIV and HCV prevention (Zibbell, 2012). Again, the injection process involves many steps that can include: preparation of the drug material from solid into a liquid form, splitting/sharing the drugs, cleaning the wound, making multiple punctures, and stopping the flow of blood. Contamination of the injection equipment or an wound can occur during many of these steps and lead to the spread of viral diseases between individuals injecting together (Scott, 2011). The most

common injection risk behaviors[3] used in this research are: receptive syringe sharing (i.e., receiving a syringe previously used by another injector), distributive syringe sharing (i.e., distributing a syringe the participant has used), sharing cookers (i.e., the objects used to mix and liquefy the drug solution), backloading (i.e., dividing the drug solution by unloading the solution into the back end of the syringe after removing the syringe plunger), frontloading (i.e., sharing drugs by drawing from the same source - usually the same cooker), sharing cottons (i.e., the objects used to remove solid adulterants from the liquid drug solution), and sharing rinse water (i.e., the water used to liquefy the drugs or to make sure the syringe is not clogged).

In 2012 an estimated 21.8% of IDUs in the United States engaged in receptive syringe sharing (i.e., injected with a syringe previously used by someone else), 21.5% engaged in distributive syringe sharing (i.e., let someone inject with their used syringe), and 34.6% obtained a syringe from a source other than a syringe exchange, pharmacy, or doctor during their most recent injection episode (USDHHS, 2013a). Furthermore, a study of non-syringe sharing practices in 5 US cities (Chicago, Baltimore, Los Angeles, New York, and Seattle) between 2002 and 2004 estimated that 47.7% of IDUs shared cookers, 35.3% shared cottons, and 35.5% shared water during the previous three months to participating in the study (Thiede et al., 2007). This suggests that many IDUs continue to engage in both syringe and non-syringe related injection risk behavior.

Individual Correlates of Injection Risk Behavior. Accordingly, a substantial body of research has focused on understanding and predicting characteristics of individuals that engage in injection risk behavior. Similar to correlates of seropositivity, cocaine injecting (Hudgins,

[3] While not all of these behaviors place the participant at risk for contracting viruses (i.e., some behaviors place the partner but not the participant at risk), these variable are often used to either measure the willingness of the participant to put others at risk or used as an indicator of the participant's more general injection risk behaviors. These variables will be further discussed in the section on latent variable modeling.

McCusker, & Stoddard, 1995; Mandell, Vlahov, Latkin, Oziemkowska, & Cohn, 1994; Wood, Li, et al., 2005; Wood et al., 2002) and greater frequency of injection (Golub et al., 2007; Mandell et al., 1994; Thiede et al., 2007) have both been found to be associated with sharing injection equipment. This association may be due to the increased risk observed among these IDUs is likely due to the large amount of physical resources required among frequent injectors that leads to increased drug and paraphernalia sharing (Remis et al., 1998; Tyndall et al., 2003). For example, syringes can only be used a certain number of times because the needles dull after repeated use. Accordingly, frequent injectors may rely on sharing injection equipment in order to facilitate more frequent drug use. Similarly, frequent drug use may also require greater monetary resources to obtain a larger amount of drugs. Therefore, frequent injectors may rely on drug sharing in order to defray the costs of frequent drug use and therefore be more likely to engage in risk behavior during the drug splitting process (Koester, Glanz, & Barón, 2005).

Most studies have found that age has been inversely associated with injection risk behavior with young IDUs showing higher levels of risk behavior as compared to older IDUs (Beletsky et al., 2014; Cassin, Geoghegan, & Cox, 1998; Golub et al., 2007; Gyarmathy et al., 2010; Thiede et al., 2007). The general higher level of risk observed among younger injectors may be partially caused by the lower observed levels of syringe exchange program participation among young injectors (Beletsky et al., 2014). However, one study (Lopez, Krueger, & Walters, 2010) found that, after controlling for age at first drug use, age was positively associated with injection risk behavior. Accordingly, while older IDUs appear to be at reduced risk for engaging in injection risk behavior, risk behavior may also be a function of time since first drug use and the relationship between age and injection risk behavior should be further explored while taking time since first drug use into account.

Other studies have examined psychological predictors of injection risk behavior. For example, a number of studies found have found that greater levels of depression predict injection risk behavior (Bailey et al., 2007; Hawkins, Latkin, Hawkins, & Chowdury, 1998; Metzger & Woody, 1991; Perdue, Hagan, Thiede, & Valleroy, 2003; Stein, Solomon, Herman, Anderson, & Miller, 2003) or moderates the relationship between network variables and injection risk behavior (Mandell, Kim, Latkin, & Suh, 1999). For example, several studies (Bailey et al., 2007; Hawkins et al., 1998; Perdue et al., 2003) have found that IDUs with higher diagnostic scores for depression were more likely to engage in receptive syringe sharing. The mechanism of the impact of depression on injection risk behavior remains unclear. However, proposed reasons that depression could increase injection risk behavior include: depression caused fatalism over contracting HIV and decreased attention paid to injection process due to depression (Stein et al., 2003).

Other studies have used cognitive behavioral theories to predict risk behavior such as protection motivation theory (Grau, Bluthenthal, Marshall, Singer, & Heimer, 2005), the AIDS risk reduction model (Longshore, Stein, & Conner, 2004), and the health belief model (Rácz, Gyarmathy, Neaigus, & Ujhelyi, 2007). These theories rely on properties of individuals such as motivation, self-efficacy, and perception of risk to explain subsequent risk behavior. In their review of cognitive behavioral studies examining injection risk behavior, Wagner, Unger, Bluthenthal, Andreeva, and Pentz (2010) found strong support for the association between self-efficacy and perceived norms in explaining injection risk behavior. However, only mixed support was documented for other cognitive behavioral constructs such as behavioral skills, knowledge, and perceived susceptibility. The authors suggest that one reason for inconsistent findings between cognitive behavioral predictors and injection risk behavior is the lack of accounting for

the environment of injection risk behavior that may jointly influence cognitive behavioral predictors and HIV risk behaviors.

Sex of the injector also predicts injection risk behavior with most studies finding that female injectors are at higher risk for injection risk behavior. For example, female injectors are more likely to have sexual partners who are injection drug users (Evans et al., 2003; Spittal et al., 2002), to require help injecting (Frajzyngier, Neaigus, Gyarmathy, Miller, & Friedman, 2007), to share injection equipment with a sexual partner (Choi, Cheung, & Chen, 2006; Gollub, Rey, Obadia, Moatti, & Group, 1998), and to share injection equipment generally (Barnard, 1993; Beletsky et al., 2014; Evans et al., 2003; Iversen, Wand, Gonnermann, & Maher, 2010; S. Montgomery et al., 2002; Pouget et al., 2005; Rhodes, 2009; Thiede et al., 2007). Some of these studies used theories of social bonding (Choi et al., 2006) and gender role theory (Cruz et al., 2007) to explain this association. For example, Cruz et al. (2007) found that traditional gender roles were pervasive among male and female injectors in Tijuana/Juarez and these roles influenced how participants managed risk such as male and females choosing different venues for their injection episodes. However, most studies relied on previous research to form their hypothesis. One study found that female IDUs who shared equipment were those with the highest levels of depression which suggested an interaction between sex, depression, and injection risk behavior (M. E. Johnson, Yep, Brems, Theno, & Fisher, 2002). Yet, the simplified observation that female injectors tend to be at high risk for sharing injection equipment likely reflects complicated social processes that are at play during injection episodes (El-Bassel, Shaw, Dasgupta, & Strathdee, 2014). This process will be further discussed as it relates to the dyadic, situational, and network correlates of injection risk behavior.

Dyadic Correlates of Injection Risk Behavior. Given that sharing injection equipment is an inherently dyadic behavior between partners, a number of studies have attempted to move beyond individual risk factors by examining dyadic predictors of injection risk behavior. One of the earliest studies examining dyadic predictors of injection risk behavior (Neaigus et al., 1995) found that having frequent contact, close relationships, or a sexual relationships with an injection partner predicted receptive syringe sharing. Following Neaigus et al.'s (1995) early study, several additional studies have found that having an injection partner who is also a sexual partner is a consistent risk factor for sharing injection equipment (Bailey et al., 2007; Gyarmathy et al., 2010; Hahn, Evans, Davidson, Lum, & Page, 2010; Hottes, Bruneau, & Daniel, 2011; Shaw, Shah, Jolly, & Wylie, 2007; Sherman, Latkin, & Gielen, 2001; Thiede et al., 2007). Similar to condom use in intimate relationships (C. Montgomery et al., 2008; Willig, 1997), injection equipment sharing among sexual partners often involves explicit or implicit statements of commitment and trust between partners (El-Bassel et al., 2014). Therefore, decisions about the injection process are embedded in the context of these relationships and relationship concerns may outweigh concerns about viral risk (Seear et al., 2012; Simmons, Rajan, & McMahon, 2012). These findings are also consistent with results indicating that IDUs are more likely to share with injection partners that they see as close friends (Rhodes et al., 2004; Valente & Vlahov, 2001) or trustworthy (Gyarmathy et al., 2010), two characteristics that many sexual partners may have.

However, the association between dyadic predictors and injection risk behavior may also be moderated by the gender of the injector and the gender of their injection partner. For example, Unger et al. (2006) found both male and female participants were at heightened risk for needle sharing when a male partner helped them inject but not when a female partner helped them

inject. Similarly, another study (Hahn et al., 2010) found that gender discordant partners are more likely to share syringes relative to male-male and Gyarmathy et al. (2010) found male-male partners were more likely to share cookers than female-female partners. However, a third study found no significant relationship between gender concordance and sharing syringes (Sherman et al., 2001).

Accordingly, the relationship between gender concordance/discordance and injection risk behavior remains unclear. Nonetheless, ethnographic (Bourgois & Schonberg, 2009) and other qualitative studies (Cruz et al., 2007) suggest that gender dynamics have some association with injection risk behavior but the precise nature of that relationship is yet to be fully developed and may vary across specific samples and contexts. Qualitative studies (El-Bassel et al., 2014) suggest that the increased likelihood of males serving as the arbitrator of drug and syringe acquisition may decrease the agency among female injectors in gender discordant injection partnerships. While females do appear to engage in elevated levels of injection risk behavior (Barnard, 1993; Beletsky et al., 2014; Iversen et al., 2010), researchers should be cautioned not to oversimplify the dynamics between male-female injection partners as many female injectors may play significant roles in acquiring drug resources and thereby retain control over the injection process (El-Bassel et al., 2014; Syvertsen et al., 2014).

Another focus of dyadic analysis of injection drug users has been the effect of serosorting on equipment sharing behavior. Serosorting is the process in which injectors attempt to only share with injection partners they perceive to have the same HIV or HCV serostatus. While the efficacy of this practice is suspect (Kim & Page, 2013) given the discordance between perceived and actual HIV/HCV status (Stein, Maksad, & Clarke, 2001) and the possibility of HCV clearance after an initial positive test, several studies have documented the presence of

serosorting among IDUs (Burt, Thiede, & Hagan, 2009; Gyarmathy et al., 2010; Hahn et al., 2010; Mizuno et al., 2011; Smith et al., 2013; Yang, Tobin, & Latkin, 2011). For example, participants who knew their own HCV serostatus are more likely to know their partner's serostatus and HCV positive participants were more likely to share with HCV positive partners (Smith et al., 2013). However, most studies examining serosorting are limited because they examine cross-sectional data and do not directly inquire about the intentions of IDU sharing behaviors (Kim & Page, 2013). While there is evidence of a tendency for injection partners to have the same serostatus and for participants who know their serostatus to know their partner's serostatus, it is not yet clear if injectors systematically chose to inject with partners they perceive to be of the same serostatus or if another process is responsible for this association. For example, studies that do not conduct biological tests for serostatus may simply reflect that people who share injection equipment are more likely to perceive each other as seroconcordant (Kim & Page, 2013)

Network Correlates of Injection Risk Behavior. Looking beyond dyadic relationships, a growing body of research has examined associations between structural network characteristics and injection risk behavior. Research on network correlates of injection risk behavior have generally focused on two types of networks: drug networks and injection networks. Drug networks are usually operationalized as the number of individuals the participant uses drugs with, often defined by using drugs in the same room at the same time. Injection networks are operationalized as the number of individuals with whom the participant has injected drugs. Studies have generally found that larger drug networks are associated with higher levels of risk behavior (De et al., 2006; Latkin, Kuramoto, Davey-Rothwell, & Tobin, 2010). For more specific examples, in studies of Baltimore, St. Petersburg, Chicago, Seattle, Los Angeles, and

New York, drug network size has been positively associated with increased frequency of injection (Latkin, Mandell, Oziemkowska, et al., 1995) while drug and injector network size have both been associated with sharing injection equipment (Cepeda et al., 2011; Latkin, Mandell, Vlahov, et al., 1995; Latkin, Mandell, Vlahov, Oziemkowska, & Celentano, 1996; Needle et al., 1998; Thiede et al., 2007), and injection network size has also been positively associated with both syringe and non-syringe paraphernalia sharing (Thiede et al., 2007). However, several studies in Baltimore, Los Angeles, Sydney, Winnipeg, Dayton, Houston, and Rio Piedras have also found no relationship between network size and risk behaviors (Lakon, Ennett, & Norton, 2006; Paquette, Bryant, & De Wit, 2011; Shaw et al., 2007; C. Williams, Liu, & Levy, 2011; M. Williams et al., 1995; Yang et al., 2011). The reason for these inconsistencies may be due to the difference of specific operational definitions of these network types, the specific context of injection drug use for each sample, as most studies are based on samples in specific geographic regions, or the variability in control characteristics included in multivariate analysis. For example, many studies (e.g., Paquette, Bryant & De Wit, 2011; Thiede et al., 2007; C. Williams, Liu, & Levy, 2011) include network size as the only network characteristic in their model and most fail to examine interactions between network characteristics (De, Cox, Boivin, Platt, & Jolly, 2007), such as size and composition, thus leading to potentially divergent findings if different network characteristics are used as control variables across studies.

Furthermore, another explanation for these inconsistencies may be that association between network size and risk behavior is likely moderated by the type of network being measured. For example, the number of drug network members providing material support (i.e., members willing to lend money) has been positively associated with sharing between network members (Suh, Mandell, Latkin, & Kim, 1997; Tobin, Davey-Rothwell, & Latkin, 2010). This

effect is likely due to the norms of reciprocity in sharing resources that increase the likelihood of sharing injection equipment (Hahn et al., 2002) and the negative consequences of not sharing paraphernalia with drug network members (Wagner et al., 2011). Conversely, larger networks offering more pro-social connections (e.g., non-IDU) have been associated with lower risk behavior (Cox et al., 2009). Having larger non-IDU network connections may discourage sharing of injection equipment through stigma attached to these behaviors that are more prevalent among non-IDUs (Mateu-Gelabert et al., 2005). This relationship could also be caused by a trade off in network membership so that IDUs with larger non-IDU networks tend to have smaller IDU networks. Smaller IDU networks may lead to less risk behavior given the less frequent opportunity to share equipment with other IDUs or the inability to seek IDUs to share equipment or drugs.

Density of IDU social networks has also been a frequent network characteristic examined in this research. Density is the proportion of observed network connections out of all possible connections. For example, drug social network density has been positively associated with frequency of injection (Latkin, Mandell, Oziemkowska, et al., 1995; Trotter, Baldwin, & Bowen, 1995), sharing needles (Curtis et al., 1995; Latkin et al., 1996), and general risk behavior (Frey et al., 1995). However, a number of studies have failed to find a significant relationship network density and risk behavior (Knowlton, Hua, & Latkin, 2004; Koram, Liu, Li, Luo, & Nield, 2011; Latkin et al., 2010; Suh et al., 1997). Similar to network size, the relationship between network density likely depends on the type of network and type of risk behavior being assessed. For example, Latkin, Mandell, Vlahov, et al. (1995) found a significant relationship between

personal support network[4] density and sharing needles but no significant relationship between density and attending a shooting gallery. This may be due to the norm enforcement mechanisms of dense social networks (Latkin, Forman, Knowlton, & Sherman, 2003) that encourages reciprocal support such as through sharing syringes. Furthermore, seeking other resources, such as through attending shooting galleries (Celentano et al., 1991), may become unnecessary when a dense social group is already providing injection resources when they are needed.

Finally, a smaller number of studies have also examined the relationship between multiplexity and injection risk behavior. Multiplexity is defined as having ties to individuals in more than one network type. For example, a relationship with Person A could be considered as multiplex if Person A was in the participant's drug network, social support network, and sexual network. Given that multiplex relationships may be more intimate or durable due to the multiple roles played by these connections, its plausible that injection risk behavior could be positively associated with multiplexity. However, the few studies examining multiplexity have generally failed to find a significant relationship with injection risk behavior. For example, having network members in two or more networks types (e.g., physical assistance and health information) was not significantly associated with needle sharing (Latkin, Mandell, Vlahov, et al., 1995; Latkin et al., 1996) frequency of injection (Latkin, Mandell, Oziemkowska, et al., 1995) or shooting gallery attendance (Latkin, Mandell, Vlahov, et al., 1995). Although, one study (Trotter et al., 1995) found that being in multiple networks (i.e., drug, social, and AIDS communication) was associated with more frequent injections. As discussed, the main exception to these findings is the consistent association between sexual and injection partnership in dyadic analysis which have

[4] *Personal network* was defined broadly as a connection between network members in any of the six network types: material assistance, socializing, intimate interaction, physical assistance, health information, and positive feedback.

not been fully elaborated within studies examining multiple structural features of drug use networks.

Therefore, a number of network characteristics have been associated with injection risk behavior but the precise nature of these relationships appears highly specific to certain network types (e.g., drug network versus material support), specific network characteristics, and the types of risk behavior because these network mechanisms likely operate through the social processes of obtaining and injecting drugs. For example, network size may facilitate increased sharing in networks where sharing behavior is an acceptable (e.g., IDU networks) network size may decrease sharing in networks that this behavior is not acceptable (e.g., non-IDU networks). Due to these complexities and continued uncertainty of relationships and mechanisms, additional investigations are required to fully clarify the associations between network characteristics and injection risk behavior.

Environmental and Situational Correlates of Injection Risk Behavior. In addition to studies examining network correlates of injection risk behavior, environmental factors such as government policy, geographic location, and neighborhood resources have been increasingly studied as predictors of injection risk behavior (Latkin, German, et al., 2013; Rhodes, Singer, Bourgois, Friedman, & Strathdee, 2005). Some of the earliest research on environmental correlates of injection risk behavior focused on the physical environment in which IDUs used drugs. For example, early studies recognized shooting galleries were as important reservoirs and vectors of HIV transmission (Chitwood et al., 1990). Given the potential for viral transmission at these locations, follow-up studies confirmed that injecting at shooting galleries was associated with sharing injection equipment (Devillé, van Ameijden, & Wolffers, 2001; Klein & Levy, 2003; Latkin et al., 1994; Neaigus et al., 1994; Wood, Tyndall, et al., 2005). While there is

considerable variability in the type of shooting galleries (Ouellet, Jimenez, Johnson, & Wiebel, 1991), these locations may explicitly encourage equipment sharing through renting of injection paraphernalia by individuals managing the site as well as encouraging incidental equipment sharing among individuals requiring help to inject or those splitting drugs (Carlson, 2000). Similar to shooting galleries, increased sharing behavior has also been documented among injectors who inject at friend's houses relative to those who inject at their own residence (Latkin et al., 1994). Accordingly, individuals who inject in public or semi-public places appear to be at increased risk of sharing injection equipment. This may be explained through the increased likelihood that they are required to share resources with those who provide the opportunity to inject in these locations (e.g., friends or shooting gallery managers) or, alternatively, may be that individuals that lack resources are more likely to seek out injection opportunities at these locations because of the increased willingness of IDUs to share resources at these sites.

Furthermore, individuals who inject in public spaces are exposed to additional barriers to hygienic injections such as police pressure that decrease carrying sterile syringes or requiring quick injections that further exacerbate the probability of injection risk behavior. Qualitative and ethnographic studies have documented the tendency for street policing practices to distract from ideal injection practices due to shifts in risk attention from viral diseases toward immediate personal safety (Aitken, Moore, Higgs, Kelsall, & Kerger, 2002; Cooper, Moore, Gruskin, & Krieger, 2005; Maher & Dixon, 1999; Rhodes et al., 2003; Small, Kerr, Charette, Schechter, & Spittal, 2006; Small, Rhodes, Wood, & Kerr, 2007). For example, arrest for possession of injection paraphernalia has been associated with shooting gallery attendance and receptive syringe sharing (Pollini et al., 2008). Similarly, being "stopped and frisked" has also been associated with lower odds of syringe exchange attendance (Beletsky et al., 2014).

Finally, several recent studies have attempted to characterize the syringe coverage of specific geographic regions in effort to predict risk behavior. Syringe coverage can be operationalized as an individual or a population level (Burrows, 2006) but in both cases is hypothesized to be a product of the availability of sterile syringes in the region. As a population level characteristic, syringe coverage can reflect a percentage of the estimated number of IDUs that have contact with syringe exchange programs or the percentage of syringe need met by SEP and pharmacy syringe sales (Heimer, 2008). As an individual characteristic, syringe coverage reflects a percentage of all injections made by the IDU using a sterile syringes (Sharma, Burrows, & Bluthenthal, 2007). Many studies (Aceijas, Hickman, Donoghoe, Burrows, & Stuikyte, 2007; Barrio et al., 2012; Tempalski et al., 2008) examining population syringe coverage as the dependent variable assume that syringe coverage is positively associated with reductions in risk behavior. This is because both empirical (Abdul-Quader et al., 2013; Des Jarlais, Feelemyer, Modi, Abdul-Quader, & Hagan, 2013) and modeling studies (Vickerman, Hickman, Rhodes, & Watts, 2006) of HIV/HCV incidence suggest that obtaining acceptable population coverage is effective at preventing HIV/HCV. At the individual level, several studies, have found that lower syringe coverage has been associated with re-using syringes (Iversen, Topp, Wand, & Maher, 2012), sharing cookers, and distributive/receptive syringe sharing (Bluthenthal, Anderson, Flynn, & Kral, 2007). While one study (Bryant, Paquette, & Wilson, 2012) failed to find this association, these results are likely explained by the high level of syringe coverage witnessed in this population (IDUs in New South Wales) that reduced the observed variability of risk behavior.

One of the most comprehensive studies using spatial multilevel modeling found that spatial access to syringes significantly predicted use of an unsterile syringe (Cooper et al., 2011;

Cooper, Des Jarlais, Ross, et al., 2012; Cooper, Des Jarlais, Tempalski, et al., 2012). In addition, Cooper, Des Jarlais, Ross, et al. (2012) also found that policing practices moderated the relationship between spatial syringe access and risk behavior so that areas of high drug-related arrest had a significantly lower slope between spatial access and risk behavior. This suggests the impact of syringe availability and coverage on risk behavior is complex and depends on specific local processes that may encourage or discourage obtaining and carrying sterile syringes.

Interventions to Reduce Injection Risk Behavior

Given the well-documented HIV/HCV risk faced by IDUs and the large number of identified individual, dyadic, network, and environmental risk factors, a wide variety of interventions have been developed in attempt to reduce the risk of acquiring HIV and HCV among IDUs. These interventions include substance abuse treatment to reduce drug use (e.g., opioid replacement therapy or substance abuse counseling), behavioral interventions to reduce risk behavior, and resource provision programs such as syringe exchange programs. Numerous evaluation studies have established the efficacy of these interventions to reduce the incidence of HIV seroconversion (A. Wodak & Cooney, 2005) among IDUs and to achieve sustained reductions in the prevalence of HIV (MacDonald, Law, Kaldor, Hales, & J Dore, 2003). These findings have been robust across countries internationally including both industrialized and developing nations (Des Jarlais & Semaan, 2008; D. Vlahov, Robertson, & Strathdee, 2010). For example, while the largest body of evidence exists in the United States, Western Europe, and Australia (Mathers et al., 2010; Alex Wodak & McLeod, 2008), countries such as Bangladesh, India, and Indonesia have all successfully implemented effective harm reduction interventions such as syringe exchange programs (Sharma, Oppenheimer, Saidel, Loo, & Garg, 2009).

For example, a systematic review and meta-analysis found that opioid substitution therapy (i.e., methadone or Buprenorphine maintenance programs) reduced the risk of HIV infection among IDUs (MacArthur et al., 2012). Similarly, risk reduction interventions within substance abuse treatment programs have also shown to be effective at reducing risk behavior (Prendergast, Urada, & Podus, 2001). Finally, a comprehensive review of evidence on syringe and needle exchange program suggested that the evidence overwhelming supported the efficacy, safety, and cost effectiveness of these programs in reducing the spread of HIV including evidence that six of the nine Bradford Hill causal criteria were satisfied through existing research (A. Wodak & Cooney, 2005, 2006). The main causal mechanism behind syringe exchanges is proposed to be the provision of sterile syringes but most modern syringe exchange programs offer a wide variety of services including HIV/HCV and STD testing, condom distribution, non-syringe paraphernalia distribution, referral to detoxification and substance abuse counseling, and instruction on hygienic injection practices (Des Jarlais, McKnight, Goldblatt, & Purchase, 2009).

The evidence for the efficacy of behavioral interventions to reduce the spread of HCV is less clear. A recent review and meta-analysis of HCV prevention interventions among IDUs found that multi-component interventions (e.g., opioid replacement therapy combined with syringe exchange programs) reduced risk of seroconversion by 75% (Hagan et al., 2011). Furthermore, preventive interventions that increase the coverage of syringe programs to 50% (i.e., an estimated 50% of syringes used IDUs are sterile and have not been previously used) may be especially effective at reducing the prevalence of HCV (Abdul-Quader et al., 2013; Des Jarlais et al., 2013). However, concern still exists that there is inadequate evidence to support the effectiveness of common strategies to prevent HCV among IDUs such as syringe exchange

programs (MacArthur et al., 2014) particularly due to the dearth of studies examining biological outcomes of these interventions such as HCV seroconversion (Palmateer et al., 2010).

Recently, a larger number of studies have utilized network mechanisms and peer education to promote safer injection practices (Latkin, German, et al., 2013). While initially used as a novel means to recruit hidden populations, networks were soon recognized as a powerful tool to leverage social influence on injection risk behaviors (Heckathorn, Broadhead, Anthony, & Weakliem, 1999). Network interventions generally train peer educators to intervene in their networks and promote safer injection practices through education and, sometimes, the provisions of sterile injection equipment (Dickson-Gomez, Weeks, Martinez, & Convey, 2006). These interventions are largely based on theories of social influence that depend on intervention participants to influence their larger network using cognitive behavioral training techniques (Kelly & Kalichman, 2002). Network interventions have been effective at reducing injection risk behavior (Latkin, Donnell, et al., 2013; Latkin, Sherman, & Knowlton, 2003; Medley, Kennedy, O'Reilly, & Sweat, 2009; Tobin, Kuramoto, Davey-Rothwell, & Latkin, 2011). Still, the effect of such interventions depend on the local context in which they are implemented. Latkin et al. (2009) found that a network intervention was effective in Philadelphia, USA, but not in Chiang Mai, Thailand. The authors speculated that local police behavior (i.e., arresting participants for having syringes) that limited participants ability to carry sterile syringes in Chiang Mai likely hindered the effectiveness of the intervention despite observing increases in the intervention group for mediators of risk behavior (e.g., talking about risk reduction). Furthermore, the impact of these interventions on incidence rates for HCV/HIV are not yet clear. For example, Garfein et al. (2007) found no significant difference between intervention (i.e., cognitive behavioral peer

education training) and control arms in HCV incidence rates and were unable to compare HIV incidence rates as no participant experienced HIV seroconversion.

Limitations of Past Research

As with all areas of research, the existing literature has a number of limitations and areas that remain unexplored. First, most studies examining situational correlates of injection risk behavior rely on event non-specific measures of participant behavior. For example, studies examining injection location largely rely on generalizations about locations that participants have injected at over a given time period. Most commonly, this variable is measured by asking if participants have injected at a certain type of location (e.g., shooting gallery) during the last 6 months (e.g., see Tobin et al., 2010). Using this method, researchers compare individuals who have and have not injected in that location during the time period. This approach can be contrasted with "event specific" approaches that ask about a single or multiple specific injection episodes. Event specific approaches can enhance the rationale for causal inference because this approach ensures independent and dependent variables occurred during the same event (Leigh, 2002). It is also possible that this approach reduces recall bias by eliciting information about specific events rather than general behavior (Hottes et al., 2011), although this has not been specifically tested for injection risk behavior. An event specific approach can also examine intra-individual variation if data is collected on multiple injection episodes, allowing for analysis of situational and dyadic predictors of injection risk behavior holding constant static individual characteristics (Leigh & Stall, 1993). Again, event specific data with multiple observations allows for examining when, where, and with whom IDUs may be at greatest risk. Accordingly, studies examining intra-individual variation will provide further insight into the immediate social mechanisms that may place individuals at higher risk for injection risk behavior.

While using event specific data is extremely common in related topic areas such as non-injection drug use and sexual risk behavior (Vosburgh, Mansergh, Sullivan, & Purcell, 2012), only a handful of studies have yet to employ this technique to examine predictors of injection risk behavior. Furthermore, most of the studies that have used this approach (Gyarmathy et al., 2010; Hottes et al., 2011; Tortu, McMahon, Hamid, & Neaigus, 2003) have either a) collected data on a single injection episode per participant or b) collected data on multiple injection episodes but used a population averaged (e.g., generalized estimating equations) model to estimate parameters that does not accurately reflect the complexity of the injection process. The main limitation of collecting data on a single injection episode is that variation within injectors cannot be observed across different injection environments. While this design has allowed an accumulation of evidence determining which individuals have the highest probability of engaging in risk behavior, it is much less informative toward the partners, locations, and situations that might place IDUs at risk. The main limitation with using a population averaged model is that within individual variance is treated as a nuisance parameter and not one to be explicitly modeled, limiting flexibility in investigation of within individual factors (Hu, Goldberg, Hedeker, Flay, & Pentz, 1998). For example, population averaged models would likely be a more desirable approach to deal with repeated observations if the primary interest of the study is to estimate the average effect of individual characteristics (e.g., being male or female) across people. However, random effect models are more desirable if the primary interest in the study is to examine how a single individual varies across different situation (e.g., when injecting with a male or female partner). Accordingly, random effect models allow for more successful modeling of the complex social processes that occurring across injection episodes

among the same individuals by providing additional flexibility in the modeling process of within individual variability.

A second limitation in the current literature is that most studies have measured each type of injection risk behavior as a separate outcome (e.g., sharing cookers, receptive syringe sharing, etc.). This is problematic for a number of reasons. First, examining each outcome separately provides a long and sometimes contradictory list of findings that may obscure important relationships across variables. By combining conceptually related variables such as injection risk behavior into a single score outcome variable, it becomes easier to compare results across studies even when the precise items may vary from one study to the next (Wagner, Unger, et al., 2010). Second, the number of injection steps that place the injector at risk during a given injection episode is quite large and a single behavior may occur multiple times in a given episode (Scott, 2011). Therefore, single indicator assessments of injection risk behavior are unlikely to accurately reflect the true breadth of injection risk behaviors. Finally, the goal of most IDU risk behavior studies, both observational and experimental interventions, is to understand or reduce the risk for contracting viral diseases. Given that many risk behaviors contribute to individual's risk of contracting viral diseases, this risk is unlikely to be accurately modeled using a single indicator dependent variable. However, injection risk behavior can be measured using latent variable modeling in effort to estimate an underlying level of risk with each risk behavior being used as an observed indicator of this risk. Using this approach, we can conceptualize each single injection risk behavior reflecting the underlying injection risk behavior in a hierarchically ordered manner. Therefore, IDUs who engage in risk behaviors that reflect the highest level of underlying risk (e.g., using a syringe after multiple IDUs used it) are also likely to engage in many other lower level risk behaviors (e.g., sharing cookers). Using all indicators, we can then

place IDUs on the spectrum from low to high levels of underlying risk behaviors according to how many and which risk behaviors the IDU engaged in. Furthermore, using latent variable modeling, these assumptions of order can be tested. For example, one study (Janulis, 2014) found that the highest risk behaviors (e.g., sharing syringes with someone they know to be HIV positive) were only endorsed by individuals with the highest levels of overall risk behavior and the low risk behaviors (e.g., injecting drugs in the same room as other IDUs) tended to be more commonly endorsed. This suggests that IDUs engage in risk behavior in a logical (i.e., ordered hierarchically) manner and that these behaviors may be meaningfully modeling using latent variable approaches.

While this approach has been more commonly applied to the study of sexual risk behavior (Fendrich, Smith, Pollack, & Mackesy-Amiti, 2009; Li, Liu, Feng, & Cai, 2011; Mattson et al., 2010; McClelland, Teplin, Abram, & Jacobs, 2002), several early studies (Darke, Hall, & Carless, 1990; Darke, Hall, Heather, Ward, & Wodak, 1991; Fry & Lintzeris, 2003; Petry, 2001) used factor analysis to provide latent variables scaling for injection risk behavior but this approach has not been widely adopted by researchers in this area. More recently, a growing number of studies (Mackesy-Amiti et al., 2013; Noor, Ross, Lai, & Risser, 2014; Watson et al., 2013) have used latent class analysis to measure injection risk behavior using a latent variable approach but the diversity (e.g., some include non-injection related risk behaviors) and the small number of these studies make the relationship between IDU characteristics and injection risk behavior as measured using latent variable modeling still unclear.

Finally, many studies examining injection risk behavior have failed to fully incorporate theoretical frameworks to conceptualize, predict, and understand characteristics associated with drug harms beyond the recognition of statistically significant co-variation (Friedman et al., 2013;

Rhodes, 2009). Of research in this area, qualitative (e.g., see Rhodes, 1997) and cognitive behavioral (e.g., see Wagner et al., 2010) approaches have the strongest theoretical foundation. For example, Rhodes (1997) used social action theory to challenge traditional individualistic theories of "individual rationality" (i.e., cognitive theories about costs, risk perceptions, and individual choice) to promote an analysis of risk behavior arising from situations, interactions between individuals, and power disparities. Nonetheless, most studies continue to focus on examining a single association between a specific characteristic and a specific risk behavior, an approach that is common in public health and social epidemiological research (McKinlay & Marceau, 2000). This process is primarily useful for the slow accumulation of data on specific associations. However, this approach makes it increasingly difficult to build consensus without meta-analysis or pooled data analysis across studies (Kivimäki & Kawachi, 2013). Furthermore, this approach tends to facilitate "black-box" conceptualizations of these associations. As noted by Galea and Link (2013), social epidemiologists have applied their methods "...with notable success, to isolate factors that co-vary with diseased and aimed to intervene on these factors without a good grasp on why they might matter" (p. 847). For example, the clarity of the causal association between sharing syringes and the spread of HIV has led to rapid gains in reduction of HIV incidence early in the US HIV epidemic among IDUs. However, these gains have slowed considerably as the vector and precise mechanism of disease transmission has blurred for HCV and the subsequent factors associated with HCV risk behavior have become similarly less clear. Accordingly, an increased emphasis on *mechanisms* that risk factors represent and use of theories to understand the conjunction and interaction of these mechanisms would likely facilitate increased clarity in this research and provide firmer foundation for risk reduction interventions.

The Social Ecology and Micro-Social Risk Environment of Injection Risk Behavior

The intersection of dyadic, network, and environmental factors that influence injection drug use can be understood as aspects of the social ecology (Latkin, German, et al., 2013; Latkin & Knowlton, 2005) or risk environment (Rhodes, 2002, 2009) for injection drug use. This study is specifically focused on those aspects of the social ecology of injection drug use that manifest in the immediate ecological level(s) above the individual level and may change from one drug use episode to another. While some recent focus has been placed on macro-structural environmental elements such as syringe coverage (Mathers et al., 2010), policing strategies (C. L. Miller et al., 2008; Rhodes et al., 2006), syringe policy (Burris, Anderson, Craigg, Davis, & Case, 2011; O'Shaughnessy, Hogg, Strathdee, & Montaner, 2012), and the impact of place and space on injection risk (Tempalski & McQuie, 2009), less emphasis has been placed on the micro-social environment surrounding specific injection episodes (e.g., dyadic, network, and situational; Latkin, German, et al., 2013) . Yet, preventive interventions often rely on the alteration of these micro-social processes to achieve sustained change. Latkin and Knowlton (2005) note that understanding the micro-social environment of injection drug use is the key to shaping preventive interventions as these interventions rely on the alteration of, "...social processes that promote and perpetuate these patterned [injection] behaviors" (p. 2).

In fact, the hypothesized causal mechanism between correlates of injection risk behavior necessarily involves these complex micro-social processes in obtaining and using injection equipment. For example, injection frequency is a consistent predictor of injection risk behavior (Golub et al., 2007; Thiede et al., 2007). The hypothesized reason that injection frequency increases risk behavior is that frequent injectors require more resources (e.g., drugs and injection equipment). Therefore, IDUs often turn to drug and equipment sharing with other IDUs in order

to obtain amounts of resources they would be unable to acquire on their own (Shaw et al., 2007; Zule, 1992). As another example, male-female injection partner disparities in injection risk behavior can be partially explained by disadvantaged social and economic position of some female IDUs (El-Bassel, Wechsberg, & Shaw, 2012). However, this relative disparity creates risk through the social processes of injection (El-Bassel et al., 2014); for example, male partners may be in charge of obtaining drugs or syringes (Tortu et al., 2003), leading to power disparities (Zule, 1992) during the process of injecting (e.g., such female IDUs being more likely to inject second with the same equipment). While studies examining correlates of injection risk behavior often rely on cross-sectional snapshots of these processes, the ultimate goal of these studies should include observing, understanding, and preventing the *social processes* that lead to the spread of viral diseases, despite the frequent oversimplification in data collection and modeling of these processes (Scott, 2011).

Accordingly, the current study is primarily concerned with the social processes that are aspects of the micro-social risk environment of injection drug use, using Rhodes et al.'s (2003) definition of micro-social risk environment: the "interplay of factors which taken together influence the social norms and values surrounding HIV/AIDS and drug injecting, the nature and structure of drug injectors' social relationships and networks, the immediate social and physical settings in which drugs are used, and the local neighborhoods and contexts in which drug injectors live" (p. 50). Aspects of particular importance to this study are: network, dyadic, and situational factors associated with these drug use episodes. To inform specific predictions about the micro-social risk environment of injection risk behavior, this study will draw upon an area of research cited in previous research (Latkin, German, et al., 2013; Latkin & Knowlton, 2005) as

important theoretical perspectives in understanding the social ecology of injection drug use: social and behavioral settings.

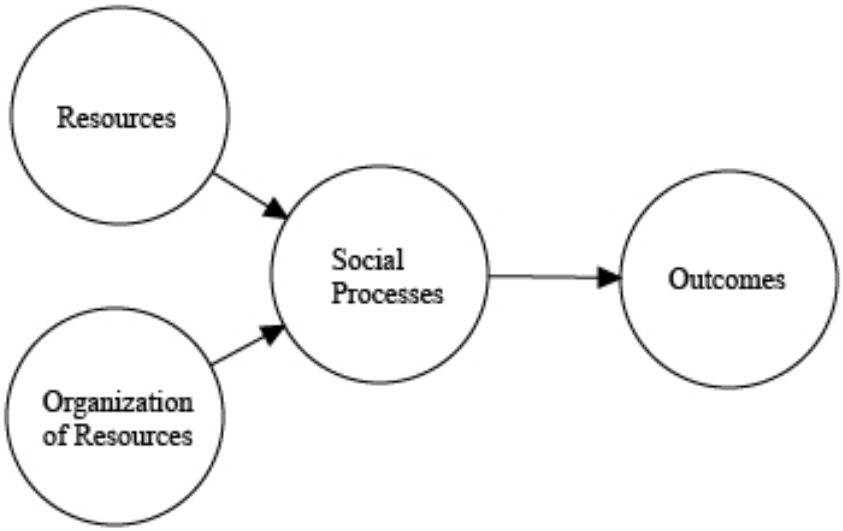
Social Settings Theory. Tseng and Seidman's (2007) theory of social settings may provide insight into the conceptual framing of injection episodes. This theory has four components: resources, organization of resources, social processes, and outcomes. In the current case of conceptualizing injection episodes as a social setting, *resources* in this setting could include training of IDUs in safer injection practices, availability of clean injection equipment, or external pressure on the time available to inject (e.g., due to street policing). The *organization of these resources* describe how these resources are distributed throughout the setting. For example, this would include unequal power over injection decisions or distribution of resources such as paraphernalia or knowledge of safer injection practices. *Social processes* are conceptualized to include norms, relationships, and participation in activities. Norms involve the influence of setting member's beliefs on the participant's beliefs and behaviors. For example, norms could dictate the acceptability of sharing equipment in a group of injectors. Relationships can be conceptualized in multiple ways but this study is primarily interested in the impact of network and dyadic characteristics. Participation in activities involves participation in roles such as structured institutional activity (e.g., syringe exchange participant) as well as unstructured non-institutional activities (e.g., "dope doctor" that helps other IDUs inject). While the settings components were theorized to have bi-directional influence, Tseng and Seidman (2007) offered the following theoretical path to stimulating change in social settings (Figure 1). This path diagram suggests that resources and distribution of resources lead to social processes, which

mediate the impact of resources on setting outcomes.[5] In the case of injection drug use, interventions have largely focused on increasing the human and physical resources through providing injection material and training in safer injection practices.

The most acute example of IDU interventions to increase resources is the supervised injection facilities that provide physical (e.g., syringes and space to inject), human (e.g., trained staff to provide guidance in injection practices), and temporal (e.g., providing a space free from police or other surveillance that may speed up injection episodes) resources in effort to reduce the spread of HIV/HCV (Degenhardt et al., 2010; Kerr et al., 2006; Wood et al., 2006). However, most injections do not take place in supervised injection facilities. Therefore, injection hygiene interventions have attempted to promote safer injection settings in less comprehensive manner by increasing the resources available to IDUs through the provision of sterile injection equipment (i.e., physical resources) and training in safer injection practices (i.e., human resources). Accordingly, the availability of these resources has been the primary focus of many studies. The drugs themselves could also be considered a resource that is likely associated with reduced setting level outcomes (e.g., if a large amount of available drugs lead to binge use). However, most studies and interventions related to injection risk behavior assume that the availability of drugs is given and therefore look at other resources to mitigate the risk caused by the availability of these drugs.

[5] Research from the network analysis paradigm also suggests that these variables could work in the opposite direction (i.e., social processes could also determine resources and resource distribution). Furthermore, Tseng and Seidman (2007) acknowledge that social processes likely also influence resources/resource distribution. Accordingly, this diagram should only be viewed as one possible route to altering setting outcomes.

Figure 1. Theoretical Path for Change in Social Settings



Organization of resources in injection settings has also been less studied compared to the other elements of these social settings. However, preliminary investigations have identified that gender differences in access to drug and drug paraphernalia are often present in these settings (El-Bassel et al., 2014; Frajzyngier et al., 2007). Similarly, a few recent studies have shown how unequally resource distribution between geographic regions may explain racial and ethnic disparities in injection risk behavior (Cooper et al., 2011; Cooper, Des Jarlais, Ross, et al., 2012), reflecting unequal distributions of injecting resources available in these settings on a larger scale.

Finally, the social processes that likely mediate the relationship between resource provision/distribution and outcomes remain much less clear in this literature (Latkin & Knowlton, 2005; Rhodes et al., 2003). While these processes have begun to be explored through studies of IDU norms (Latkin, Donnell, et al., 2013; Tobin et al., 2011) and networks (De et al., 2007), most studies have not focused on the immediate social circumstances and processes during specific injection events or how and if interventions promoting resources impact social processes (i.e., the potential mediating role of social processes), as discussed in the limitation section. Again, the exception to this rule is ethnographic and other qualitative approaches that

have documented the social processes surrounding injection episodes (e.g., see Zule, 1992). However, these insights remain largely unconfirmed in a quantitative framework. Given that much remains unknown about these social processes and their importance in mediating health outcomes, these processes are the primary focus of the current study.

The Current Study

The current study is intended to expand upon preliminary investigations (Gyarmathy et al., 2010; McMahon, Pouget, & Tortu, 2007; Unger et al., 2006) of the micro-social risk environment for injection drug use and further explore situational, dyadic, and network characteristics associated with injection risk behavior. This study will use Tseng and Seidman's (2007) theory of social settings to inform predictions of specific associations, as understood in the context of existing literature on injection drug use. By providing a more wholistic model of individual, network, dyadic, and situational correlations, this study will further clarify the relationships between resources, social processes, and injection risk behavior.

This study will use data from the Sexual Acquisition and Transmission of HIV cooperative agreement program (SATHCAP) and will leverage this event specific data to provide novel insights into the associations between injection risk behavior and these characteristics. Due to the complex dependencies of event-specific data and the use of multiple indicators used to measure the dependent variable, multilevel structural equation modeling (SEM) was used to estimate model parameters. The theoretical path diagram for the expected relationships can be seen in Figure 2. The model involves two main aspects. First, the bottom half of the model examines "within" individual variation in injection risk behavior and predictors. In Figure 2, *injection risk behavior* at each episode is measured by the 4 observed indicators (i.e., receptive syringe sharing, using a syringe to mix drugs, sharing non-syringe

paraphernalia, and distributive syringe sharing). Predictors at the within level (e.g., number of injectors, gender concordance, sexual partnership, etc.) represent characteristics of injection episodes that can vary from one episode to the next. At this level, random intercepts are represented by small black circles that are at the end of an arrow (i.e., y1b - y4b) while random slopes are represented by small black circles in the middle of arrows (i.e., *S1* and *S2*). The top half of the model represents the "between" individual variation in injection risk behavior measured at the between level through the latent variables created from the random intercepts of the four within level indicators. The between level also has two latent variables that account for the random slopes (i.e., *S1* and *S2*) at the within level. Predictors at the between level represent characteristics of the individual or their network that are constant for each participant (e.g., gender, network size, etc.). In addition, at either levels of the model interactions are represented using an arrow that leads to the middle of another variable's arrow indicating that the originating variable is moderating the relationship between the two variables.

All predicted relationships are based on social setting theory (Tseng & Seidman, 2007) and previous findings of injection risk behavior literature. For further clarification, the predicted associations expected in this study are specifically designated through the following hypotheses and Table 1 indicates the aspect(s) of Tseng and Seidman (2007) theory of social setting to which each hypothesis corresponds.

Dyadic Predictors. For dyadic predictors, gender concordance is expected to have a negative relationship with risk behavior (i.e., so that concordant pairs are less likely to engage in risk behavior; ***Hypothesis$_{1a}$***) as suggested by limited previous research (Hahn et al., 2010). Furthermore, power and resource disparities between male and female IDUs (El-Bassel et al., 2014) may lead to increased risk behavior in gender discordant injection partners (e.g., because

one partner is reliant on the other to obtain these resources) as suggested by the impact of organization of resources in social setting theory (Tseng & Seidman, 2007). Sexual partnership is also predicted to have a positive association with injection risk behavior (***Hypothesis$_{1b}$***) based on previous research (Bailey et al., 2007; Hottes et al., 2011) and the impact of the social processes (Tseng & Seidman, 2007) caused by the intimacy and trust inherent in sexual relationships.

However, both gender concordance and sexual partnership are predicted to be moderated by the gender of the participant (i.e., a cross level interaction with gender, level 2, predicting the slopes of gender concordance and sexual partnership, level 1; ***Hypothesis$_{1c}$*** and ***Hypothesis$_{1d}$***, respectively). This relationship is predicted based on the unequal distribution of resources between male and female IDUs and the subsequent power disparities previously recorded in gender discordant pairs favoring males (El-Bassel et al., 2014; Tortu et al., 2003). I predict that being female will increase the negative association between gender concordance and injection risk behavior. Similarly, I predict that being female will increase the association between sexual partnership and injection risk behavior for identical reasons.[6] Therefore, this hypothesis will examine if the unequal distribution of resources among male and female IDUs creates additional risk among females via the social processes associated with gender concordance and sexual multiplex injection partnerships. Thereby, this hypothesis will examine how different aspects of the injection setting (i.e., distribution of resources and social processes) may interact using Tseng and Seidman's (2007) framework.

Length of injection partnership is expected to have a positive association with injection risk behavior (***Hypothesis$_{1e}$***) because a longer length of partnership is likely to be a proxy variable for the closeness of the two IDUs, which itself is associated with injection risk behavior

[6] These two dyadic variables are complicated by same-sex sexual relationships, particularly female-female relationships.

(Valente & Vlahov, 2001). In Tseng and Seidman's (2007) framework, the social processes inherent in long term injection partnership (e.g., accumulation of trust, greater intimacy, etc.) are also likely to facilitate higher levels of risk behavior. Perceived concordant HIV serostatus is also predicted to have a positive association with risk behavior (***Hypothesis$_{1f}$***) given the current evidence supporting serosorting between injection partners (Hahn et al., 2010; Smith et al., 2013). That is, participants who believe they are the same HIV serostatus may be more likely to share equipment given that sharing equipment will not change their HIV status if they only share with same serostatus partners. In the absence of perceived risk in sharing equipment, natural social processes (Tseng & Seidman, 2007) that promote risk behavior in these settings such as reciprocity may promote injection risk behavior.

Network Predictors. For network variables, injection network size is predicted to have a positive relationship with injection risk behavior (***Hypothesis$_{2a}$***) given the previous findings suggesting drug/injection network size was positively associated with risk behavior (Cepeda et al., 2011; Latkin, Mandell, Oziemkowska, et al., 1995; Latkin, Mandell, Vlahov, et al., 1995). In the social setting framework, the mechanism of this association is assumed to work through the social processes of obtaining and injecting drugs. For example, this association could be due to the increased opportunity to engage in risk behavior or the normative pressure to share resources that could be enhanced among individuals with larger IDU social networks.

Environmental Predictors. For environmental or situational predictors, the number of IDUs present at the injection episode is predicted to have a positive association with injection risk behavior (***Hypothesis$_{3a}$***), while the number of non-IDUs present is predicted to be negatively associated with injection risk behavior. The number of IDUs present at the episode may limit the per-person distribution of injection resources and thereby increase the likelihood of participants

engaging in risk behavior in an effort to pool the limited resources, as predicted using social setting theory (Tseng & Seidman, 2007). It is also possible that IDUs being present at an injection episode likely increases the social pressure and norms (i.e., facilitate social processes) that lead to sharing injection paraphernalia. Therefore, a larger number of injectors being present at an episode is likely to provide both the opportunity and increased normative pressure to engage in this behavior, two social processes associated with setting outcomes (Tseng & Seidman, 2007). Furthermore, similar to the injecting public areas (Small et al., 2007), a larger number of injectors being present may limit the amount of time an injector has to inject behavior (i.e., temporal resources in the Tseng and Seidman (2007) framework) due to a fear of being disrupted by other injectors or in effort to avoid requests to share their resources. This reduction in temporal resources could also lead to increased risk behavior. The number of non-IDUs present at the injection episode is expected to be negatively correlated with injection risk behavior (***Hypothesis$_{3b}$***) and I also expect an interaction between the number of injection drug users and non-injection drug users so that the the number of non-IDUs will reduce the association between the number of IDUs and risk behavior (***Hypothesis$_{3c}$***). Again, these relationships are based on the number of non-IDUs present being associated with a decrease in the normative social pressure to share injection equipment associated with the presence of additional IDUs due to the fact that non-IDUs place more stigma on injection risk behavior (Mateu-Gelabert et al., 2005). Therefore, norms in these settings are less likely to be conducive for risk behavior which should subsequently decrease the likelihood of this behavior (Tseng & Seidman, 2007). Finally, injecting in one's own residence is predicted to be inversely associated with risk behavior (***Hypothesis$_{3d}$***) given the elevated risk observed at shooting galleries and (Koester et al., 2005) and that injecting in the participant's residence also makes it most likely

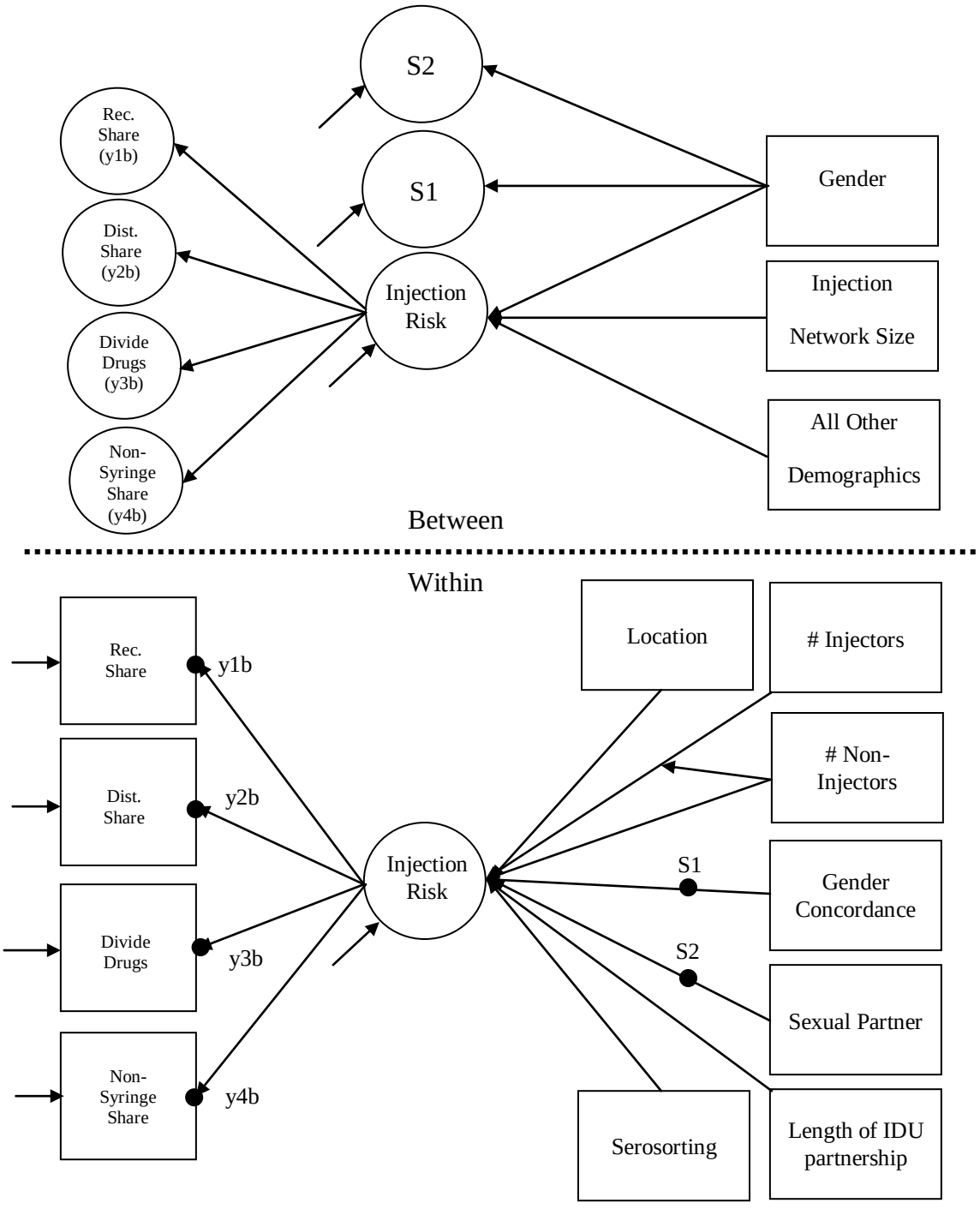
that the participant will have greater control over and availability of the injection resources. Accordingly, this increased control of resources, is likely to lead to more desirable outcomes for these individuals (Tseng & Seidman, 2007).

Current Study Contributions. By examining these hypotheses, this study would advance current knowledge of dyadic, network, and environmental predictors of injection risk behaviors in the following ways. First, the key contribution this study would provide is overcoming limitations of past research that only examined a single injection episode, that used population averaged or marginal models (e.g., generalized estimating equations) of multiple injection episodes, or used mixed models but only examined dyadic characteristics. By doing so, this study should provide novel insight into the social processes of injection episodes that are associated with injection risk behavior. For example, this study will examine the number of people using drugs at the specific episode, the physical location of the episode, as well as the dyadic characteristics of specific partners. The ability to separately estimate network factors at the individual level with the social circumstances of each injection episode should also provide novel insight toward the mechanisms of social network associations with injection risk behavior. For example, one proposed reason that drug network size is positively associated with risk behavior is that larger drug networks tend to increase the number of individuals present during an injection episode and thereby increase the likelihood of sharing equipment. However, this study provides separate estimates for the number of injectors present at the episode and the number of injectors in the participant's IDU network, allowing for a clearer picture of the potential mechanism between network size and risk behavior.

Second, this study will overcome limitations of the previous literature by measuring behavior by using a multiple indicator (i.e., with a latent variable) measurement model of the

dependent variable, injection risk behavior. The measurement of injection risk is inherently complicated due to the multitude of risk behaviors, potential differences in time frame, and complexity of the injection process (Samuels, Vlahov, Anthony, & Chaisson, 1992). As discussed, most studies have examined each risk behavior as a separate dependent variable despite the goals of these studies to understand and prevent the spread of viral diseases among IDUs. While other types of composite scores are possible (e.g., scales weighted by experts or sum scores), latent variable measurement provides advantages to both single-item and composite- scoring methods in a number of ways. As noted that by McClelland et al. (2002), three traditional approaches have been used in calculating composite scores of viral transmission risk: counting the number of times engaging in risk behaviors, weighting behaviors based on expert opinion, and weighting behaviors based on seroconversion. However, simple counts or other sum scores do not provide unequal weighting for behaviors that differentially contribute to viral risk (e.g., sharing cookers versus sharing syringes) while weights made by experts may still not accurately reflect seroconversion risk. Weightings based on seroconversion risk would be most desirable but precise data is not readily available on injection risk behaviors and may vary considerably between specific contexts and based on the stage of the HIV/HCV epidemics. Latent variable modeling provides an alternative approach that empirically derives the item weights and provides numerous benefits over the traditional single indicator approach. For example, latent variable measurement provides increased parsimony by offering a single parameter estimate of each relationship between the independent variables and injection risk behavior, explicit modeling of measurement error, incorporation of both person and item characteristics in calculating total scores, and improved handling of missing data if the participant only has missing data on some items (Janulis, 2014; Mattson et al., 2010). It is

Figure 2. Model Path Diagram



certainly true that this modeling approach would not be ideal in all situations. For example, if the goal of an intervention is to reduce the frequency of a specific behavior (e.g., sharing cookers) then a study evaluating this intervention would ideally examine this outcome without pooling it with other indicators. However, as noted, in many cases modeling injection risk behavior as a latent variable provides multiple benefits over separately examining each outcome. For example, studies examining injection risk behavior generally measure only a small sample of possible risk behaviors. By pooling variables and estimating scores as latent factors, we can examine the shared variance between items to form a measurement model that more accurately reflects the concept of underlying viral risk. Furthermore, IDUs have been shown to respond to risk behavior questions in a meaningful hierarchical manner, with those IDUs engaging in the highest risk behaviors (e.g., sharing with known HIV positive injectors) generally engaging in many lower level risk behaviors while many injectors engaging in lower level of risk behaviors (e.g., sharing cookers) that do not engage in higher level risk behaviors. Accordingly, given the broad focus of the current study on general injection risk and the additional information in the modeling parameters (e.g., factor loadings), examining each indicator's contribution to the composite score, the benefits of latent variable measurement outweigh the limitations of this approach.

Third, this study will incorporate Tseng and Seidman (2007) theory of social settings to conceptually integrate findings on individual, situational, and dyadic predictors of injection risk behavior. While previous research has largely overlooked theoretical frameworks for predicting injection risk behavior, this study uses a theory of social settings to both inform predictions and interpret these findings in a more holistic understanding of injection risk behavior. As discussed in the outline of the hypotheses, social setting theory will be used to understand the underlying mechanisms that may explain the expected associations in this study. For example, the

availability and distribution of drug use resources such as drugs and injection paraphernalia likely drive the social processes (e.g., sharing) that create high-risk scenarios. Furthermore, the availability and distribution of resources may be driven by the social and physical circumstances of a given injection episode. Accordingly, we will use the available information about individuals, networks, and situational characteristics to model predictors of injection risk behavior while using Tseng and Seidman's (2007) theory of social settings to the guide the understanding of how resources, the organization of resources, and social processes may give rise to these associations.

Table 1. Hypothesis and Tseng and Seidman's (2007) theory of social settings

	Resources	Organization Of Resources	Social Processes
Hypothesis 1			
a. Gender concordance will be negatively associated with injection risk behavior.		Previous research has found that female IDUs tend to have less control over injection equipment (i.e., physical resources).	The resource imbalance combined with gender norms/roles that place less stigma on gender discordant sharing will lead to increased risk among discordance partners.
b. Sexual partnership will be positively associated with injection risk behavior.			Sexual partners are more likely to share resources given relationship aspects that promote intimacy and trust that sometimes outweigh concerns about risk.
c. The association between gender concordance and injection risk behavior will be modified the sex of the participant so that being female will be associated with a stronger negative relationship between gender concordance and injection risk behavior.		Given that previous research finds that gender discordant physical resource imbalances tend to favor male IDUs, this imbalance will enhance the risk witnessed among	In addition to resource imbalances, gender roles also favor males in dominant roles (e.g., where the male injects the female partner). Therefore, male IDUs will have increased control over the

Table 1 (cont'd)

	female IDUs with discordance partners.	process and in effort to mitigate their own risk may increase the risk of the female participant (e.g., pressure the IDUs to inject after the partner using the same equipment).
d. Sexual partnership will be modified by the sex of the participant so that being female will be associated with a stronger positive relationship between sexual partnership concordance and injection risk behavior.	Again, female IDUs tend to have less access to injection resources such as paraphernalia compared to their male injection partners	The unequal resources and gender norms/roles that favor males in positions of control over the injection process may greater risk exposure among female IDUs in dual sexual/injection partnerships.[a]
e. Length of injection partnership will be positively associated with injection risk behavior.		Long term injection partners are more likely to share equipment due to the trust and intimacy that accumulates during long term partnerships.
f. Perceived serostatus concordance will we associated with increased risk behavior		Seroconcordant partners are more

Table 1 (cont'd)

as compared to perceived discordant or unknown HIV-status partners.			likely to share equipment given that a belief in seroconcordance reduces the perception of risk in sharing and therefore relationship factors of reciprocity and sharing may overcome concerns of risk.
Hypothesis 2			
a. Injection network size will be positively associated to injection risk behavior.	While the a larger IDU network could increase or decrease available physical resources at a specific episode, previous research has generally found larger networks associated with greater risk behavior suggesting that networks may strain the availability of physical injection resources at any given episode.		Participants with larger IDU networks may be exposed to more pro-sharing norms regardless of the specific injection episode and may participate in greater levels of sharing.
Hypothesis 3			
a. The number of injectors present during the injection episode will be positively associated with injection risk behavior	A greater number of injectors may limit the temporal resources of	A greater number of injectors will likely reduce the amount of	A greater number of injection may increase norms of sharing or

Table 1 (cont'd)

	the participant given that participants may want to inject more quickly to avoid sharing drugs with other injectors, similar to the impact of injecting in other public spaces found in previous research	paraphernalia per person and thereby make it more likely multiple people use the same equipment.	increase the likelihood of being pressured to share by any individual IDU present (i.e., through relationships). Combined with less resources per person, this will lead to greater likelihood of engaging in sharing.
b. The number of non-injectors present during the injection episode will be negatively associated with injection risk behavior			Non-IDU social norms have a higher level of stigma attached to injection equipment sharing and will therefore reduce the level of risk behavior through this normative pressure.
c. The number of non-injectors present during the injection episode will moderate the relationship between number of injectors present and injection risk behavior so that an increase in non-injectors will reduce the association between the number of injectors and injection risk behavior.		The ratio of IDUs to non-IDUs could be considered an aspect of the "social organization" of resources in the setting that likely impact the normative pressure on IDUs	Again, non-IDU social norms look less favorably toward equipment sharing behavior. Therefore, a greater number of non-IDUs will likely decrease the normative effect of IDUs that are present.
d. Injecting at the participant's home will	Participants are likely	Among IDUs present	Greater access and

Table 1 (cont'd)

be associated with lower injection risk behavior	to have more injection paraphernalia (i.e., physical resources) and greater freedom for the amount of time available to inject (i.e., temporal resources) at their own residence as opposed to other locations.	at an injection episode, participants are more likely to have greater control over temporal and physical resources because they are the individual granting access to the drug use space.	control over resources will counteract normative and relational pressure to share paraphernalia.

a. Again, this relationship is complicated by same-sex female sexual partnerships and if these relationships represent a large percentage of concurrent sexual and injection partnerships then this hypothesis may have to be re-examined

Method

This study used data from the Sexual Acquisition and Transmission of HIV Cooperative Agreement Program (SATHCAP; Compton, Normand, & Lambert, 2009) . The cooperative agreement included data collection at three U.S. sites (i.e., Chicago, IL; Los Angeles, CA; and Raleigh Durham, NC), and one international site (i.e., St. Petersburg, Russia). However, only data from the three U.S. sites currently available via the National Addiction and HIV Archive Program will be used in this study. The SATHCAP project was primarily designed to examine sexual transmission of HIV among high risk groups such as men who have sex with men (MSM) and drug users, including both IDUs and non-IDUs. However, the sample of IDUs will be the sole focus of this study, including both MSM and non-MSM who are IDUs, but excluding all participants who did not inject with another individual in the previous six months. Despite the study's emphasis on sexual transmission, the questionnaire also gathers information on HIV/HCV drug related risk behaviors including gathering data on up to four injection episodes that allow us to pursue these previously underdeveloped topics.

Recruitment/Sampling

The recruitment of participants for all SATHCAP sites utilized respondent driven sampling (Iguchi et al., 2009). Respondent driven sampling is a chain referral sampling technique that uses dual incentives intended to produce un-biased population estimates for hidden populations (Heckathorn, 1997). This method has been commonly used to improve upon convenience sampling among populations that traditionally cannot be sampled using probability samples due to the low frequency of the behavior in population samples and/or strong stigma attached to the target characteristic(s) of the target population. This method has frequently been used when sampling IDUs (Heckathorn, Semaan, Broadhead, & Hughes, 2002) and MSM

(Kendall et al., 2008). The method involves providing two types of incentives. First, primary incentives are given to participants to compensate them for their participation. However, incentives also reward participants for recruiting additional members into the study. Seed participants are generally gathered using non-probability convenience sampling (e.g., through community outreach, advertising the study, or simply well known members of a given community). Seed participants then begin the snowball mechanism of the recruitment technique, with each wave of participants recruiting an additional wave from their social network. This process continues until participant characteristics of the sample stabilize and new participants can be considered independent of initial seed participants (Ramirez-Valles, Heckathorn, Vázquez, Diaz, & Campbell, 2005).

While previous studies using respondent driven sampling targeted a single population, SATHCAP employed an RDS recruitment technique that targeted drug users (IDU and non-IDU), MSM, and their sexual partners (both male and female). Accordingly, SATHCAP employed a relatively novel respondent driven sampling methodology. That is, participants in the study were provided some coupons to recruit any person who, "used heroin, methamphetamine, cocaine, or crack, or injected another drug in the past six months", "any man who had anal sex with another man in the past six months" as well as "any person with whom you have had sex in the past six months" (p. S12, Iguchi et al., 2009). At the Illinois and North Carolina sites, seeds were actively recruited through approaching community members known to meet the eligibility criteria. At the California site, seeds were passively recruited through flyers due to institutional review board requirements. Eligibility was screened in the following ways: 1) coupons were examined for authenticity, 2) participants answered a short screening questionnaire to see if their characteristics met the requirements of the coupon they obtained (e.g., if they received a higher

risk coupon, they were screened for being a drug user or MSM), 3) demographics were screened for duplicate participants (e.g., same birthday and biometric features such as tattoos). All participants, including seeds, were compensated for their time although compensation differed across sites due to different institutional review board requirements.

Recruitment occurred in two separate phases: between September 2005 to December 2006 for phase 1 and between November 2006 to August 2008 for phase 2. During phase 1 all participants were given three coupons to give to network members that met either of the higher risk criteria (i.e., drug user or MSM) and three coupons to recruit any of their sex partners from the past six months. One of the sex partner coupons was designated for individuals that were not drug users if the participant was a drug user or for a sex partner that was a woman if the participant was a MSM. These coupons were designed to encourage recruitment of partners that may have roles as HIV risk "bridges" to the general population. Both sex partners and higher risk recruits were eligible to become recruiters themselves. However, sex partners were simply given three coupons to recruit their sex partners and these recruits (i.e., sex partners of sex partners of higher risk groups) were ineligible to become recruiters.

Phase 2 recruitment was similar to that of phase 1 with some minor adjustments, primarily made to adjust for under recruitment of non-drug using sex partners. All participants from phase 1 were ineligible for recruitment in phase 2. Participants in phase 2 were given two coupons for higher risk groups and two coupons for opposite sex partners. Higher risk participants were always given these 4 coupons while participant recruited as opposite sex partners were given only 2 coupons to recruit opposite sex partners. However, the number of higher risk coupons was increased to 4 coupons midway through phase 2 in order to get sufficient recruitment of this group.

Finally, participants from both phases who recruited other participants completed a final questionnaire when they returned to obtain their secondary incentives. This questionnaire was designed to assess the characteristics of individuals who had refused the coupon as well as the characteristics of individuals who were given coupons but did not chose to participate in the study.

Inclusion Criteria. The current study utilized a subsample of IDUs from the larger sample collected in the SATHCAP study. Any participants from either phase of recruitment were included in the current study if they injected with at least one person during the last 6 months ("with" means, "people who injected drugs at the same place and time as you"). This inclusion criterion was necessary because individuals who have not injected in the same place and time as another individual would not have provided data on specific injection episodes. This criteria includes 835 total participants with 55 providing data on four injection episodes, 391 providing data on three injection episodes, 207 providing data on a two injection episodes, and 182 providing data on a single injection episode leading to a total. Demographics of this subsample and those of the entire sample can be found in Table 2.

Measures

The measures used in this study can be broadly organized into two groups: level 2 (i.e., individual) measures and level 1 (i.e., injection episode) measures. Level 2 measures include demographics, drug use, and personal network characteristics. These variables do not change across injection episodes. Level 1 measures included situational characteristics (i.e., characteristics of the injection episode), dyadic characteristics (i.e., characteristics that depend on the participant and the injection partners), and injection risk behavior. These variables are injection episode specific and therefore can have variability within individual participants.

Copies of the exact wording of the questionnaire for all measures that will be used in the study can be found in Appendix A. Given the fact that participants were recruited using respondent driven sampling, it is possible, and perhaps very likely, that there are dependencies in the data (e.g., partners referenced in an injection episode that later appear as participants) not modeled using the simple 2-level structure proposed in this study. Unfortunately, information is not provided in the dataset to model this cross-classification. Consequently, dependency may remain in the data even after accounted for the multilevel nesting. However, studies with similar recruitment and analysis have also been limited by this same possibility (Ober, Shoptaw, Wang, Gorbach, & Weiss, 2009) and this issue will remain as a similar limitation in the current study.

Table 2. Demographics of Non-IDU vs. IDU Sample

	Non-IDU		IDU	
	n (%)	M (SD)	n (%)	M (SD)
Age		42.79 (9.9)		42.61 (10.8)
Gender				
Male	2410 (62.5%)		564 (67.5%)	
Female	1407 (36.5%)		-	
Race				
African American	3038 (78.8%)		447 (53.5%)	
White	567 (14.7%)		290 (34.7%)	
Other	105 (2.7%)		17 (2.0%)	
Hispanic/Latino	310 (8.0%)		201 (24.1%)	
Homeless	1549 (40.2%)		433 (51.9%)	

Note. IDU refers to individuals who individuals who reported an injection partner in the past 6 months. Blank cells are censored due to the requirements of the data use agreement.

Level 2 (Individual) Measures

Demographics. The following demographic variables will be included in the study. Age was measured in years as a continuous variable. Gender will be measured as male or female (0 =

Male, 1 = Female). Transgender participants will be coded as the currently identified gender.[7] Race will be coded as White, African American, and Other using two dummy coded variables indicating if the participant was African American (0 = African American, 1 = White) or Other (0 = African American, 1 = Other). Hispanic/Latino will be coded as a separate question as Hispanic or non-Hispanic (0 = Non-Hispanic, 1 = Hipanic/Latino). Finally, participants will be coded yes/no if they identify as homeless if they were homeless anytime during the past year (0 = Yes, 1 = No).

Drug Use. Participants will have two continuous indicators of frequency of crack/cocaine or heroin/other opiates. For both drug types, drug use frequency is defined as the number of times the participant used the respective drug during the previous 30 days. Number of years injecting drugs will also be assessed. This will be measured by subtracting the current age of the participant by the age at which they first injected drugs (e.g., a zero will indicate they started using drugs within the past year). Injection frequency will also be assessed using a continuous indicator reporting how many times the participant injected drugs during the previous 30 days.

Network Characteristics. The injection network size will be measured by the participant's response to the following question: "About how many different people did you inject drugs within the past 6 months? (By "with", we mean people who injected drugs at the same place and time as you.)". While a period of 6 months may be prone to some measurement

[7] While transgender injectors are unlikely to experience the same level of risk as non transgender injectors (Clements-Nolle, Marx, Guzman, & Katz, 2001), the small number of transgender participants that inject drugs (this number cannot be disclosed due a small cell count and requirements of the data use agreement) made it not possible to separately examine this group.

error, this interval is standard and has been used extensively in past research (Ramirez-Valles et al., 2005; Shaw et al., 2007; Suh et al., 1997).[8]

Level 1 (Injection Episodes) Measures

Level 1 measures are specific to each injection episode. Data on one to four injection episodes were elicited from each participant. Only individuals who reported that they injected in the same place and time as another individual during the previous 6 months were asked about specific injection partners and situations. Those who had injected with at least one individual were asked to provide the initials of up to three individuals they had "recently injected with". In addition, participants were also asked if one of these named partners was the partner with whom they most frequently inject. If none of the previously named partners were their most frequent partner, information was also elicited on their most recent injection episode with the most frequent partner. This created the possibility of four episodes being observed (i.e., if the participant named three partners and none of them were their most frequent partner). For each individual named, the participants provided information about the characteristics of those individuals and the most recent situation in which they injected with that individual.

Situational Characteristics. Two characteristics of the physical environment of the injection episode will be included in the analysis. First, the location of the injection episode will be categorized using a dichotomous indicator reporting if the participant injected in their own home or injected in another location (0 = Own residence, 1 = Another residence). Second, the location will also be categorized with two binary variable indicating if the location was the most common location the participant injects at with that partner (0 = Most common location, 1 = Not

[8] While a separate variable indicating the "non-IDU drug use network size" was originally planned to be included in the analysis, the variable measuring the total number of drug uses in the network was not associated with the injection network size in the expected manner. That is, the number of total drug users was frequently smaller than the injection network. Accordingly, this variable was not included in the analysis.

most common location). Another binary variable indicated if data were missing on this being the most common location (0 = Not missing, 1 = Missing). Two additional variables examined the non-dyadic social environment of the injection episode. The first will measure how many other individuals were injecting at the same site. The second will measure how many other individuals where using drugs at the same site but not injecting.

Dyadic Characteristics. Several variables examined the dyadic characteristics between the participant and the injection partner. Two variables examined gender concordance. This variable will include one binary indicator describing if the participant and the partner identify as the same gender (0 = Different Gender, 1 = Same Gender) and a second variable identifying if that episode has missing data on gender (0 = Not missing, 1 = Missing). Three dummy variables will indicate the perceived concordance of HIV status between the participant and the partner with HIV-discordance (i.e., indicating the participant believes they do not share the same serostatus) being used as the reference category. One variable will indicate if they are of unknown concordance (i.e., the participant is unsure about their own or the partners HIV status; 0 = Known Concordance, 1 = Unknown Concordance). Another variable will indicate if the participant believes the partner to be HIV-concordant (0 = Not Known to be Concordant, 1 = Concordant). Therefore, a discordant dyad would receive two "0's", while an unknown concordant dyad would receive a "1" on the first variable and a "0" on the second, while a concordant dyad would receive a "0" on the first variable and a "1" on the second variable. Finally, a third variable will indicate if data on HIV concordance is missing (0 = Not Missing, 1 = Missing). A binary variable will indicate if the injection partner is also a sex partner. Finally, four binary variables indicate the length of the injection partnership (i.e., how long they have been injecting together). This variable was transformed from a raw duration of injection

partnership to four binary indicators for the following reasons. First, the distribution was biased to certain values due to the fact that some participants answered this question in days while others in months or years. Therefore, when converting these values into a single metric (e.g., days) the variable did not approximate a continuous distribution due to overrepresentation of certain values (e.g., 365 days if the participant indicated they had injected with that partner for 1 year). Second, a large number of participants (19.0%) could not answer this question because this was the first time they injected with the partner. A categorical coding scheme allows for the classification of these particular individuals' injection partnership duration as a separate code. Thus, the first binary indicator signified if the participants were first time injection partners (1 = new partner, 0 = not new partner). Additionally, for other participants, three dummy codes were used to indicate the injection partnership in quartiles. Using the lowest quartile of injection partnership as the reference, one variable indicated the partnership was in the second quartile (0 = Not in the second quartile, 1 = in the second quartile) while two additional dummy codes identified those in the third and fourth quartile, respectively.

Injection Risk Behavior. Injection risk behavior will be measured with four variables. One indicator was ordinal while the other three indicators were binary. As will be discussed further in the analysis section, these variables were measured as a single continuous latent variable. The three-point ordinal indicator will measure if the participant engaged in receptive syringe sharing and, if they did, whether they used bleach to clean the syringe before injecting (0 = No receptive sharing, 1 = receptive sharing with bleach 2 = receptive sharing no bleach). The first binary indicator will measure if the participant used a used syringe to mix, measure, or divide the drugs (0 = Did not use, 1 = Did Use). The second binary indicator will measure if the participant shared any other non-syringe injection paraphernalia (e.g., cookers, cottons, rinse

water; 0 = Did not share, 1 = Did share). The third binary variable will indicate if the participant engaged in distributive syringe sharing (i.e., if the partner used the participants syringe *after* the participant injected; 0 = Did not engage in distributive sharing, 1 = Did engage in distributive sharing).

Analytic Approach

The nature of eliciting data on multiple injection episodes for each participant requires a modeling technique that can overcome the limitations of traditional general linear modeling. This requirement is common to all studies of nested or repeated measure data that violate the assumption of independence of observations (Muthén & Satorra, 1989). Multilevel models (also known as mixed models) are a common tool to accomplish this goal (Paterson & Goldstein, 1991). However, multilevel models are not the only approach to adequately deal with nested observation. Appropriate models such as generalized estimating equations often provide an alternative solution that can adequately model this data (Zorn, 2001). In fact, a contentious debate exists over the assumptions, utility, and appropriateness of generalized estimating equations versus mixed models (e.g., see Hubbard et al., 2010). Nonetheless, for the purpose of this study, multilevel modeling provided a more compelling solution for two reasons. First, multilevel modeling allows for explicit modeling of the random parameters (Gardiner, Luo, & Roman, 2009) and, as a population averaging approach, generalized estimating equation (GEE) does not provide this opportunity. By explicitly modeling the covariance structure of nested data, multilevel models allow examination of questions that are not possible in generalized estimating equations (Goldstein, Browne, & Rasbash, 2002). In the current study for example, multilevel models allow for examining how the effect of episode specific variables (e.g., sexual partnership) on injection risk behavior may differ across individuals (e.g., males versus females). Second,

GEE cannot incorporate analysis of nested data in conjunction with latent variable measurement in a single model framework. As discussed, this study used multiple indicators to create a single latent variable measure of injection risk behavior in effort to utilize the multiple advantages of a latent variable measurement approach (MacCallum & Austin, 2000). Accordingly, multilevel structural equation modeling (Bovaird, 2007) was used in this study in order to exploit the advantages of both of these statistical tools in a unified modeling approach.[9]

Multilevel Structural Equation Modeling

The current study used a model that includes a latent factor dependent variable measured by four indicators and multiple observed predictors (Figure 2). This approach is sometimes called a multilevel multiple indicator multiple cause model as well as a multilevel confirmatory factor analysis with covariates. This measurement model will be briefly discussed before moving on to discuss the modeling approach.

Measurement Model. As discussed, the measurement model includes four indicators (i.e., receptive syringe sharing, dividing drugs, paraphernalia sharing, and distributive syringe sharing) and models these variables as a single factor. While distributive syringe sharing is not a direct causal risk factor for the participant to contract viral diseases (i.e., because it only places the partner at risk), this variable has shown to be a good indicator when measuring injection risk behavior using a latent variable approach (Darke, Hall, Wodak, Heather, & Ward, 1992; Janulis, 2014; Petry, 2001) and may reflect a willingness to engage in risk of other unmeasured variables. Accordingly, distributive syringe sharing was included as an indicator of injection risk behavior given the limited number of observed indicators for injection risk behavior in the current dataset and the previously observed strong factor loading of this indicator in similar factor models. One

[9] An alternative approach is possible using multivariate data analysis. However, this approach is less parsimonious and was therefore not used.

limitations of a latent variable approach is that the measurement model implicitly assumes measurement invariance across all covariates. That is, we assume that no covariate has an association with the measurement indicators except through the latent variable. The accuracy of this assumption is unclear. However, given the limited investigations into measurement invariance in multilevel SEMs (Jak, Oort, & Dolan, 2013), the small cluster size in the data, and the already complex nature of the model, I see this as a necessary assumption in the current study. Furthermore, multilevel structural equation modeling also assumes that the factor structure and loadings are consistent across each injection episode. Accordingly, a preliminary analysis was undertaken to examine the accuracy of this assumption by performing a confirmatory factor analysis of all four injection episodes and comparing the fit of a model with constrained factor loadings across episodes to that of a model with factor loadings freed across episodes.

Model Fit. For the estimator, maximum likelihood with robust standard errors (MLR) was used because this is the only estimator that allows for categorical indicators in multilevel structural equation modeling with random slopes (Muthen & Muthen, 2012).[10] Using this estimation method, missing data on dependent variables (i.e., injection risk behavior) was handled using full information maximum likelihood so that participants with two to four observed injection episodes will contribute to parameter estimates in the within and between portions of the model while participants with a single injection episode will contribute only to the parameter estimates in the between portion of the model. However, episodes or participants with missing data on any independent variables were excluded from analysis using listwise deletion (number of episodes deleted = 87). As indicated in the method section, dummy codes

[10] For all models, the standard integration technique was used with 7 integration points used for Models 1-4 and the default number of integration points, 15, used to run the final model as suggested by Muthen (2010) for computationally demanding modeling.

were used to minimize missing values and preliminary analysis was undertaken to examine those cases with missing values.

Unfortunately, there is currently no method for estimating a multilevel random slope model with categorical indicators that includes global measures of fit such as Chi-square, RMSEA, CFI, or TLI (Geiser, Bishop, Lockhart, Shiffman, & Grenard, 2013).[11] Although global fit indices are not available when using MLR with random slopes, an iterative approach is possible to examine if nested models significantly improve fit using the Wald test of nested models (Muthen & Muthen, 2014). Accordingly, the modeling process will be an iterative process that progressively frees different parameters of the model to examine if freeing these parameters significantly improves model fit (Appendix B). The first model (i.e., *Model 1*) included the full model absent of random slopes with factor loadings constrained to be equal across the within and between levels of the model. *Model 2* was the same model with all factor loadings freed across levels (except for the fixed loading for identification). Using the best fitting model as the reference, *Model 3* freed the random slope for *gender concordance* and *Model 4* freed the slope for *sexual partner multiplexity*. Finally, the last model (*Model 5*) included *gender* as a predictor of both slopes.

Hypothesis

After establishing an acceptably fitting model, all hypotheses of direct effects of network, dyadic, or situational predictors on injection risk behavior were tested using the p-value for the estimated path coefficient between the given variable and risk behavior. The interactions that were within a single level (i.e., *IDUs present * non-IDUs present*) were tested by examining the p-value for the estimated path coefficient between the product term of these two variables and

[11] However, in effort to provide some insight into the overall fit of the model, Models 1 and 2 were also estimated using the weighted least squares estimator using a diagonal weight matrix (WLSMV).

injection risk behavior. Like all interactions, estimates of associations with random slopes must be interpreted after taking into account the moderating variables (i.e., the participant's gender in this case). In the current study, gender was coded so that male participants were used as the reference group. Accordingly, default estimates of *gender concordance* and *sexual partnership* were for male participants in the final model. Therefore, a test for simple slopes was utilized to also provide a test for the effect of *gender concordance* and *sexual partnership* for female participants. Finally, the effect of the *gender* on level-1 random slopes was evaluated by examining the path coefficient between gender and both random slopes (e.g., latent variables S1 and S2 for *gender concordance* and *sexual partner multiplexity*, respectively).

Results

Missing Data

As discussed above, although full information maximum likelihood was used to handle missing data on the observed dependent variables (i.e., indicators injection risk behavior), episodes or individuals with missing data on independent variables were excluded from analysis using listwise deletion. Accordingly, there exist two types of missing data. First, observations were excluded if participants were missing data on all dependent variable indicators (i.e., these participants reported the initials of an injection partner but not any data on the four injection risk behaviors). Second, observations were excluded if they were missing data on any independent variable. Therefore, an additional preliminary analysis was undertaken to examine the nature of missing data in the sample.

First, 13 cases were missing data on all dependent variables representing 1.6% of all cases in the sample while 126 injection episodes were missing data on all outcomes representing 6.3% of all episodes in the sample. Demographic comparisons between participants with missing

data on all dependent variables can be found in Appendix C.[12] Statistical significance tests (i.e., chi-square for categorical and t-test for continuous variables) indicated that male, Hispanic, and or infrequent cocaine injectors were also more likely to have this type of missing data. Accordingly, missing data on dependent variables reduced the sample to 822 cases reporting on 1863 injection episodes (205 individuals with one episode (24.9%), 220 with two episodes (26.8%), 370 with three episodes (45.0%), and 27 with four episodes (3.3%))

An additional 38 cases and 85 injection episodes were excluded in the primary modeling procedures due to missing data on the independent variables leading to a final number of 1778 injection episodes being observed by 784 participants (195 individuals with one episode (24.9%), 211 with two episodes (26.9%), 351 with three episodes (44.8%), and 27 with four episodes (3.4%)). Accordingly, the number of excluded participants was 6.1% of the entire IDU sample while the number of excluded episodes was 10.6% of all possible episodes. Demographic and episode specific variable comparison (for non-missing variables) can be found in Table 3 showing the percentage of each category with no missing data on any independent variable. Furthermore, an exploratory analysis was undertaken to compare observations with any missing independent variables. This analysis examined the bivariate association between all model variables and being missing on any independent variable (i.e., a dummy code indicating 0 = not missing and 1 = missing). Missingness on any variable was only associated with two independent variables (i.e., cases with gender concordant and new partners were more likely to have missing data) and none of the outcome variables (see Appendix D for detailed results).[13]

[12] Comparing episode specific data across missing data groups would also be ideal. However, the vast majority (88.1%) of episodes with missing data were missing data on all episode specific variables and therefore these comparisons are not possible.

[13] Pearson chi-square tests were used for categorical variables and t-tests were used for continuous variables. The Benjamini–Hochberg procedure was used to control for false discovery rate in analysis of missing.

Accordingly, this exploratory analysis suggests that, for many of the variables of primary interest in this study, missing and non-missing episodes were quite similar. While it is unclear if the missing completely at random assumption is met, the relatively small number of missing cases and the small number of associations with relevant variables suggests parameter estimates are

Table 3. Comparison of Cases with any Missing Data on Independent Variables

Variable	Non-Missing
Most Common Location	
Yes	95.3%
No	97.7%
Gender Concordance	
Discordant	93.7%
Concordant	96.8%
Sexual Partners	
Yes	94.8%
No	95.9%
HIV Concordance	
Unknown Concordance	
Yes	96.2%
No	94.7%
Concordant	
Yes	94.1%
No	95.6%
Partnership Length	
New Injection Partner	92.1%
Second quartile	97.3%
Third quartile	96.6%
Fourth quartile	95.4%
Female	
Yes	96.6%
No	94.9%
Race	
Black	95.0%
Race - Other/Multiple	93.5%
Hispanic	
Yes	93.8%
No	95.9%

unlikely to be substantially biased (Graham, 2009; McKnight, McKnight, Sidani, & Figueredo, 2007). However, this limitation will be revisited in the discussion section.

Preliminary Analysis

Before examining the full model, a preliminary analysis was performed in order to test the assumption of equal factor loadings across the four measured injection episodes. Kendall's tau correlation coefficients between all indicators of injection risk behavior can be found in Table 4 while Table 5 presents the factor loadings and model fit for each four-factor model. Again, this model assessed each episode as belonging to a separate factor with each factor being measured by the four observed indicators of injection risk behavior (i.e., receptive sharing, distributive sharing, diving drugs, and sharing other equipment). A graphical representation of this factor model can be found in Appendix E. In this model, each episode is represented by a single latent factor (E1 - E4) corresponding to the four measured injection risk indicators at that specific episode. The first model had fixed factor loadings across injection episodes (Model P1) while the second freed these parameters across episodes (Model P2). This allows for a test to examine if the observed indicators have the same measurement properties across each injection episodes, an assumption imbedded in a multilevel structural equation modeling approach. The log-likelihood test for change in model fit indicated that freeing the factor loadings did not significantly improve model fit ($\chi^2(9) = 5.85$, $p = 0.754$). Accordingly, the null model with equal factor loadings across injection episodes was not rejected and the assumption of measurement invariance across injection episodes for the multilevel structural equation model was not violated.

Table 4. Kendall's Tau Correlation Coefficient for Injection Risk Behavior

Episode	Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1. Rec. Share	-															
	2. Dist. Share	**.656**	-														
	3. Divide Drugs	**.477**	**.543**	-													
	4. Non-syringe share	**.349**	**.353**	**.433**	-												
2	5. Rec. Share	**.583**	**.506**	**.402**	**.270**	-											
	6. Dist. Share	**.485**	**.547**	**.408**	**.277**	**.684**	-										
	7. Divide Drugs	**.361**	**.385**	**.598**	**.352**	**.511**	**.533**	-									
	8. Non-syringe share	**.306**	**.303**	**.396**	**.625**	**.404**	**.374**	**.529**	-								
3	9. Rec. Share	**.484**	**.475**	**.340**	**.206**	**.545**	**.609**	**.398**	**.295**	-							
	10. Dist. Share	**.457**	**.522**	**.356**	**.243**	**.518**	**.650**	**.350**	**.287**	**.710**	-						
	11. Divide Drugs	**.354**	**.351**	**.544**	**.336**	**.344**	**.381**	**.579**	**.411**	**.501**	**.489**	-					
	12. Non-syringe share	**.252**	**.240**	**.336**	**.591**	**.233**	**.247**	**.365**	**.658**	**.357**	**.325**	**.524**					
4	13. Rec. Share	**.461**	**.231**	**.271**	**.410**	**.537**	**.421**	**.318**	**.373**	**.695**	**.808**	**.299**	**.447**	-			
	14. Dist. Share	**.390**	**.402**	**.308**	**.436**	**.467**	**.491**	**.355**	**.436**	**.650**	**.671**	0.30	**.517**	**.693**	-		
	15. Divide Drugs	**.327**	**.389**	**.613**	**.398**	**.467**	**.483**	**.461**	**.524**	**.451**	**.474**	**.521**	**.470**	**.401**	**.492**	-	
	16. Non-syringe share	**.375**	0.22	**.393**	**.554**	**.435**	**.450**	**.302**	**.511**	**.325**	**.408**	0.24	**.653**	**.426**	**.449**	**.372**	-

Note. Bold values indicate p-value of less than 0.05

Table 5. Factor loadings and Model Fit for Confirmatory Factor Analysis

	Model P1	Model P2
Episode 1		
Rec. Share	1.00	1.00
Dist. Share	**1.14 (0.19)**	**1.31 (0.26)**
Divide Drugs	**0.67 (0.10)**	**0.86 (0.14)**
Non-syringe share	**0.50 (0.07)**	**0.56 (0.10)**
Episode 2		
Rec. Share	1.00	1.00
Dist. Share	**1.14 (0.19)**	**1.05 (0.25)**
Divide Drugs	**0.67 (0.10)**	**0.63 (0.13)**
Non-syringe share	**0.50 (0.07)**	**0.51 (0.10)**
Episode 3		
Rec. Share	1.00	1.00
Dist. Share	**1.14 (0.19)**	**0.84 (0.26)**
Divide Drugs	**0.67 (0.10)**	**0.51 (0.14)**
Non-syringe share	**0.50 (0.07)**	**0.37 (0.09)**
Episode 4		
Rec. Share	1.00	1.00
Dist. Share	**1.14 (0.19)**	1.60 (0.92)
Divide Drugs	**0.67 (0.10)**	**0.60 (0.24)**
Non-syringe share	**0.50 (0.07)**	**0.53 (0.18)**
AIC	7176.28	7188.96
BIC	7331.76	7386.85
Loglikelihood	-3555.14	-3552.48
Correction Factor	1.15	1.09

Note. Model P1 has all factor loadings fixed across injection episodes while model P2 freed factor loadings across episodes.

Model Comparison

Following the preliminary analysis, models were tested using an iterative approach beginning with the most constrained model and examining if freeing parameters significantly improved model fit, using Wald's test (Bentler, 1990) for nested models. Results for all models

can be found in Table 6.[14] Beginning with the first two models that excluded all random slopes, freeing the factor loadings across the within and between levels (Model 2) did not improve fit over the fully constrained model (Model 1), $W = 5.84$, df = 3, p = 0.120. Therefore, the null model (i.e., Model 1) was retained and all subsequent models included factor loadings constrained to be equal across the between and within levels of the model. Next, Model 3 freed the random slope for the effect of *gender concordance* on injection risk behavior. Model 3 significantly improved fit over Model 1 ($W = 24.08$, df = 1, $p < 0.001$) suggesting that the relationship between *gender concordance* and injection risk behavior did vary across individuals. This was also confirmed by the significance of the variance for the random slope ($\sigma^2_{s1} = 2.21$, p = 0.031). Model 4 significantly improved the fit of the model over Model 3 by freeing the slope for *sexual partnership* ($W = 343.93$, df = 1, $p < 0.001$), again corresponding with a significant variability in this slope parameter ($\sigma^2_{s2} = 0.09$, $p < 0.001$). Finally, Model 5 also significantly improved model fit over Model 4, ($W = 15.04$, df = 2, $p < 0.001$), by including the participant's *gender* as a predictor of both the random slopes for *gender concordance* as well as *sexual partnership*. Accordingly, all hypotheses were examined using Model 5 with both random slopes freed and gender used as a predictor of these slopes.

Hypothesis

Using Model 5 as the final model, each hypothesis was assessed by examining the path coefficient between the independent variables and the latent variable, either injection risk behavior or the random slopes. Parameter estimates and standard errors for all hypotheses can be found under Model 5 in the far right column of Table 6.

[14] To provide a rough estimate of model fit to the data, results with absolute model fit indices for models without random slopes (i.e., Model 1 and Model 2) using WLSMV estimation can be found in Appendix F.

Hypothesis 1

Hypotheses 1_a through 1_f involved dyadic predictors of injection risk behavior. As discussed, two estimates (i.e., one for females and one for males) were examined for the Hypotheses 1_a and 1_b because these hypotheses involved parameters with random slopes. For males, *gender concordance* was not a significant predictor of injection risk behavior ($\gamma = -0.51$, $p = 0.060$) while *sexual partnership* was positively associated with risk behavior ($\gamma = 1.07$, $p < 0.001$). For females, both *gender concordance* ($\gamma = 1.10$, $p = 0.001$) and *sexual partnership* ($\gamma = 2.21$, $p < 0.001$) were significantly positively associated with injection risk behavior. As suggested by the simple slopes, female participants had significantly more positive slopes for both *gender concordance* ($\gamma = 1.60$, $p < 0.001$) and *sexual partnership* ($\gamma = 1.14$, $p = 0.014$) as assessed by the path coefficient between *gender* and each random slope (Hypothesis1_d and Hypothesis1_e). This indicated that females with injection partners that were female or sexual partners were more likely to engage in risk behavior. Finally, no significant residual variability remained in either random slope remained after accounting for *gender* as a predictor ($\sigma^2_{s1} = 1.92$, $p = 0.050$; $\sigma^2_{s2} = 0.61$, $p = 0.592$), suggesting nearly all variability in these slopes was accounted for by participant's gender. Moving to other dyadic variables, length of injection partnership (Hypothesis1_e) was not significantly associated with injection risk behavior when comparing the first ($\gamma = 0.26$, $p = 0.336$), second ($\gamma = 0.38$, $p = 0.171$), and third ($\gamma = 0.34$, $p = 0.213$) quartile of injection partnership to episodes in the lowest quartile of injection partnerships. However, injecting with a first time partner was negatively associated with injection risk ($\gamma = -1.26$, $p = 0.008$). There was also no evidence of serosorting (Hypothesis1_f) as dyads with unknown concordance ($\gamma = -0.42$, $p = 0.490$) and those that were sero-concordant ($\gamma = -0.66$, $p = 0.292$) showed no significant difference in level of risk as compared to those with known discordance.

Table 6. Model Parameters for Models 1 through 5

	Model 1	Model 2	Model 3	Model 4	Model 5
Model Fit					
Loglikelihood	-3288.64	-3277.68	-3284.55	-3284.50	-3276.34
Scaling Correction Factor	1.20	1.25	1.19	1.15	1.18
AIC	6651.28	6635.36	6645.09	6647.01	6634.67
BIC	6854.16	6854.69	6853.45	6860.86	6859.49
Wald Test	-	5.84, p = 0.120	24.08 p < 0.001	343.93 p < 0.001	15.04, p < 0.001
Parameters					
Within					
Factor Loadings[a]					
Receptive Sharing	1.00	1.00	1.00	1.00	1.00
Distributive Sharing	**1.12 (0.17)**	**1.21 (0.20)**	**1.12 (0.16)**	**1.12 (0.16)**	**1.13 (0.17)**
Divide Drugs	**0.70 (0.11)**	**0.92 (0.21)**	**0.71 (0.11)**	**0.70 (0.11)**	**0.71 (0.11)**
Non-syringe sharing	**0.55 (0.08)**	**1.07 (0.30)**	**0.55 (0.08)**	**0.55 (0.08)**	**0.55 (0.08)**
Path Coefficients					
Gender Concordance	0.30 (0.20)	0.20 (0.16)	0.15 (0.21)	0.12 (0.21)	-0.51 (0.27)
Female (Simple Slope)	-	-	-	-	**1.10 (0.32)**
Missing	0.09 (0.55)	0.13 (0.40)	0.07 (0.53)	0.05 (0.53)	-0.11 (0.53)
Sexual Partner	**1.61 (0.26)**	**1.02 (0.31)**	**1.62 (0.26)**	**1.61 (0.22)**	**1.07 (0.28)**
Female (Simple Slope)	-	-	-	-	**2.21 (0.42)**
Partnership Length					
New Partner	**-1.20 (0.48)**	**-0.88 (0.37)**	**-1.27 (0.49)**	**-1.27 (0.49)**	**-1.26 (0.48)**
1st Quartile (Reference)	-	-	-	-	-
2nd quartile	0.31 (0.27)	0.35 (0.21)	0.30 (0.27)	0.30 (0.27)	0.26 (0.27)
3rd quartile	0.43 (0.28)	**0.50 (0.23)**	0.41 (0.28)	0.41 (0.28)	0.38 (0.28)

Table 6 (cont'd)

	Model 1	Model 2	Model 3	Model 4	Model 5
4th quartile	0.38 (0.28)	**0.55 (0.23)**	0.36 (0.28)	0.37 (0.28)	0.34 (0.27)
HIV Concordance					
Discordant (Reference)	-	-	-	-	-
Unknown Concordance	-0.36 (0.62)	-0.16 (0.48)	-0.32 (0.61)	-0.33 (0.60)	-0.42 (0.61)
Concordant	-0.60 (0.64)	-0.36 (0.50)	-0.59 (0.62)	-0.60 (0.62)	-0.61 (0.62)
Missing	-0.18 (0.62)	-0.06 (0.47)	-0.13 (0.60)	-0.14 (0.60)	-0.20 (0.60)
# of people injecting	0.02 (0.04)	-0.02 (0.03)	0.02 (0.03)	0.02 (0.03)	0.01 (0.03)
# non-injectors using drugs	**0.10 (0.04)**	**0.08 (0.03)**	**0.10 (0.03)**	**0.10 (0.03)**	**0.10 (0.03)**
# of injectors * # of non-injectors	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Inject at home	-0.26 (0.22)	-0.22 (0.17)	-0.27 (0.22)	-0.27 (0.22)	-0.27 (0.22)
Location is Common Location	-0.59 (0.36)	-0.48 (0.27)	-0.54 (0.36)	-0.54 (0.36)	-0.50 (0.35)
Missing	-0.26 (0.41)	-0.39 (0.30)	-0.21 (0.42)	-0.21 (0.42)	-0.23 (0.41)
Residual Variance - Within					
Injection Risk (Latent)	**1.91 (0.51)**	**1.19 (0.43)**	**1.47 (0.47)**	**1.45 (0.46)**	**1.35 (0.45)**
Between					
Factor Loadings[a]					
Rec. Share	1.00	1.00	1.00	1.00	1.00
Dist. Share	**1.12 (0.17)**	**1.05 (0.16)**	**1.12 (0.16)**	**1.12 (0.16)**	**1.13 (0.17)**
Divide Drugs	**0.70 (0.11)**	**0.63 (0.11)**	**0.71 (0.11)**	**0.70 (0.11)**	**0.71 (0.11)**
Non-syringe sharing	**0.55 (0.08)**	**0.45 (0.07)**	**0.55 (0.08)**	**0.55 (0.08)**	**0.55 (0.08)**
Thresholds					
Rec. Share					
Shared - used bleach	**4.16 (1.06)**	**3.77 (1.08)**	**3.98 (1.05)**	**3.96 (1.05)**	**3.15 (1.04)**
Shared - did not use bleach	**6.04 (1.10)**	**5.71 (1.11)**	**5.90 (1.09)**	**5.89 (1.09)**	**5.01 (1.08)**
Dist. Share	**4.25 (1.27)**	**3.77 (1.23)**	**4.12 (1.23)**	**4.08 (1.22)**	**3.22 (1.21)**
Divide Drugs	**1.59 (0.74)**	1.34 (0.76)	**1.51 (0.72)**	**1.49 (0.72)**	0.94 (0.73)

Table 6 (cont'd)

	Model 1	Model 2	Model 3	Model 4	Model 5
Other equipment	0.20 (0.57)	0.10 (0.68)	0.14 (0.56)	0.12 (0.55)	-0.30 (0.57)
Path Coefficients					
Injection Network Size	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)
Female	0.51 (0.30)	0.61 (0.34)	0.43 (0.29)	0.42 (0.30)	-0.86 (0.49)
Age	-0.04 (0.02)	**-0.06 (0.03)**	-0.04 (0.02)	-0.04 (0.02)	-0.04 (0.02)
Race					
Black	**1.06 (0.37)**	**1.27 (0.42)**	**1.01 (0.36)**	**1.01 (0.36)**	**1.00 (0.36)**
Race - Other/Multiple	0.16 (0.53)	0.18 (0.61)	0.21 (0.53)	0.20 (0.53)	0.13 (0.52)
Hispanic	0.32 (0.50)	0.39 (0.57)	0.31 (0.49)	0.32 (0.50)	0.33 (0.49)
Homeless	**1.74 (0.34)**	**2.03 (0.40)**	**1.75 (0.34)**	**1.75 (0.34)**	**1.72 (0.34)**
Drug Use					
Crack/Cocaine Frequency	-0.01 (0.01)	-0.01 (0.02)	-0.01 (0.01)	-0.01 (0.01)	-0.01 (0.01)
Heroin/Opioids Frequency	**-0.04 (0.01)**	**-0.05 (0.02)**	**-0.04 (0.01)**	**-0.04 (0.02)**	**-0.04 (0.01)**
Injection Frequency	-0.00 (0.01)	-0.00 (0.01)	-0.00 (0.01)	-0.00 (0.01)	-0.00 (0.01)
Injection Duration	**0.04 (0.02)**	**0.05 (0.02)**	**0.05 (0.02)**	**0.05 (0.02)**	**0.04 (0.02)**
Random Slopes Predictors					
Gender Concordance					
Female	-	-	-	-	**1.60 (0.42)**
Sexual Partnership					
Female	-	-	-	-	**1.14 (0.47)**
Residual Variance - Between					
Injection Risk (Latent)	**9.65 (2.16)**	**12.49 (2.95)**	**8.84 (2.00)**	**8.85 (1.97)**	**8.39 (1.95)**
Gender Concordance	-	-	**2.21 (0.90)**	**2.34 (0.93)**	1.92 (0.98)
Sexual Partnership	-	-	-	**0.09 (0.01)**	0.61 (0.72)

Note. Bold values indicate p-value of less than 0.05. All hypotheses were tested using path coefficients from model 5. [a] Factor loadings for the first factor indicator were fixed at 1 for identification purposes.

Hypotheses 2 and 3

Hypotheses 2 and 3 examined network and situational predictors of injection risk behavior. Injection network size was not significantly associated with injection risk ($\gamma = 0.00$, $p = 0.652$; Hypothesis 2_a). While the number of injectors at the injection episode was not associated with risk behavior ($\gamma = 0.04$, $p = 0.311$; Hypothesis 3_a), the number of non-injection drug users was positively associated with risk behavior ($\gamma = 0.09$, $p = 0.006$), contradicting the expected direction in Hypothesis 3_b. However, there was no significant interaction between the number of injectors and the non-injectors present during the injection episode ($\gamma = 0.00$, $p = 0.990$; Hypothesis 3_c). Finally, injecting at one's own home was not significantly related to injection risk behavior ($\gamma = -0.27$, $p = 0.208$; Hypothesis 3_d).

Other Covariates

While not the main focus of the current study, the association between several variables and injection risk behavior were also included in the model. The injection site being the most common site of injection was not associated with risk behavior ($\gamma = -0.50$, $p = 0.160$). However, both black ($\gamma = 1.00$, $p = 0.006$) and homeless ($\gamma = 1.72$, $p < 0.001$) participants witnessed higher levels of injection risk behavior but female ($\gamma = -0.86$, $p = 0.077$), other race ($\gamma = 0.13$, $p = 0.796$), and Hispanic ($\gamma = 0.33$, $p = 0.499$) were not significant predictors of injection risk behavior. Similarly, age had no association with injection risk ($\gamma = -0.04$, $p = 0.083$). Finally, neither frequency of crack/cocaine use ($\gamma = -0.04$, $p = 0.552$) nor injection frequency ($\gamma = -0.00$, $p = 0.631$) were significantly associated with risk behavior. However, injection duration was positively associated ($\gamma = 0.04$, $p = 0.009$) while frequency of heroin/opioid use was negatively associated ($\gamma = -0.04$, $p = 0.001$) with risk.

Discussion

Given the continued burden of HCV and HIV among injection drug users, understanding the social processes associated with the spread of these diseases remains an important goal of public health research. However, previous research has largely focused on between person variation in injection risk behavior (Rhodes, 2009) or failed to use analytic methods idealy suited to assess within person variability (e.g., see Montgomery et al., 2013) . This study attempted to overcome limitations in previous research by exploiting data with multiple observations of drug use episodes for each participant in effort to examine within person variation of injection risk behavior in addition to modeling the traditional between person variation. The results of the current study will first be discussed in the context of social setting theory and previous research before moving on to study limitations and the implications for future research.

Dyadic Predictors

Contradicting Hypothesis 1_a, gender concordance did not have a negative association with risk behavior for both males and females. After accounting for the cross-level interaction with the participant's gender (Hypothesis 1_c), gender concordance had no significant association for males but was a significant positive predictor of injection risk behavior for females, the opposite direction of the hypothesized relationship. This suggests that gender concordant injection partnerships represented a risk factor unique to females. In the context of social setting theory, these findings may suggest that norms surrounding female-female injection partnerships may facilitate increased levels of risk behavior (Latkin et al., 2010). For example, Davey-Rothwell and Latkin (2007) found that perceived approval of equipment sharing was not a significant predictor for females but was for males, suggesting different normative influences may exist in gender concordant partnerships among females as compared to males. This finding

also suggests that there was no evidence of disadvantaged social locations among female with discordant injection partners due to more restricted access to drug resources (Tortu et al., 2003) or gender norms (Barnard, 1993; Bourgois, Prince, & Moss, 2004) that encourage females to share equipment with male partners. However, the positive association between injection risk behavior and gender concordant partners among females could suggest that these partnerships exist in the contexts with reduced overall levels of available injection resources. For example, previous studies have found that female injectors are less likely to have access to drug resources (Tortu et al., 2003; Wagner, Lankenau, et al., 2010). Accordingly, females may be forced to share equipment, and thereby increase risk, when injecting with other female partners due to lower levels of overall resources available to these injectors. Finally, given the unexpected findings in the current study and the mixed findings of previous research (Gyarmathy et al., 2010; Hahn et al., 2010; Sherman et al., 2001), these findings may suggest that the association between gender concordance and injection risk is highly specific to local contexts and may be sensitive to other un-measured social processes.

As expected, there was a positive association between sexual partnership and injection risk behavior across group males and females (Hypothesis 1_b). Furthermore, as expected in Hypothesis 1_d, the association between sexual partnership and injection risk behavior was significantly more positive for female injectors as compared to males. This concurs with findings from several studies indicating that sexual partners were at increased probability for engaging in injection risk behavior for both male and female injectors (Bailey et al., 2007; Hottes et al., 2011). Furthermore, in the context of social setting theory, this may suggest that the resource imbalances or gender norms may enhance the potential risk of sexual partnerships for female injectors. For example, females' sexual partners may be responsible for obtaining drugs (El-

Bassel et al., 2014) and, due to this responsibility, may subsequently retain greater control over the injection process (e.g., injecting first with the same equipment to be used by the female sexual partner). This finding also concurs with results from a number of smaller studies indicating sexual partnerhsips may be more detrimental, in terms of injection risk, to female injectors as compared to males (Choi et al., 2006; Gollub et al., 1998). However, by using event specific data, the current study confirms that it is not merely individuals that inject with sexual partners that are at higher risk, but the specific injection episodes with sexual partners that are related to heighted risk. That is, injecting with a sexual partner was observed at the episode level rather than the individual. Therefore, the positive assocaition between sexual partnership and risk behavior found in this study suggests that the same individual is at greater risk when injecting with a sexual partner compared to non-sexual partners.

As for injection partnership duration, the results of Hypothesis 1_e were mixed. While new partners were at decreased risk for injection risk behavior, there was no significant relationship between length of partnership and injection risk behavior across the various quartiles of injection partnership for non-new partners. This suggests that longer partnership durration was not associated with higher levels of risk as predicted and there was no impact of the expected increase of intimacy of long term injection partnerships on injection risk behavior. In the context of social setting theory, this suggests the norms related to new (i.e., first time) partners may reduce risk behavior but trust or intimacy accrued over long term partners do not appear to impact risk, or may act primarily through other factors such as sexual partnership. Previous research has also been mixed on the association between partnership length and injection risk behavior. While emotional closeness between injection partners predicts injection risk behavior in a number of studies (Barnard, 1993; Sherman et al., 2001; Tortu et al., 2003), several studies

specifically examining the relationship between partnership length and risk behavior found non-significant results (Niccolai et al., 2010; Paintsil et al., 2009). Accordingly, the current study's finding concur with these previous findings. However, it is possible that the coding procedure that turned this continuous variable into discrete categories may have obscured the relationship between these variables. Although previous studies (e.g., Morris et al., 2014) have used similar categorical coding schemes, future work could clarify the association between injection risk behavior and injection partnership duration using more nuanced measurement of this variable.

Similarly, no evidence of serosorting was observed in the current study (i.e., increased likleihood to engage in risk behavior with partners perceived to have the same HIV serostatus). Previous studies generally found support for the presence of serosorting behavior (Burt et al., 2009; Chen, McFarland, & Raymond, 2014; Smith et al., 2013; Yang et al., 2011). However, other studies have found no evidence of serosorting (Hagan et al., 2006) or limited evidence of serosorting only among a minority of injectors (Mizuno et al., 2011). Accordingly, the current results similarly suggest that injection drug users do not appear to be selecting partners based on perceived serostatus in all situations. However, the current finding is limited by the fact that a roughly a third of observations (33.2%) of injection episodes had missing data on the partner's HIV status. Accordingly, the statistical test in the current study may have limited power to detect an effect given this missing data. HIV/HCV serosorting and the conditions and settings in which serosorting may be more or less likely remains an active area for research.

Network Predictors

Contrary to Hypothesis 2, no signficant relationship between size of the participant's injection network and injection risk behavior was observed. This may suggest that the size of injection networks may have little effect on injection risk behavior, as found in previous studies

(Paquette et al., 2011; Shaw et al., 2007). Several studies have found a positive association between network size and injection risk (Cepeda et al., 2011; Latkin, Mandell, Vlahov, et al., 1995; Latkin et al., 1996; Needle et al., 1998; Thiede et al., 2007). However, differences in the current study from most previous studies (e.g., the current study used sampling population linked to MSM and statistical models that controlled for episode specific variables) could explain why the current findings differ from those in the past. However, the non-significant relationship between injection network size and risk behavior may also be inaccurate due to the inherent difficulty of recalling the number of injectors in the "same place and time" in the last 6 months among individuals who frequently inject drugs. Accordingly, this instrument could introduce measurement error that may have attenuated the relationship between injection network size and risk behavior. Alternative measurement techniques that use more recent time periods, most specific relationships, or use recall techniques that have been vetted and refined (Brewer & Garrett, 2001; Brewer, Garrett, & Kulasingam, 1999) would likely provide improved measurement properties.

Environmental Predictors

For Hypothesis 3, the number of injectors at an episode had no relationship and the number of non-injectors was positively associated with injection risk behavior contradicting both Hypothesis 3_a and 3_b. This suggests that alternative setting factors may be at play in these settings that were not considered. For example, given that at least one other injector was present at all injection episodes due to the manner in which the questionnare elicited episodes, injection episodes with more non-injectors may be settings in which injection resources (e.g., syringes and cookers) are more scarce. For example, injecting at a location with multiple non-injectors may suggest that the location is not a location primarily used for injecting. Consequently, this could

make the availability and surplus of injection equipment less likely if injection equipment is not frequently stored at the physical location, thereby increasing the likelihood of engaging in risk behavior. Alternatively, due to the stigma of injection drug use, locations with many non-injectors may reduce the temporal resources available to injectors and require more hurried injection episodes. Therefore, these episodes may facilitate higher levels of risk behavior similar to other examples of public injecting (Small et al., 2007). Although previous studies have found that non-IDU norms may discourage sharing behavior (Cox et al., 2009; Mateu-Gelabert et al., 2005), the material requirements of the injection process may outweigh these norms in situations with many non-injectors. However, studies specifically designed to test hypotheses examining norms and resources (e.g., by measuring perceived injection norms or the number of sterile syringes available at the injection locations) would be better equipped to examine this relationship.

Finally, no significant relationship was observed between injecting at home and risk behavior (Hypothesis 3_d). From the perspective of social setting theory, this may suggest that participant's injection episodes at homes had no greater resources than those at other locations or that injecting at one's home provides no privledged control over the injection process. Previous studies that have compared specific types of injection locations (e.g., home vs. shooting gallery vs. outdoors) have found mixed results with some finding signficant associations (Bailey et al., 2007; Latkin et al., 1994) while others found no relationship between injecting location (R. A. Johnson, Gerstein, Cerbone, & Brown, 2002). Accordingly, the association between injection location and injection risk behavior continues to remain unclear. Studies examining this association would benefit by explicitly inclduing assessment of possible mediating variables

(e.g., resources and social proceses) to clarify the impact of injecting location on injection risk behavior.

Given the novel approach of the current study that allows estimation of within person variability across partners and settings, a particulary noteworthy finding that was not one of the main hypotheses is that significant variability was observed in injection risk behavior across injection episodes, as measured using the four indicator latent variable. This indicates that participants in the current study did experience different levels of injection risk behvaior across injection episodes. More specifically, in a null model with no within-level predictors (Appendix G), 13.2% (ICC = 0.132) of the unexplained variability in injection risk behavior took place at the within-person level indicating that a sizable percentage of variability existed across different injection episodes. This finding suggests that setting and partner level characteristics are important factors in determining the observed level of risk behavior for specific drug use episodes. Furthermore, the significant variability of the within-level latent factor in the final model (i.e., Model 5) suggests that significant variability continued to exist across injection episodes after accounting for all the included explanatory variables at the within level. Clearly, the included partner and setting level independent variables were not sufficient to account for all setting level variability and much remains unknown about influential setting and partner level factors. More generally, only a single setting variable (i.e., number of non-injection drug users) was significant while several dyadic variables were signifcaint at the within level. Accordingly, much remains unknown about setting specific variables that may impact injection risk. Limitations of this study that may help shed light on this unexplained variability will first be examined before moving on the implications of the current study for future research.

Limitations

First, the current study used pre-existing data that was not primarily designed to assess episode specific variability in injection risk behavior or to test the theoretical application of social setting theory to injection episodes. Accordingly, important variables related to injection settings and social setting theory could not be included in the model. For example, the control over the drugs used to inject is likely an important variable related to injection risk behavior. Previous studies have found that some males may have greater control over the order of injecting (i.e., the ability to inject first) due to their responsibility in obtaining the drugs (El-Bassel et al., 2014). A study specifically tailored to examine the associations between event specific characteristics (e.g., who paid for or brought the drugs into the setting), control over resources (e.g., who chose the order of injection or who split the drugs between partners), the amount of available resources (e.g., the number of sterile syringes), and injection risk behavior would likely provide increased clarity of these associations and greater insight into competing hypothesis about the mechanisms of these associations. Similarly, explicitly measuring injection norms during specific episodes may provide greater insight into the social pressures of sharing within specific settings.

Second, measurement of event specific data is somewhat unique and the approach of the current study (i.e., collecting data on injection episodes up to 6 months prior to the data collection) is likely prone to potential biases. For example, participants may suffer recall bias or other forms of measurement error due to the difficulty of remembering injection specific information that may have occurred weeks or months before the questionnaire is completed. While similar approaches have been used in previous studies of sexual risk behavior and substance use (Vosburgh et al., 2012), the novelty of this approach being applied to injection risk

behavior makes the validity and reliability of this measurement process uncertain. Similarly, the current study conflated partner and setting level variables given the manner in which the questionnaire elicited drug use events. That is, because setting level variables were collected relating only to specific injection episodes with specific injection partners, the variability of partner and setting are the same. Therefore, collecting observations in this manner limits the ability to examine partner effects separately from event specific characteristics.

Third, in contrast to most multilevel studies, this study has small cluster sizes ($n \leq 4$) but a large number of clusters ($n = 835$). Accordingly, the study likely had substantial power to detect between person associations but less statistical power to detect within person associations. Accordingly, the small cluster size at the within level may have limited the power for this model to detect associations between setting/dyadic variables and injection risk behavior. This may partially explain the failure to find expected associations in some variables at the within level. Future studies that provide a larger sample of injection episodes per participant would likely provide greater insight into associations at the within level.

Fourth, the current study used a rather complex adaptation of respondent driven sampling to recruit the study population. Furthermore, injection drug users were not the primary characteristic for which participants were sampled. While the current sample (i.e., 784) is on the larger size for hidden populations such as IDUs, given the duel incentives used for recruitment it is unclear if these findings can be generalized to a larger population.

Fifth, un-modeled dependencies likely exist between observations in the current study due to the snowball RDS recruitment procedures. For example, participants may have named injection partners that were also participants in the study and data to identify this cross-classification was not available in the dataset. While recruitment and sampling of hidden

populations like injection drug users will remain a challenge for future studies, approaches specifically tailored to eliminate or account for un-modeled dependency may provide the most accurate parameter estimates and standard errors. For example, more accurate estimates might be provided if event specific data were included in the injection drug use questions in traditional nationally representative household surveys such as the NSDUH that lack the complex dependencies inherent in RDS samples.[15] Alternatively, advanced statistical methods that can account for complex dependencies in data analysis continue to be developed and refined. For example, Bastos, Pinho, Codeço, and Bastos (2012) have proposed analyzing RDS data using an error term that explicitly models the network recruitment. These methods will likely continue to improve given the recent explosion of research using and understanding the impact of RDS sampling methodology in social science and public health research (Gile & Handcock, 2010). As these methods improve, the confidence in the accuracy of parameter estimates and standard errors should also improve.

Future Directions

Given the new insights into injection settings provided by the current study and these acknowledged limitations, this study suggests a number of avenues for future research examining injection settings and the social processes associated with injection risk behavior. First, significant within person variability in injection drug risk behavior remained unexplained after including all independent predictors were included in the final model. Accordingly, uncovering variables that more accurately explain this variability remains an important area for future research. This work could be particularly important in identify the mediating social processes

[15] While most such surveys do have issues of dependency due to complex sampling designs (e.g., survey strata), these dependencies are relatively easily accounted for using analytic techniques appropriate for complex survey designs.

relevant to the impact of syringe exchange programs and behavioral interventions among IDUs. For example, social setting theory suggests that networks and norms are key variables that explain setting outcomes. Network variables could be more comprehensively measured by collecting structural data (e.g., ego network density) on multiple types of networks in injection settings (e.g., friendship, injection, sexual, etc). Furthermore, previous studies (Davey-Rothwell & Latkin, 2007) have utilized measures of descriptive (i.e., perceived prevalence of behavior) and injunctive (i.e., perceived approval) norms among injection drug users. More explicitly measuring these norms would likely clarify the processes and mechanisms at play in these settings. As discussed, the continued burden of HCV (Nelson et al., 2011; Suryaprasad et al., 2014) and the uncertain impact of behavioral interventions on the reduction of HCV (Gillies et al., 2010; MacArthur et al., 2014; Palmateer et al., 2010) suggests that continued improvement in these interventions may be required to obtain sustained reduction in HCV incidence and prevalence among IDUs. Identifying these mediating social processes in injection settings may assist in this process of improving interventions in effort to maximize their impact.

Second, as discussed, the current study conflates partner and setting level characteristics due to the format of the questionnaire. Future studies could provide greater insight by collecting data on injection settings (e.g., physical location) separate from information on each partner present at the setting. While this data would increase the complexity of analysis given the potential for cross-classification of partners across settings, it would allow examination of the variability of partner related factors from those of setting related factors. This information would be helpful for interventions to know if specific partner types (e.g., sexual partners) are the primary episode specific factors associated with injection risk before or if setting level characteristics that may be associated with partner types may be responsible for variability in

episode specific injection risk behavior. This data would also be more challenging to collect. However, ecological momentary assessment (Shiffman, Stone, & Hufford, 2008) or other real-time data collection techniques such as coded ethnography (Scott, 2011) could provide the data required to perform such complex analysis. Similarly, these approaches may also improve upon the discussed measurement issues inherent in a study that inquires about specific injection episodes up to 6 months prior to the data collection. Furthermore, these methods would allow for researchers to easily obtain a large number of observations per participant and therefore overcome the limitation of low statistical power at the within participant level.

Third, given that the current study adds to the accumulating evidence that IDUs respond to questions regarding injection risk behaviors in a hierarchical and logical manner and due to the advantages provided by latent variable measurement discussed in this study, the use of latent variable measurement of injection risk behavior should be continued to be explored. For example, future studies that incorporate additional questions (e.g., backloading, frontloading, number of punctures, etc.) would likely increase the observed variability in injection risk behavior and more accurately reflect the true breadth of these behaviors. However, additional studies are required to evaluate the measurement properties of more comprehensive injection risk behavior inventories. For example, studies examining the predictive validity of latent variable measurement of injection risk behavior on seroconversion would be particularly insightful and would provide much needed data on the degree to which this measurement approach accurately reflects viral transmission risk.

Implications for HIV/HCV Prevention Interventions

The findings of the current study also have practical implications for IDU preventive interventions. As discussed, the significant variability across different episodes suggests that

partner and setting factors impact the level of risk behavior at each event. In the current study, participants injecting with sexual partners or non-first time partners were more likely to engage in risk behavior. Accordingly, behavioral interventions may benefit from targeting these relationships as particularly important for reducing risk behavior. For example, previous interventions have attempted to increase communication about and promote self-efficacy to engage in harm reduction practices through skill building exercises with sexual partners (Jiwatram-Negrón & El-Bassel, 2014). While IDU interventions have begun to explore the targeting of intimate partner relationships and communication between sexual partners (Dwyer, Fraser, & Treloar, 2011; El-Bassel et al., 2011), this approach has been much more widely utilized in sexual health interventions (El-Bassel et al., 2001; El-Bassel et al., 2005; Harvey et al., 2008; Jiwatram-Negrón & El-Bassel, 2014; Witte et al., 2006). Accordingly, the full utility of this approach has yet to be extended to injection related interventions. Future interventions and evaluation studies should expand upon the previous work of sexual heath interventions and examine mediating social processes between partners that may be particularly valuable for successful interventions.

Furthermore, female injectors were more likely to be at risk when injecting with gender concordant partners or sexual partners. Accordingly, gender specific programming may also be beneficial in order to target circumstances that may place females at unique or increased level of risk. For example, pre-exposure prophylaxis may provide leverage to prevent HIV among women whose injection or sexual partners are unwilling to engage in other risk reduction activities (Bontell & Strathdee, 2014).While the current study focused on sexual partnership and gender concordance, other social processes are almost certainly involved in health behavior inequities across gender groups. However, and similar to sexual partnership interventions, gender

specific programming has been much more common in sexual HIV risk reduction interventions (Ehrhardt et al., 2002; Melendez, Hoffman, Exner, Leu, & Ehrhardt, 2003; S. Miller, Exner, Williams, & Ehrhardt, 2000; Shain et al., 1999). The efficacy of gender specific programming for reduction of injection related harms should similarly be examined. However, it is also important to note that the complexities and diversity of experiences among female IDU and gender specific programming should address this diversity. For example, financial situations of female injectors differs considerably based on their specific economic situation; while financial dependency with injector partners may place some female injectors at heighted risk, other female injectors may have higher financial earnings that can be used to mitigate risk (El-Bassel et al., 2014). Furthermore, to the extent that these relationships reflect unequal distribution of power or resources, the resource distributions themselves may be a target for intervention activities. For example, purposefully increasing access to harm reduction resources among women may facilitate a more equal distribution of these resources (Amaro, 1995; Wingood & DiClemente, 2000).

Finally, as increased emphasis has been placed on structural and community interventions for injection drug users (Golden, Collins, Cunningham, Newman, & Card, 2013), it remains important to the success of these interventions to identify mediating causal variables in effort to maximize the impact and better understand the mechanisms of action for these programs (Latkin, German, et al., 2013). Event level data and explicit modeling of shifting social processes would allow for more specific exploration of the potential causal mechanisms and identification of the most important components of community interventions.

Conclusion

This study utilized a novel approach to analyzing event specific data of multiple observations of drug use episodes in effort to further elucidate the partner and setting characteristics that influence injection risk behavior. The findings confirm that both dyadic and setting level factors appear to play a significant role explaining within person variability in injection risk behavior. However, these associations varied for males and females in the current study, with females having increased risk when injecting with sexual or other female partners. Furthermore, significant variability remained unexplained and future studies are required to more accurately understand the dyadic, networks, and environmental factors that influence injection risk.

APPENDICES

Appendix A. Questionnaire

Level 2 Variables

Demographics

Q12. What is your date of birth? __ __ / __ __ / __ __ __ __ mm / dd / yyyy

Q13. Are you: (Choose one)

1 MALE
2 FEMALE
3 TRANSGENDER, MALE to FEMALE
4 TRANSGENDER, FEMALE to MALE

Q19. What is your race? (Please check all that apply)

__ White
__ Black/African American
__ American Indian or Alaska Native
__ Asian or Pacific Islander
__ Other
__ Refuse to Answer

Q16. Are you Spanish/Hispanic/Latino?

1 Yes
2 No Skip to Q19
-8 Refuse to Answer Skip to Q19

Q44. At any time during the past year, did you consider yourself homeless?

1 Yes
2 No
-8 Refuse to Answer

Drug Use

Q120. Did you use powder cocaine in the past 6 months?

1 Yes
2 No Skip to instruction before Q121a
-7 Don't Know Skip to instruction before Q121a
-8 Refuse to Answer Skip to instruction before Q121a

Q120b. How many days did you use powder cocaine (coke) by itself (other than crack) that you injected or snorted in the past 30 days?

— —

00 zero Skip to instruction before Q121a
-8 Refuse to Answer Skip to instruction before Q121a

Q122. Did you use heroin in the past 6 months?

1 Yes
2 No Skip to instruction before Q123a
-7 Don't Know Skip to instruction before Q123a
-8 Refuse to Answer Skip to instruction before Q123a

Q122b. How many days did you use heroin in the past 30 days?

— —

00 zero Skip to instruction before Q123a
-8 Refuse to Answer Skip to instruction before Q12a

Q133. How old were you the first time you injected drugs?

— —

-8 Refuse to Answer

Q136. In the past 30 days, about how many times did you inject drugs?

— — —

000 zero Skip to Q142a
-8 Refuse to Answer

Network Characteristics

Q147. About how many different people did you inject drugs within the past 6 months? (By "with", we mean people who injected drugs at the same place and time as you.)

— — —

-8 Refuse to Answer

RDSM1. How many people do you know personally (i.e., you know their name, you know who they are, and they know you, and you have seen them in the last 6 months) who use heroin, methamphetamines, and/or powder or crack cocaine or who inject some other drug?

— — —

-8 = Refuse to Answer

Level 1 Variables

Situational Characteristics

Q182. Where did you last inject drugs with [INJECTION PARTNER]: (Choose one)

1 In your home
2 In your neighborhood
3 In a different neighborhood but within 20 miles from your neighborhood
4 More than 20 miles away from your neighborhood
-8 Refuse to Answer

Q181. Is this where you most often inject with [INJECTION PARTNER]?

1 Yes
2 No
-8 Refuse to Answer

Dyadic Characteristics

Q170. Please choose one answer. Is [INJECTION PARTNER]: (Choose one)

1 Male
2 Female
3 Transgender
-8 Refuse to Answer

Q171. What race or ethnic group is [INJECTION PARTNER]? (Choose one)

01 Black (not Hispanic)
02 White (not Hispanic)
03 Hispanic
04 Asian or Pacific Islander
05 American Indian or Alaskan Native
10 Other
-7 Don't Know
-8 Refuse to Answer

Q196. What is [INJECTION PARTNER]'s HIV status? (Choose one)

1 I don't know or am not sure
2 I am sure she/he is HIV negative
3 I am sure she/he is HIV positive
-8 Refuse to Answer

Q175. Have you injected with [INJECTION PARTNER] more than one time?

1 Yes
2 No Skip to Q178
-8 Refuse to Answer Skip to Q178

Q176. For how long have you injected drugs with [INJECTION PARTNER]? Do you want to answer in days, months, or years? (Choose one)

1 DAYS
2 MONTHS
3 YEARS
-8 Refuse to Answer

If Q176 is equal to "Refuse to Answer", then skip to Q178.

Q177. For how many [Response to Q176] have you injected drugs with [INJECTION PARTNER]?

— — —

-8 Refuse to Answer

Injection Risk Behavior

Q189. The last time you injected with [INJECTION PARTNER], did you inject with a syringe after [INJECTION PARTNER] had used it?

1 Yes
2 No Skip to Q191
-8 Refuse to Answer Skip to Q191

Q190. Was the syringe cleaned with bleach before you injected with it?

1 Yes
2 No
-7 Don't Know
-8 Refuse to Answer

Q191. The last time you injected with [INJECTION PARTNER], did [INJECTION PARTNER] inject with a syringe after you used it?

1 Yes
2 No
-7 Don't Know

-8 Refuse to Answer

Q192. Did you mix, measure, or divide the drugs with [INJECTION PARTNER] using a single syringe?

1 Yes
2 No Skip to Q195
-8 Refuse to Answer Skip to Q195

Q195. The last time you injected with [INJECTION PARTNER], did you share other injecting equipment, such as cookers, cotton, rinse water, or anything else, with [INJECTION PARTNER]?

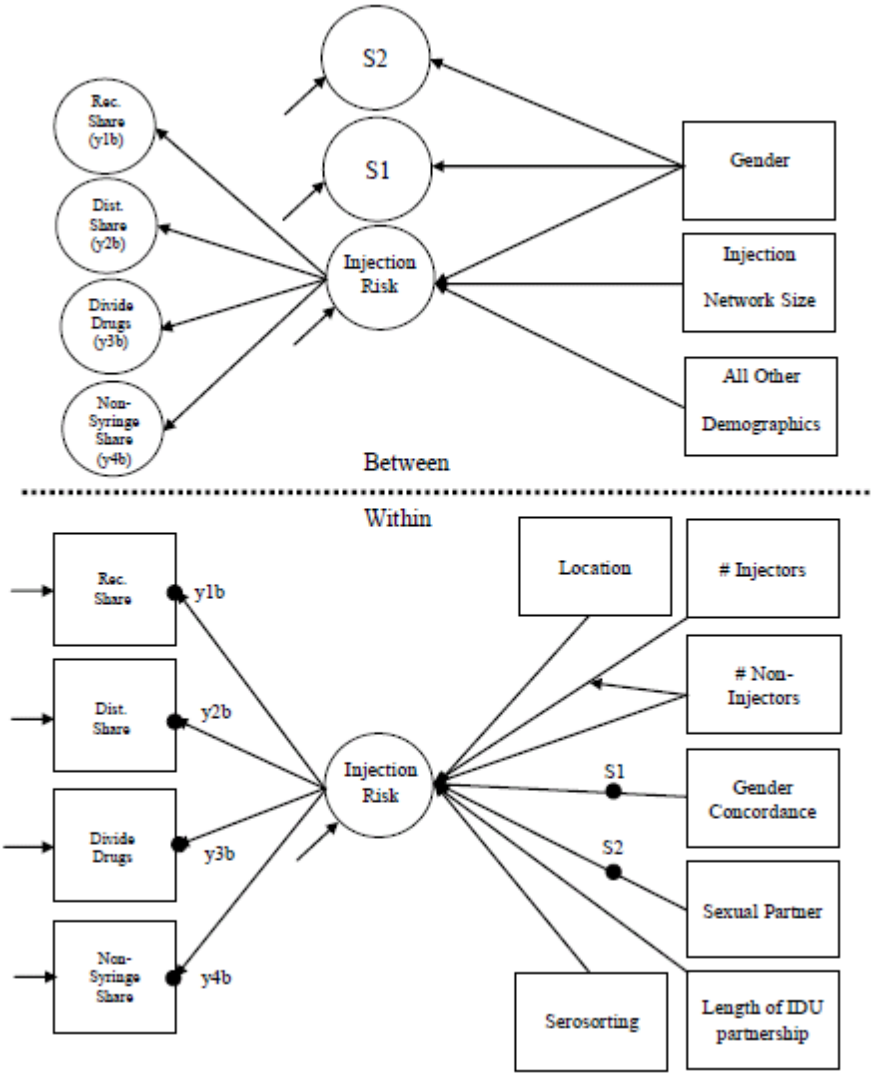
1 Yes
2 No
-8 Refuse to Answer

Appendix B. Modeling Steps

Table 7. Modeling Steps and Freed Parameters

	Freed Paramaters
Model 2	Freed factor loadings across less
Model 3	Random slope for *gender concordance* (*S1*)
Model 4	Random slope for *sexual partnership* (*S2*)
Model 5	*Gender* as a predictor of *S1* (*gender* → *S1*) and *S2* (*gender* → *S2*)

Figure 3. Model with Modeling Steps



Appendix C. Comparison of Cases with Missing Data on All Dependent Variables

Table 8. Comparison of Cases with Missing data on All Dependent Variables

Variable	Non-Missing	Missing	Significance Test
	n (%)	n (%)	
Gender			
Male	1271 (92.4)	104 (7.6)	**11.34**
Female	592 (96.4)	22 (3.6)	
Race			
Black	848 (94.7)	47 (5.3)	3.22
Race - Other/Multiple	385 (91.7)	35 (8.3)	3.58
Hispanic			
Yes	419 (89.0)	52 (11.0)	**23.03**
No	1444 (95.1)	74 (4.9)	
Homeless			
Yes	983 (93.5)	68 (6.5)	0.07
No	880 (93.8)	58 (6.2)	
	M (SD)	M (SD)	
Network Size	8.04 (18.4)	6.87 (10.9)	0.70
Frequency Crack/Cocaine	8.11 (10.6)	5.09 (8.7)	**3.15**
Frequency Heroin/Opioids	14.41 (13.3)	11.64 (13.3)	2.29
Frequency of Injection	22.76 (34.1)	19.56 (23.5)	1.03
Injection Duration	19.07 (13.1)	18.59 (12.8)	0.11

Note. Significance test is a chi-square value for categorical and t-test value for continuous variables.

Appendix D. Association with Missing on any independent variable

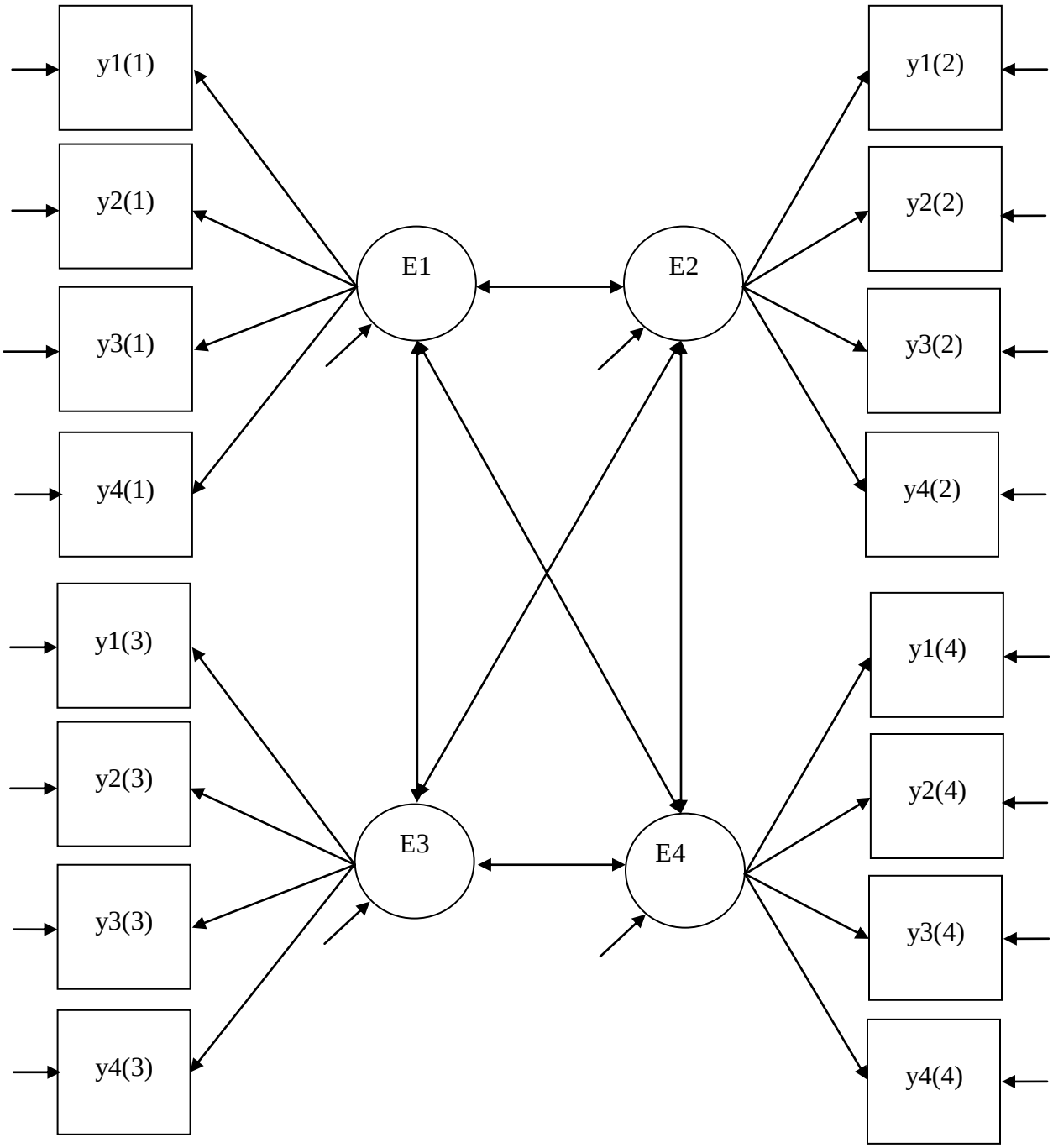
Table 9. Association with Missing on any independent variable

Variable	Statistic	
	χ^2	t
Inject at home	2.13	
Most Common Location	1.71	
# of injectors		-0.64
# of non-injectors		0.52
Gender Concordant	**10.30**	
Sexual Partner	1.47	
HIV Concordance		
Unknown Concordance	2.37	
Concordant	2.13	
Partnership Length		
New Partner	**11.24**	
Second quartile	3.83	
Third quartile	1.62	
Fourth quartile	0.08	
Female	2.79	
Age		-1.80
Race		
Black	0.55	
Race - Other/Multiple	4.16	
Hispanic	3.35	
Homeless	3.87	
Injection Network Size		1.22
Drug Use		
Frequency of Crack/Cocaine		1.55
Frequency of Heroin/Opioids		2.43
Frequency of Injection		1.43
Injection Duration		2.59
Receptive Sharing		1.40
Distributive Sharing		0.23
Divide Drugs		0.01
Share other equipment		1.96

Note. Bold values indicate significant value after controlling for false discovery rate using Benjamini Hochberg correction. Statistical tests did not take into account the clustered nature of the data but this should only bias standard errors toward increased likelihood to reject the null hypothesis.

Appendix E. Four Factor Model

Figure 4. Four Factor Model



Appendix F. Model fit using WLSMV Estimator

Table 10. Model fit using WLSMV Estimator

	Model 1	Model 2
Model Fit Statistics		
χ^2	**113.49**, p = 0.035	**107.839**, p = 0.030
RMSEA	0.013	0.013
CFI	0.975	0.974
TLI	0.966	0.964
Parameters		
Within		
Factor Loadings		
Receptive Sharing	1.00	1.00
Distributive Sharing	**1.41 (0.25)**	**1.68 (0.37)**
Divide Drugs	**1.41 (0.26)**	**1.53 (0.31)**
Share other equipment	**0.96 (0.16)**	**1.01 (0.18)**
Path Coefficients		
Inject at home	-0.15 (0.15)	-0.14 (0.14)
Location is Common Location	-0.46 (0.24)	-0.43 (0.22)
Missing	-0.11 (0.26)	-0.07 (0.40)
# of people injecting	0.04 (0.03)	0.04 (0.02)
# non-injectors using drugs	**0.11 (0.03)**	**0.11 (0.03)**
# of injectors * # of non-injectors	0.00 (0.01)	0.00 (0.01)
Gender Concordance	0.22 (0.15)	0.21 (0.14)
Missing	-0.07 (0.43)	-0.07 (0.40)
Sexual Partner	**1.31 (0.18)**	**1.23 (0.18)**
HIV Concordance		
Unknown Concordance	-0.18 (0.61)	-0.16 (0.57)
Concordant	-0.32 (0.61)	-0.29 (0.57)
Missing	-0.09 (0.60)	-0.08 (0.56)
Partnership Length		
New Partner	**-0.96 (0.31)**	**-0.89 (0.29)**
First Quartile (Reference)		
Second quartile	0.27 (0.19)	0.25 (0.18)
Third quartile	0.31 (0.20)	0.29 (0.19)
Fourth quartile	0.24 (0.21)	0.22 (0.19)
Residual Variance – Within		
Injection Risk Behavior (Latent)	**1.32 (0.27)**	**1.16 (0.24)**

Table 10 (cont'd)

Between		
Factor Loadings		
Rec. Share	1.00	1.00
Dist. Share	**1.41 (0.25)**	**1.34 (0.27)**
Divide Drugs	**1.41 (0.26)**	**1.32 (0.26)**
Non-syringe sharing	**0.96 (0.16)**	**0.94 (0.16)**
Thresholds		
Rec. Share		
Shared - used bleach	0.71 (1.14)	0.69 (1.11)
Shared - did not use bleach	2.24 (1.15)	2.16 (1.11)
Dist. Share	2.50 (1.40)	2.72 (1.54)
Divide Drugs	**4.13 (1.67)**	**4.18 (1.71)**
Non-syringe sharing	**2.67 (1.23)**	**2.64 (1.22)**
Path Coefficients		
Female	0.37 (0.21)	0.38 (0.22)
Age	-0.03 (0.02)	-0.03 (0.02)
Race		
Black	**0.71 (0.26)**	**0.72 (0.27)**
Race - Other/Multiple	0.36 (0.34)	0.37 (0.35)
Hispanic	0.12 (0.32)	0.12 (0.34)
Homeless	**1.25 (0.23)**	**1.32 (0.24)**
Injection Network Size	0.00 (0.02)	0.00 (0.01)
Drug Use		
Frequency of Crack/Cocaine	-0.01 (0.01)	-0.01 (0.01)
Frequency of Heroin/Opioids	**-0.03 (0.01)**	**-0.03 (0.01)**
Frequency of Injection	-0.00 (0.00)	-0.00 (0.00)
Injection Duration	**0.03 (0.01)**	**0.03 (0.01)**
Residual Variance – Between		
Injection Risk (Latent)	**3.90 (0.84)**	**4.33 (0.96)**

Note. Bold parameters indicate $p < 0.05$ and standard errors are presented in parentheses. RMSEA = root mean squared error of approximation, CFI = Comparative Fit Index, and TLI = Tucker Lewis Index. Chi-square statistics are not directly comparable when using WLSMV estiamtion.

Appendix G. Null (Intercept Only) Model

Table 11. Null Model

Parameters	
Within	
Factor Loadings	
Receptive Sharing	1.00
Distributive Sharing	**1.17 (0.19)**
Divide Drugs	**0.68 (0.11)**
Share other equipment	**0.50 (0.07)**
Residual Variance – Within	
Injection Risk (Latent)	**2.21 (0.56)**
Between	
Factor Loadings	
Rec. Share	1.00
Dist. Share	**1.17 (0.19)**
Divide Drugs	**0.68 (0.11)**
Non-syringe sharing	**0.50 (0.07)**
Thresholds	
Rec. Share	
Shared - used bleach	**3.45 (0.36)**
Shared - did not use bleach	**5.42 (0.57)**
Dist. Share	**3.70 (0.49)**
Divide Drugs	**1.12 (0.15)**
Non-syringe sharing	**-0.14 (0.11)**
Residual Variance – Between	
Injection Risk (Latent)	**14.45 (3.05)**
ICC	0.13

Note. ICC indicates the intraclass correlation coefficient or (Within Variance / Within + Between Variance)

REFERENCES

References

Abdul-Quader, A. S., Feelemyer, J., Modi, S., Stein, E. S., Briceno, A., Semaan, S., . . . Des Jarlais, D. C. (2013). Effectiveness of Structural-Level Needle/Syringe Programs to Reduce HCV and HIV Infection Among People Who Inject Drugs: A Systematic Review. *AIDS and Behavior*, 1-15.

Aceijas, C., Hickman, M., Donoghoe, M. C., Burrows, D., & Stuikyte, R. (2007). Access and coverage of needle and syringe programmes (NSP) in Central and Eastern Europe and Central Asia*. *Addiction, 102*(8), 1244-1250.

Aceijas, C., & Rhodes, T. (2007). Global estimates of prevalence of HCV infection among injecting drug users. *International Journal of Drug Policy, 18*(5), 352-358.

Aitken, C. K., Moore, D., Higgs, P., Kelsall, J., & Kerger, M. (2002). The impact of a police crackdown on a street drug scene: evidence from the street. *International Journal of Drug Policy, 13*(3), 193-202.

Alter, M. J. (2002). Prevention of spread of hepatitis C. *Hepatology, 36*(5B), s93-s98.

Alter, M. J. (2006). Epidemiology of viral hepatitis and HIV co-infection. *Journal of Hepatology, 44, Supplement 1*(0), S6-S9. doi: 10.1016/j.jhep.2005.11.004

Alter, M. J. (2007). Epidemiology of hepatitis C virus infection. *World Journal of Gastroenterology, 13*(17), 2436-2441.

Amaro, H. (1995). Love, sex, and power: Considering women's realities in HIV prevention. *American Psychologist, 50*(6), 437-447.

Amon, J. J., Garfein, R. S., Ahdieh-Grant, L., Armstrong, G. L., Ouellet, L. J., Latka, M. H., . . . Kerndt, P. (2008). Prevalence of Hepatitis C Virus Infection among Injection Drug Users in the United States, 1994-2004. *Clinical Infectious Diseases-Chicago-, 46*(12), 1852-1858.

Averhoff, F. M., Glass, N., & Holtzman, D. (2012). Global burden of hepatitis C: considerations for healthcare providers in the United States. *Clinical Infectious Diseases, 55*(suppl 1), S10-S15.

Bailey, S. L., Ouellet, L. J., Mackesy-Amiti, M. E., Golub, E. T., Hagan, H., Hudson, S. M., . . . Garfein, R. S. (2007). Perceived risk, peer influences, and injection partner type predict receptive syringe sharing among young adult injection drug users in five US cities. *Drug and Alcohol Dependence, 91*, S18-S29.

Barnard, M. A. (1993). Needle sharing in context: patterns of sharing among men and women injectors and HIV risks. *Addiction, 88*(6), 805-812.

Barrio, G., Bravo, M. J., Brugal, M. T., Díez, M., Regidor, E., Belza, M. J., & de la Fuente, L. (2012). Harm reduction interventions for drug injectors or heroin users in Spain: expanding coverage as the storm abates. *Addiction, 107*(6), 1111-1122.

Bastos, L. S., Pinho, A. A., Codeço, C., & Bastos, F. I. (2012). *Binary regression analysis with network structure of respondent-driven sampling data*. arXIV. Retrieved from http://arxiv.org/abs/1206.5681

Beletsky, L., Heller, D., Jenness, S. M., Neaigus, A., Gelpi-Acosta, C., & Hagan, H. (2014). Syringe access, syringe sharing, and police encounters among people who inject drugs in New York City: A community-level perspective. *International Journal of Drug Policy, 25*(1), 105-111.

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin, 107*(2), 238-246.

Bluthenthal, R. N., Anderson, R., Flynn, N. M., & Kral, A. H. (2007). Higher syringe coverage is associated with lower odds of HIV risk and does not increase unsafe syringe disposal among syringe exchange program clients. *Drug and Alcohol Dependence, 89*(2-3), 214-222.

Bonacini, M., Louie, S., Bzowej, N., & Wohl, A. R. (2004). Survival in patients with HIV infection and viral hepatitis B or C: a cohort study. *AIDS, 18*(15), 2039-2045.

Bontell, I., & Strathdee, S. A. (2014). Women, drugs and HIV. *International Journal of Drug Policy*. doi: 10.1016/j.drugpo.2014.09.003

Bourgois, P., Prince, B., & Moss, A. (2004). The everyday violence of hepatitis C among young women who inject drugs in San Francisco. *Human Organization, 63*(3), 253-264.

Bourgois, P., & Schonberg, J. (2009). Righteous Dopefiend: University of California Press.

Bovaird, J. A. (2007). Multilevel structural equation models for contextual factors. In T. D. Little, J. A. Bovaird & N. A. Card (Eds.), *Modeling contextual effects in longitudinal studies* (pp. 149-182). Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

Brady, J. E., Friedman, S. R., Cooper, H., Flom, P. L., Tempalski, B., & Gostnell, K. (2008). Estimating the Prevalence of Injection Drug Users in the US and in Large US Metropolitan Areas from 1992 to 2002. *Journal of Urban Health, 85*(3), 323-351.

Brewer, D. D., & Garrett, S. B. (2001). Evaluation of interviewing techniques to enhance recall of sexual and drug injection partners. *Sexually transmitted diseases, 28*(11), 666-677.

Brewer, D. D., Garrett, S. B., & Kulasingam, S. (1999). Forgetting as a cause of incomplete reporting of sexual and drug injection partners. *Sexually transmitted diseases, 26*(3), 166-176.

Broz, D., Pham, H., Spiller, M., Wejnert, C., Le, B., Neaigus, A., & Paz-Bailey, G. (2014). Prevalence of HIV infection and risk behaviors among younger and older injecting drug users in the United States, 2009. *AIDS and Behavior, 18*(3), 284-296.

Bruneau, J., Daniel, M., Abrahamowicz, M., Zang, G., Lamothe, F., & Vincelette, J. (2011). Trends in human immunodeficiency virus incidence and risk behavior among injection drug users in Montreal, Canada: A 16-year longitudinal study. *American Journal of Epidemiology, 173*(9), 1049-1058.

Bruneau, J., Roy, É., Arruda, N., Zang, G., & Jutras-Aswad, D. (2012). The rising prevalence of prescription opioid injection and its association with hepatitis C incidence among street-drug users. *Addiction, 107*(7), 1318-1327.

Bryant, J., Paquette, D., & Wilson, H. (2012). Syringe Coverage in an Australian Setting: Does a High Level of Syringe Coverage Moderate Syringe Sharing Behaviour? *AIDS and Behavior, 16*(5), 1156-1163.

Burris, S., Anderson, E., Craigg, A., Davis, C., & Case, P. (2011). Racial disparities in injection-related HIV: A case study of toxic law. *Temple Law Review, 82*(5), 1263-1307.

Burrows, D. (2006). Rethinking coverage of needle exchange programs. *Substance use & misuse, 41*(6-7), 1045-1048.

Burt, R. D., Thiede, H., & Hagan, H. (2009). Serosorting for hepatitis C status in the sharing of injection equipment among Seattle area injection drug users. *Drug and Alcohol Dependence, 105*(3), 215-220. doi: http://dx.doi.org/10.1016/j.drugalcdep.2009.07.005

Carlson, R. G. (2000). Shooting galleries, dope houses, and injection doctors: examining the social ecology of HIV risk behaviors among drug injectors in Dayton, Ohio. *Human Organization, 59*(3), 325-333.

Cassin, S., Geoghegan, T., & Cox, G. (1998). Young injectors: a comparative analysis of risk behaviour. *Irish journal of medical science, 167*(4), 234-237.

CDC. (2013). *HIV Surveillance Report, 2011*. Retrieved from http://www.cdc.gov/hiv/surveillance/resources/reports/2008report/#1.

Celentano, D. D., Vlahov, D., Cohn, S., Anthony, J. C., Solomon, L., & Nelson, K. E. (1991). Risk factors for shooting gallery use and cessation among intravenous drug users. *American Journal of Public Health, 81*(10), 1291-1295.

Cepeda, J. A., Odinokova, V. A., Heimer, R., Grau, L. E., Lyubimova, A., Safiullina, L., . . . Niccolai, L. M. (2011). Drug network characteristics and HIV risk among injection drug users in Russia: The roles of trust, size, and stability. *AIDS and Behavior*, 1-8.

Chaisson, R. E., Bacchetti, P., Osmond, D., Brodie, B., Sande, M. A., & Moss, A. R. (1989). Cocaine use and HIV infection in intravenous drug users in San Francisco. *Jama, 261*(4), 561-565.

Chaisson, R. E., Moss, A. R., Onishi, R., Osmond, D., & Carlson, J. R. (1987). Human immunodeficiency virus infection in heterosexual intravenous drug users in San Francisco. *American Journal of Public Health, 77*(2), 169-172.

Chen, Y.-H., McFarland, W., & Raymond, H. F. (2014). Risk behaviors for HIV in sexual partnerships of San Francisco injection drug users. *AIDS Care, 26*(5), 554-558.

Chitwood, D. D., Griffin, D. K., Comerford, M., Page, J., Trapido, E. J., Lai, S., & McCoy, C. B. (1995). Risk factors for HIV-1 seroconversion among injection drug users: a case-control study. *American Journal of Public Health, 85*(11), 1538-1542.

Chitwood, D. D., McCoy, C. B., Inciardi, J. A., McBride, D. C., Comerford, M., Trapido, E., . . . Fletcher, M. A. (1990). HIV seropositivity of needles from shooting galleries in south Florida. *American Journal of Public Health, 80*(2), 150-152.

Choi, S. Y., Cheung, Y. W., & Chen, K. (2006). Gender and HIV risk behavior among intravenous drug users in Sichuan Province, China. *Social Science & Medicine, 62*(7), 1672-1684.

Clatts, M. C., Colón-López, V., Giang, L. M., & Goldsamt, L. A. (2010). Prevalence and incidence of HCV infection among Vietnam heroin users with recent onset of injection. *Journal of Urban Health, 87*(2), 278-291.

Clements-Nolle, K., Marx, R., Guzman, R., & Katz, M. (2001). HIV prevalence, risk behaviors, health care use, and mental health status of transgender persons: Implications for public health intervention. *American Journal of Public Health, 91*(6), 915-921.

Colón, H. M., Robles, R. R., Deren, S., Sahai, H., Finlinson, H. A., Andía, J., . . . Oliver-Vélez, D. (2001). Between-city variation in frequency of injection among Puerto Rican injection drug users: East Harlem, New York, and Bayamon, Puerto Rico. *Journal of Acquired Immune Deficiency Syndromes (1999), 27*(4), 405-413.

Compton, W. M., Normand, J., & Lambert, E. (2009). Sexual Acquisition and Transmission of HIV Cooperative Agreement Program (SATHCAP), July 2009. *Journal of Urban Health, 86*, 1-4.

Compton, W. M., & Volkow, N. D. (2006). Major increases in opioid analgesic abuse in the United States: concerns and strategies. *Drug and Alcohol Dependence, 81*(2), 103-107.

Cooper, H., Des Jarlais, D. C., Ross, Z., Tempalski, B., Bossak, B., & Friedman, S. R. (2011). Spatial Access to Syringe Exchange Programs and Pharmacies Selling Over-the-Counter Syringes as Predictors of Drug Injectors' Use of Sterile Syringes. *American Journal of Public Health, 101*(6), 1118-1125.

Cooper, H., Des Jarlais, D. C., Ross, Z., Tempalski, B., Bossak, B. H., & Friedman, S. R. (2012). Spatial access to sterile syringes and the odds of injecting with an unsterile syringe among injectors: A longitudinal multilevel study. *Journal of Urban Health, 89*(4), 678-696.

Cooper, H., Des Jarlais, D. C., Tempalski, B., Bossak, B. H., Ross, Z., & Friedman, S. R. (2012). Drug-related arrest rates and spatial access to syringe exchange programs in New York City health districts: Combined effects on the risk of injection-related infections among injectors. *Health & Place, 18*(2), 218-228.

Cooper, H., Moore, L., Gruskin, S., & Krieger, N. (2005). The impact of a police drug crackdown on drug injectors' ability to practice harm reduction: a qualitative study. *Social Science & Medicine, 61*(3), 673-684.

Cox, J., Morissette, C., De, P., Tremblay, C., Allard, R., Graves, L., . . . Roy, E. (2009). Access to sterile injecting equipment is more important than awareness of HCV status for injection risk behaviors among drug users. *Substance use & misuse, 44*(4), 548-568.

Craib, K. J. P., Spittal, P. M., Wood, E., Laliberte, N., Hogg, R. S., Li, K., . . . Schechter, M. T. (2003). Risk factors for elevated HIV incidence among Aboriginal injection drug users in Vancouver. *Canadian Medical Association Journal, 168*(1), 19-24.

Crofts, N., Hopper, J., Bowden, D., Breschkin, A., Milner, R., & Locarnini, S. (1993). Hepatitis C virus infection among a cohort of Victorian injecting drug users. *The Medical Journal of Australia, 159*(4), 237-241.

Crosby, R. A. (2013). State of condom use in HIV prevention science and practice. *Current HIV/AIDS Reports, 10*(1), 59-64.

Cruz, M. F., Mantsios, A., Ramos, R., Case, P., Brouwer, K. C., Ramos, M. E., . . . Strathdee, S. A. (2007). A qualitative exploration of gender in the context of injection drug use in two US–Mexico border cities. *AIDS and Behavior, 11*(2), 253-262.

Curtis, R., Friedman, S. R., Neaigus, A., Jose, B., Goldstein, M., & Ildefonso, G. (1995). Street-level drug markets: network structure and HIV risk. *Social Networks, 17*(3-4), 229-249.

Darke, S., Hall, W., & Carless, J. (1990). Drug use, injecting practices and sexual behaviour of opioid users in Sydney, Australia. *British Journal of Addiction, 85*(12), 1603-1609.

Darke, S., Hall, W., Heather, N., Ward, J., & Wodak, A. (1991). The reliability and validity of a scale to measure HIV risk-taking behaviour among intravenous drug users. *AIDS, 5*, 181-185.

Darke, S., Hall, W., Wodak, A., Heather, N., & Ward, J. (1992). Development and validation of a multi-dimensional instrument for assessing outeome of treatment among opiate users: the Opiate Treatment Index. *British Journal of Addiction, 87*, 733-742.

Davey-Rothwell, M. A., & Latkin, C. A. (2007). Gender differences in social network influence among injection drug users: Perceived norms and needle sharing. *Journal of Urban Health, 84*(5), 691-703.

De, P., Cox, J., Boivin, J. F., Platt, R. W., & Jolly, A. M. (2007). The importance of social networks in their association to drug equipment sharing among injection drug users: a review. *Addiction, 102*(11), 1730-1739.

De, P., Jolly, A. M., Cox, J., & Boivin, J. F. (2006). Characterizing the Drug-injecting Networks of Cocaine and Heroin Injectors in Montreal. *Canadian Journal of Public Health, 97*(3), 207-209.

Degenhardt, L., Mathers, B. M., Vickerman, P., Rhodes, T., Latkin, C., & Hickman, M. (2010). Prevention of HIV infection for people who inject drugs: why individual, structural, and combination approaches are needed. *The Lancet, 376*(9737), 285-301.

Denis, F., Adjide, C. C., Rogez, S., Delpeyroux, C., Rogez, J. P., & Weinbreck, P. (1997). Seroprevalence of HBV, HCV and HDV hepatitis markers in 500 patients infected with the human immunodeficiency virus. *Pathologie-biologie, 45*(9), 701-708.

Des Jarlais, D. C., Feelemyer, J. P., Modi, S. N., Abdul-Quader, A., & Hagan, H. (2013). High coverage needle/syringe programs for people who inject drugs in low and middle income countries: a systematic review. *BMC Public Health, 13*(53), 1-13.

Des Jarlais, D. C., Marmor, M., Friedmann, P., Titus, S., Aviles, E., Deren, S., . . . Monterroso, E. (2000). HIV incidence among injection drug users in New York City, 1992-1997: evidence for a declining epidemic. *American Journal of Public Health, 90*(3), 352–359.

Des Jarlais, D. C., McKnight, C., Goldblatt, C., & Purchase, D. (2009). Doing harm reduction better: syringe exchange in the United States. *Addiction, 104*, 1441–1446.

Des Jarlais, D. C., & Semaan, S. (2008). HIV prevention for injecting drug users: the first 25 years and counting. *Psychosomatic Medicine, 70*(5), 606-611.

Devillé, W., van Ameijden, E. J., & Wolffers, I. (2001). Risk factors of HIV infection and needle sharing among injecting drug users in Ho Chi Minh City, Viet Nam. *Journal of Substance Abuse, 13*(1), 45-58.

Diaz, T., Des Jarlais, D. C., Vlahov, D., Perlis, T. E., Edwards, V., Friedman, S. R., . . . Monterroso, E. R. (2001). Factors associated with prevalent hepatitis C: differences among young adult injection drug users in lower and upper Manhattan, New York City. *American Journal of Public Health, 91*(1), 23–30.

Dickson-Gomez, J., Weeks, M., Martinez, M., & Convey, M. (2006). Times and places: Process evaluation of a peer-led HIV prevention intervention. *Substance use & misuse, 41*(5), 669-690.

Donoghoe, M. C., & Wodak, A. (1998). Health and social consequences of injecting drug use. In A. Bell, D. C. Des Jarlais & G. V. Stimson (Eds.), *Drug Injecting And HIV Infection: Global Dimensions and Local Responses*. London: UCL Press.

Dwyer, R., Fraser, S., & Treloar, C. (2011). Doing things together? Analysis of health education materials to inform hepatitis C prevention among couples. *Addiction Research & Theory, 19*(4), 352-361.

Ehrhardt, A. A., Exner, T. M., Hoffman, S., Silberman, I., Leu, C. S., Miller, S., & Levin, B. (2002). A gender-specific HIV/STD risk reduction intervention for women in a health care setting: short-and long-term results of a randomized clinical trial. *AIDS Care, 14*(2), 147-161.

El-Bassel, N., Gilbert, L., Wu, E., Witte, S. S., Chang, M., Hill, J., & Remien, R. H. (2011). Couple-based HIV prevention for low-income drug users from New York City: a randomized controlled trial to reduce dual risks. *JAIDS Journal of Acquired Immune Deficiency Syndromes, 58*(2), 198-206.

El-Bassel, N., Shaw, S. A., Dasgupta, A., & Strathdee, S. A. (2014). People Who Inject Drugs in Intimate Relationships: It Takes Two to Combat HIV. *Current HIV/AIDS Reports*, 1-7.

El-Bassel, N., Wechsberg, W. M., & Shaw, S. A. (2012). Dual HIV risk and vulnerabilities among women who use or inject drugs: no single prevention strategy is the answer. *Current opinion in HIV and AIDS, 7*(4), 326-331.

El-Bassel, N., Witte, S. S., Gilbert, L., Sormanti, M., Moreno, C., Pereira, L., . . . Steinglass, P. (2001). HIV prevention for intimate couples: A relationship-based model. *Families, Systems, & Health, 19*(4), 379-395.

El-Bassel, N., Witte, S. S., Gilbert, L., Wu, E., Chang, M., Hill, J., & Steinglass, P. (2005). Long-term effects of an HIV/STI sexual risk reduction intervention for heterosexual couples. *AIDS and Behavior, 9*(1), 1-13.

El-Serag, H. B., Giordano, T. P., Kramer, J., Richardson, P., & Souchek, J. (2005). Survival in hepatitis C and HIV co-infection: a cohort study of hospitalized veterans. *Clinical Gastroenterology and Hepatology, 3*(2), 175-183.

Evans, J. L., Hahn, J. A., Page-Shafer, K., Lum, P. J., Stein, E. S., Davidson, P. J., & Moss, A. R. (2003). Gender differences in sexual and injection risk behavior among active young injection drug users in San Francisco (the UFO Study). *Journal of Urban Health, 80*(1), 137-146.

Fendrich, M., Smith, E. V., Pollack, L. M., & Mackesy-Amiti, M. E. (2009). Measuring sexual risk for HIV: a Rasch scaling approach. *Archives of Sexual Behavior, 38*(6), 922-935.

Finlinson, H. A., Colan, H. M., Negran, J., & Robles, R. R. (2008). Designing an experimental HIV/HCV intervention to promote the safe re-use of drug preparation materials by injection drug users in Puerto Rico. *Harm Reduction Journal, 5*(14), 1-5.

Frajzyngier, V., Neaigus, A., Gyarmathy, V. A., Miller, M., & Friedman, S. R. (2007). Gender differences in injection risk behaviors at the first injection episode. *Drug and Alcohol Dependence, 89*(2), 145-152.

Frey, F. W., Abrutyn, E., Metzger, D. S., Woody, G. E., O'Brien, C. P., & Trusiani, P. (1995). Focal networks and HIV risk among African-American male intravenous drug users. *NIDA research monograph, 151*, 89-108.

Friedman, S. R., Jose, B., Deren, S., Des Jarlais, D. C., & Neaigus, A. (1995). Risk factors for human immunodeficiency virus seroconversion among out-of-treatment drug injectors in high and low seroprevalence cities. *American Journal of Epidemiology, 142*(8), 864-874.

Friedman, S. R., Sandoval, M., Mateu-Gelabert, P., Rossi, D., Gwadz, M., Dombrowski, K., . . . Perlman, D. (2013). Theory, measurement and hard times: some issues for HIV/AIDS research. *AIDS and Behavior, 17*(6), 1915-1925.

Fry, C. L., & Lintzeris, N. (2003). Psychometric properties of the Blood-borne Virus Transmission Risk Assessment Questionnaire (BBV-TRAQ). *Addiction, 98*(2), 171-178.

Galea, S., & Link, B. G. (2013). Six paths for the future of social epidemiology. *American Journal of Epidemiology, 178*(6), 843-849.

Gardiner, J. C., Luo, Z., & Roman, L. A. (2009). Fixed effects, random effects and GEE: what are the differences? *Statistics in medicine, 28*(2), 221-239.

Garfein, R. S., Doherty, M. C., Monterroso, E. R., Thomas, D. L., Nelson, K. E., & Vlahov, D. (1998). Prevalence and incidence of hepatitis C virus infection among young adult injection drug users. *JAIDS Journal of Acquired Immune Deficiency Syndromes, 18*, S11-S19.

Garfein, R. S., Golub, E. T., Greenberg, A. E., Hagan, H., Hanson, D. L., Hudson, S. M., . . . Purcell, D. W. (2007). A peer-education intervention to reduce injection risk behaviors for HIV and hepatitis C virus infection in young injection drug users. *AIDS, 21*(14), 1923-1932.

Geiser, C., Bishop, J., Lockhart, G., Shiffman, S., & Grenard, J. L. (2013). Analyzing latent state-trait and multiple-indicator latent growth curve models as multilevel structural equation models. *Frontiers in Psychology, 4*, 1-23. doi: 10.3389/fpsyg.2013.00975

Gile, K. J., & Handcock, M. S. (2010). Respondent Driven Sampling: An Assessment of Current Methodology. *Sociological Methodology, 40*(1), 285-327.

Gillies, M., Palmateer, N., Hutchinson, S., Ahmed, S., Taylor, A., & Goldberg, D. (2010). The provision of non-needle/syringe drug injecting paraphernalia in the primary prevention of HCV among IDU: a systematic review. *BMC Public Health, 10*(721), 1-16.

Golden, R. E., Collins, C. B., Cunningham, S. D., Newman, E. N., & Card, J. J. (2013). Overview of Structural Interventions to Decrease Injection Drug-Use Risk *Best Evidence Structural Interventions for HIV Prevention* (pp. 41-121): Springer.

Goldstein, H., Browne, W., & Rasbash, J. (2002). Multilevel modelling of medical data. *Statistics in medicine, 21*(21), 3291-3315.

Gollub, E. L., Rey, D., Obadia, Y., Moatti, J.-P., & Group, M. S. (1998). Gender differences in risk behaviors among HIV+ persons with an IDU history: The link between partner characteristics and women's higher drug-sex risks. *Sexually transmitted diseases, 25*(9), 483-488.

Golub, E. T., Strathdee, S. A., Bailey, S. L., Hagan, H., Latka, M. H., Hudson, S. M., & Garfein, R. S. (2007). Distributive syringe sharing among young adult injection drug users in five US cities. *Drug and Alcohol Dependence, 91*, S30-S38.

Gossop, M., Griffiths, P., Powis, B., & Strang, J. (1992). Severity of dependence and route of administration of heroin, cocaine and amphetamines. *British Journal of Addiction, 87*(11), 1527-1536.

Graham, J. W. (2009). Missing data analysis: Making it work in the real world. *Annual Review of Psychology, 60*, 549-576.

Grau, L. E., Bluthenthal, R. N., Marshall, P., Singer, M., & Heimer, R. (2005). Psychosocial and behavioral differences among drug injectors who use and do not use syringe exchange programs. *AIDS and Behavior, 9*(4), 495-504.

Grebely, J., Raffa, J. D., Lai, C., Krajden, M., Conway, B., & Tyndall, M. W. (2007). Factors associated with spontaneous clearance of hepatitis C virus among illicit drug users. *Canadian journal of gastroenterology, 21*(7), 447-451.

Grund, J. P. C., Friedman, S. R., Stern, L. S., Jose, B., Neaigus, A., Curtis, R., & Des Jarlais, D. C. (1996). Syringe-mediated drug sharing among injecting drug users: Patterns, social context and implications for transmission of blood-borne pathogens. *Social Science & Medicine, 42*(5), 691-703.

Gyarmathy, V. A., Li, N., Tobin, K., Hoffman, I. F., Sokolov, N., Levchenko, J., . . . Latkin, C. (2010). Injecting equipment sharing in Russian drug injecting dyads. *AIDS and Behavior, 14*(1), 141-151.

Hagan, H., Campbell, J., Thiede, H., Strathdee, S., Ouellet, L., Kapadia, F., . . . Garfein, R. S. (2006). Self-reported hepatitis C virus antibody status and risk behavior in young injectors. *Public Health Reports, 121*(6), 710-719.

Hagan, H., Des Jarlais, D. C., Stern, R., Lelutiu-Weinberger, C., Scheinmann, R., Strauss, S., & Flom, P. L. (2007). HCV synthesis project: preliminary analyses of HCV prevalence in relation to age and duration of injection. *International Journal of Drug Policy, 18*(5), 341-351.

Hagan, H., Pouget, E. R., & Des Jarlais, D. C. (2011). A systematic review and meta-analysis of interventions to prevent hepatitis C virus infection in people who inject drugs. *Journal of Infectious Diseases, 204*(1), 74-83.

Hagan, H., Pouget, E. R., Des Jarlais, D. C., & Lelutiu-Weinberger, C. (2008). Meta-regression of hepatitis C virus infection in relation to time since onset of illicit drug injection: the influence of time and place. *American Journal of Epidemiology, 168*(10), 1099-1109.

Hagan, H., Pouget, E. R., Williams, I. T., Garfein, R. L., Strathdee, S. A., Hudson, S. M., . . . Ouellet, L. J. (2010). Attribution of hepatitis C virus seroconversion risk in young injection drug users in 5 US cities. *Journal of Infectious Diseases, 201*(3), 378-385.

Hagan, H., Thiede, H., & Des Jarlais, D. C. (2004). Hepatitis C virus infection among injection drug users: survival analysis of time to seroconversion. *Epidemiology, 15*(5), 543-549.

Hagan, H., Thiede, H., Weiss, N. S., Hopkins, S. G., Duchin, J. S., & Alexander, E. R. (2001). Sharing of drug preparation equipment as a risk factor for hepatitis C. *American Journal of Public Health, 91*, 42-46.

Hahn, J. A., Evans, J. L., Davidson, P. J., Lum, P. J., & Page, K. (2010). Hepatitis C virus risk behaviors within the partnerships of young injecting drug users. *Addiction, 105*(7), 1254-1264.

Hahn, J. A., Page-Shafer, K., Lum, P. J., Bourgois, P., Stein, E., Evans, J. L., . . . Moss, A. R. (2002). Hepatitis C virus seroconversion among young injection drug users: relationships and risks. *Journal of Infectious Diseases, 186*(11), 1558-1564.

Hall, H. I., Song, R., Rhodes, P., Prejean, J., An, Q., Lee, L. M., . . . McKenna, M. T. (2008). Estimation of HIV incidence in the United States. *The Journal of the American Medical Association, 300*(5), 520-529.

Harvey, S. M., Kraft, J. M., West, S. G., Taylor, A. B., Pappas-DeLuca, K. A., & Beckman, L. J. (2008). Effects of a health behavior change model–based HIV/STI prevention intervention on condom use among heterosexual couples: a randomized trial. *Health Education & Behavior, 36*(5), 878-894.

Havens, J. R., Lofwall, M. R., Frost, S., Oser, C. B., Leukefeld, C. G., & Crosby, R. A. (2013). Individual and Network Factors Associated With Prevalent Hepatitis C Infection Among Rural Appalachian Injection Drug Users. *American Journal of Public Health, 103*(1), e44-e52.

Hawkins, W. E., Latkin, C., Hawkins, M. J., & Chowdury, D. (1998). Depressive symptoms and HIV-risk behavior in inner-city users of drug injections. *Psychological reports, 82*(1), 137-138.

Heckathorn, D. D. (1997). Respondent-driven sampling: a new approach to the study of hidden populations. *Social Problems*, 174-199.

Heckathorn, D. D., Broadhead, R. S., Anthony, D. L., & Weakliem, D. L. (1999). AIDS and social networks: HIV prevention through network mobilization. *Sociological focus, 32*(2), 159-179.

Heckathorn, D. D., Semaan, S., Broadhead, R. S., & Hughes, J. J. (2002). Extensions of respondent-driven sampling: a new approach to the study of injection drug users aged 18–25. *AIDS and Behavior, 6*(1), 55-67.

Heimer, R. (2008). Community coverage and HIV prevention: assessing metrics for estimating HIV incidence through syringe exchange. *International Journal of Drug Policy, 19*, 65-73.

Hope, V., Hickman, M., Ngui, S., Jones, S., Telfer, M., Bizzarri, M., . . . Parry, J. (2011). Measuring the incidence, prevalence and genetic relatedness of hepatitis C infections among a community recruited sample of injecting drug users, using dried blood spots. *Journal of Viral Hepatitis, 18*(4), 262-270.

Hottes, T. S., Bruneau, J., & Daniel, M. (2011). Gender-Specific Situational Correlates of Syringe Sharing During a Single Injection Episode. *AIDS and Behavior, 15*(1), 75-85.

Hu, F. B., Goldberg, J., Hedeker, D., Flay, B. R., & Pentz, M. A. (1998). Comparison of population-averaged and subject-specific approaches for analyzing repeated binary outcomes. *American Journal of Epidemiology, 147*(7), 694-703.

Hubbard, A. E., Ahern, J., Fleischer, N. L., Van der Laan, M., Lippman, S. A., Jewell, N., . . . Satariano, W. A. (2010). To GEE or not to GEE: comparing population average and mixed models for estimating the associations between neighborhood risk factors and health. *Epidemiology, 21*(4), 467-474.

Hudgins, R., McCusker, J., & Stoddard, A. (1995). Cocaine use and risky injection and sexual behaviors. *Drug and Alcohol Dependence, 37*(1), 7-14.

Huo, D., Bailey, S. L., Garfein, R. S., & Ouellet, L. J. (2005). Changes in the sharing of drug injection equipment among street-recruited injection drug users in Chicago, Illinois, 1994-1996. *Substance use & misuse, 40*(1), 63-76.

Iguchi, M. Y., Ober, A. J., Berry, S. H., Fain, T., Heckathorn, D. D., Gorbach, P. M., . . . Shoptaw, S. (2009). Simultaneous recruitment of drug users and men who have sex with men in the United States and Russia using respondent-driven sampling: sampling methods and implications. *Journal of Urban Health, 86*(1), 5-31.

Iversen, J., Topp, L., Wand, H., & Maher, L. (2012). Individual-level syringe coverage among Needle and Syringe Program attendees in Australia. *Drug and Alcohol Dependence, 122*(3), 195-200.

Iversen, J., Wand, H., Gonnermann, A., & Maher, L. (2010). Gender differences in hepatitis C antibody prevalence and risk behaviours amongst people who inject drugs in Australia 1998–2008. *International Journal of Drug Policy, 21*(6), 471-476.

Jak, S., Oort, F. J., & Dolan, C. V. (2013). A test for cluster bias: Detecting violations of measurement invariance across clusters in multilevel data. *Structural equation modeling: a multidisciplinary journal, 20*(2), 265-282.

Janulis, P. (2014). Improving measurement of injection drug risk behavior using item response theory. *The American journal of drug and alcohol abuse, 40*(2), 143-150. doi: 10.3109/00952990.2013.848212

Jiwatram-Negrón, T., & El-Bassel, N. (2014). Systematic review of couple-based HIV intervention and prevention studies: advantages, gaps, and future directions. *AIDS and Behavior, 18*(10), 1864-1887.

Johnson, M. E., Yep, M. J., Brems, C., Theno, S. A., & Fisher, D. G. (2002). Relationship among gender, depression and needle sharing in a sample of injection drug users. *Psychology of Addictive Behaviors, 16*(4), 338-341.

Johnson, R. A., Gerstein, D. R., Cerbone, F. G., & Brown, J. (2002). HIV risk behaviors in African-American drug injector networks: implications of injection-partner mixing and partnership characteristics. *Addiction, 97*(8), 1011-1024.

Kaplan, E. H., & Heimer, R. (1992). A model-based estimate of HIV infectivity via needle sharing. *JAIDS Journal of Acquired Immune Deficiency Syndromes, 5*(11), 1116-1118.

Kelly, J. A., & Kalichman, S. C. (2002). Behavioral research in HIV/AIDS primary and secondary prevention: recent advances and future directions. *Journal of Consulting and Clinical Psychology, 70*(3), 626-639.

Kendall, C., Kerr, L. R., Gondim, R. C., Werneck, G. L., Macena, R. H. M., Pontes, M. K., . . . McFarland, W. (2008). An empirical comparison of respondent-driven sampling, time location sampling, and snowball sampling for behavioral surveillance in men who have sex with men, Fortaleza, Brazil. *AIDS and Behavior, 12*(1), 97-104.

Kerr, T., Stoltz, J., Tyndall, M., Li, K., Zhang, R., Montaner, J., & Wood, E. (2006). Impact of a medically supervised safer injection facility on community drug use patterns: a before and after study. *BMJ: British Medical Journal, 332*(7535), 220-222.

Kim, A., & Page, K. (2013). Hepatitis C Virus Serosorting in People Who Inject Drugs: Sorting Out the Details. *Journal of Infectious Diseases, 208*(12), 1929-1931.

Kivimäki, M., & Kawachi, I. (2013). Need for more individual-level meta-analyses in social epidemiology: example of job strain and coronary heart disease. *American Journal of Epidemiology, 177*(1), 1-2.

Klein, H., & Levy, J. A. (2003). Shooting gallery users and HIV risk. *Journal of Drug Issues, 33*(3), 751-768.

Knowlton, A., Hua, W., & Latkin, C. (2004). Social support among HIV positive injection drug users: implications to integrated intervention for HIV positives. *AIDS and Behavior, 8*(4), 357-363.

Koester, S., Glanz, J., & Barón, A. (2005). Drug Sharing Among Heroin Networks: Implications for HIV and Hepatitis B and C Prevention. *AIDS and Behavior, 9*(1), 27-39.

Koram, N., Liu, H., Li, J., Luo, J., & Nield, J. (2011). Role of Social Network Dimensions in the Transition to Injection Drug Use: Actions Speak Louder than Words. *AIDS and Behavior*, 1-10.

Kozlov, A. P., Shaboltas, A. V., Toussova, O. V., Verevochkin, S. V., Masse, B. R., Perdue, T., . . . Heimer, R. (2006). HIV incidence and factors associated with HIV acquisition among injection drug users in St Petersburg, Russia. *AIDS, 20*(6), 901-906.

Lakon, C. M., Ennett, S. T., & Norton, E. C. (2006). Mechanisms through which drug, sex partner, and friendship network characteristics relate to risky needle use among high risk youth and young adults. *Social Science & Medicine, 63*(9), 2489-2499.

Latkin, C., Donnell, D., Liu, T., Davey-Rothwell, M., Celentano, D., & Metzger, D. (2013). The dynamic relationship between social norms and behaviors: the results of an HIV prevention network intervention for injection drug users. *Addiction, 108*(5), 934-943.

Latkin, C., Donnell, D., Metzger, D., Sherman, S., Aramrattna, A., Davis-Vogel, A., . . . Perdue, T. (2009). The efficacy of a network intervention to reduce HIV risk behaviors among drug users and risk partners in Chiang Mai, Thailand and Philadelphia, USA. *Social Science & Medicine, 68*(4), 740-748.

Latkin, C., Forman, V., Knowlton, A., & Sherman, S. (2003). Norms, social networks, and HIV-related risk behaviors among urban disadvantaged drug users. *Social Science & Medicine, 56*(3), 465-476.

Latkin, C., German, D., Vlahov, D., & Galea, S. (2013). Neighborhoods and HIV: A social ecological approach to prevention and care. *American Psychologist, 68*(4), 210-224.

Latkin, C., Knowlton, A., & Sherman, S. (2001). Routes of drug administration, differential affiliation, and lifestyle stability among cocaine and opiate users: implications to HIV prevention. *Journal of Substance Abuse, 13*(1), 89-102.

Latkin, C., & Knowlton, A. R. (2005). Micro-social structural approaches to HIV prevention: a social ecological perspective. *AIDS Care, 17*, 102-113.

Latkin, C., Kuramoto, S., Davey-Rothwell, M. A., & Tobin, K. (2010). Social norms, social networks, and HIV risk behavior among injection drug users. *AIDS and Behavior, 14*(5), 1159-1168.

Latkin, C., Mandell, W., Oziemkowska, M., Celentano, D., Vlahov, D., Ensminger, M., & Knowlton, A. (1995). Using social network analysis to study patterns of drug use among urban drug users at high risk for HIV/AIDS. *Drug and Alcohol Dependence, 38*(1), 1-9.

Latkin, C., Mandell, W., Vlahov, D., Knowlton, A., Oziemkowska, M., & Celentano, D. (1995). Personal network characteristics as antecedents to needle-sharing and shooting gallery attendance. *Social Networks, 17*(3-4), 219-228.

Latkin, C., Mandell, W., Vlahov, D., Oziemkowska, M., & Celentano, D. (1996). People and places: behavioral settings and personal network characteristics as correlates of needle sharing. *JAIDS Journal of Acquired Immune Deficiency Syndromes, 13*(3), 273-280.

Latkin, C., Mandell, W., Vlahov, D., Oziemkowska, M., Knowlton, A., & Celentano, D. (1994). My place, your place, and no place: Behavior settings as a risk factor for HIV-related injection practices of drug users in Baltimore, Maryland. *American Journal of Community Psychology, 22*(3), 415-430.

Latkin, C., Sherman, S., & Knowlton, A. (2003). HIV prevention among drug users: Outcome of a network-oriented peer outreach intervention. *Health Psychology, 22*(4), 332-339.

Leigh, B. C. (2002). Alcohol and condom use: a meta-analysis of event-level studies. *Sexually transmitted diseases, 29*(8), 476-482.

Leigh, B. C., & Stall, R. (1993). Substance use and risky sexual behavior for exposure to HIV: Issues in methodology, interpretation, and prevention. *American Psychologist, 48*(10), 1035-1045.

Li, J., Liu, H., Feng, T., & Cai, Y. (2011). Psychometric assessment of HIV/STI sexual risk scale among MSM: A Rasch model approach. *BMC Public Health, 11*(1), 763-770.

Longshore, D., Stein, J. A., & Conner, B. T. (2004). Psychosocial antecedents of injection risk reduction: a multivariate analysis. *AIDS Education and Prevention, 16*(4), 353-366.

Lopez, W. D., Krueger, P. M., & Walters, S. T. (2010). High-risk drug use and sexual behaviors among out-of-treatment drug users: An aging and life course perspective. *Addictive Behaviors, 35*(5), 432-437.

Lorvick, J., Kral, A. H., Seal, K., Gee, L., & Edlin, B. R. (2001). Prevalence and duration of hepatitis C among injection drug users in San Francisco, Calif. *American Journal of Public Health, 91*(1), 46-47.

Maas, B., Fairbairn, N., Kerr, T., Li, K., Montaner, J. S. G., & Wood, E. (2007). Neighborhood and HIV infection among IDU: place of residence independently predicts HIV infection among a cohort of injection drug users. *Health & Place, 13*(2), 432-439.

MacArthur, G. J., Minozzi, S., Martin, N., Vickerman, P., Deren, S., Bruneau, J., . . . Hickman, M. (2012). Opiate substitution treatment and HIV transmission in people who inject drugs: systematic review and meta-analysis. *BMJ: British Medical Journal, 345*(e5945), 1-16. doi: http://dx.doi.org/10.1136/bmj.e5945

MacArthur, G. J., van Velzen, E., Palmateer, N., Kimber, J., Pharris, A., Hope, V., . . . Goldberg, D. (2014). Interventions to prevent HIV and Hepatitis C in people who inject drugs: A review of reviews to assess evidence of effectiveness. *International Journal of Drug Policy, 25*(1), 34-52.

MacCallum, R. C., & Austin, J. T. (2000). Applications of structural equation modeling in psychological research. *Annual Review of Psychology, 51*(1), 201-226.

MacDonald, M., Law, M., Kaldor, J., Hales, J., & J Dore, G. (2003). Effectiveness of needle and syringe programmes for preventing HIV transmission. *International Journal of Drug Policy, 14*(5), 353-357.

Mackesy-Amiti, M. E., Finnegan, L., Ouellet, L. J., Golub, E. T., Hagan, H., Hudson, S. M., . . . Garfein, R. S. (2013). Peer-education intervention to reduce injection risk behaviors benefits high-risk young injection drug users: a latent transition analysis of the CIDUS 3/DUIT Study. *AIDS and Behavior, 17*(6), 2075-2083.

Madden, A., & Cavalieri, W. (2007). Hepatitis C prevention and true harm reduction. *International Journal of Drug Policy, 18*(5), 335-337.

Maher, L., & Dixon, D. (1999). Policing and public health: Law enforcement and harm minimization in a street-level drug market. *British journal of criminology, 39*(4), 488-512.

Maher, L., Jalaludin, B., Chant, K. G., Jayasuriya, R., Sladden, T., Kaldor, J. M., & Sargent, P. L. (2006). Incidence and risk factors for hepatitis C seroconversion in injecting drug users in Australia. *Addiction, 101*(10), 1499-1508.

Mandell, W., Kim, J., Latkin, C., & Suh, T. (1999). Depressive symptoms, drug network, and their synergistic effect on needle-sharing behavior among street injection drug users. *The American journal of drug and alcohol abuse, 25*(1), 117-127.

Mandell, W., Vlahov, D., Latkin, C., Oziemkowska, M., & Cohn, S. (1994). Correlates of needle sharing among injection drug users. *American Journal of Public Health, 84*(6), 920-923.

Mateu-Gelabert, P., Maslow, C., Flom, P., Sandoval, M., Bolyard, M., & Friedman, S. (2005). Keeping it together: stigma, response, and perception of risk in relationships between drug injectors and crack smokers, and other community residents. *AIDS Care, 17*(7), 802-813.

Mathei, C., Shkedy, Z., Denis, B., Kabali, C., Aerts, M., Molenberghs, G., . . . Buntinx, F. (2006). Evidence for a substantial role of sharing of injecting paraphernalia other than syringes/needles to the spread of hepatitis C among injecting drug users. *Journal of Viral Hepatitis, 13*(8), 560-570.

Mathers, B. M., Degenhardt, L., Ali, H., Wiessing, L., Hickman, M., Mattick, R. P., . . . Strathdee, S. A. (2010). HIV prevention, treatment, and care services for people who inject drugs: a systematic review of global, regional, and national coverage. *The Lancet, 375*(9719), 1014-1028.

Mathers, B. M., Degenhardt, L., Bucello, C., Lemon, J., Wiessing, L., & Hickman, M. (2013). Mortality among people who inject drugs: a systematic review and meta-analysis. *Bulletin of the World Health Organization, 91*(2), 102-123.

Mathers, B. M., Degenhardt, L., Phillips, B., Wiessing, L., Hickman, M., Strathdee, S. A., . . . Toufik, A. (2008). Global epidemiology of injecting drug use and HIV among people who inject drugs: a systematic review. *The Lancet, 372*(9651), 1733-1745.

Mattson, C., Campbell, R. T., Karabatsos, G., Agot, K., Ndinya-Achola, J., Moses, S., & Bailey, R. C. (2010). Scaling sexual behavior or "sexual risk propensity" among men at risk for HIV in Kisumu, Kenya. *AIDS and Behavior, 14*(1), 162-172.

McClelland, G. M., Teplin, L. A., Abram, K. M., & Jacobs, N. (2002). HIV and AIDS risk behaviors among female jail detainees: implications for public health policy. *American Journal of Public Health, 92*(5), 818-825.

McKinlay, J. B., & Marceau, L. D. (2000). To boldly go... *American Journal of Public Health, 90*(1), 25-33.

McKnight, P. E., McKnight, K. M., Sidani, S., & Figueredo, A. J. (2007). *Missing data: A gentle introduction*: Guilford Press.

McMahon, J. M., Pouget, E. R., & Tortu, S. (2007). Individual and couple-level risk factors for hepatitis C infection among heterosexual drug users: a multilevel dyadic analysis. *Journal of Infectious Diseases, 195*(11), 1572-1581.

Medley, A., Kennedy, C., O'Reilly, K., & Sweat, M. (2009). Effectiveness of peer education interventions for HIV prevention in developing countries: a systematic review and meta-analysis. *AIDS Education and Prevention, 21*(3), 181-206.

Mehta, S. H., Astemborski, J., Kirk, G. D., Strathdee, S. A., Nelson, K. E., Vlahov, D., & Thomas, D. L. (2011). Changes in blood-borne infection risk among injection drug users. *Journal of Infectious Diseases, 203*(5), 587-594.

Melendez, R. M., Hoffman, S., Exner, T., Leu, C.-S., & Ehrhardt, A. A. (2003). Intimate partner violence and safer sex negotiation: effects of a gender-specific intervention. *Archives of Sexual Behavior, 32*(6), 499-511.

Metzger, D., & Woody, G. (1991). Risk Factors for Needle Sharing Among Methadone-Treated Patients. *Am J Psychiatry, 148*(5), 636-640.

Miller, C., Johnston, C., Spittal, P. M., Li, K., Laliberte, N., Montaner, J. S., & Schechter, M. T. (2002). Opportunities for prevention: Hepatitis C prevalence and incidence in a cohort of young injection drug users. *Hepatology, 36*(3), 737-742.

Miller, C. L., Firestone, M., Ramos, R., Burris, S., Ramos, M. E., Case, P., . . . Strathdee, S. A. (2008). Injecting drug users' experiences of policing practices in two Mexican–US border cities: Public health perspectives. *International Journal of Drug Policy, 19*(4), 324-331.

Miller, S., Exner, T., Williams, S., & Ehrhardt, A. (2000). A gender-specific intervention for at-risk women in the USA. *AIDS Care, 12*(5), 603-612.

Mizuno, Y., Purcell, D. W., Metsch, L. R., Gomez, C. A., Knowlton, A. R., & Latka, M. H. (2011). Is injection serosorting occurring among HIV-positive injection drug users? Comparison by injection partner's HIV status. *Journal of Urban Health, 88*(6), 1031-1043.

Montgomery, C., Lees, S., Stadler, J., Morar, N. S., Ssali, A., Mwanza, B., . . . Pool, R. (2008). The role of partnership dynamics in determining the acceptability of condoms and microbicides. *AIDS Care, 20*(6), 733-740.

Montgomery, M. E., Fatch, R. S., Evans, J. L., Yu, M., Davidson, P. J., Page, K., & Hahn, J. A. (2013). Injecting Risk Behavior among Traveling Young Injection Drug Users: Travel Partner and City Characteristics. *Journal of Urban Health, 90*(3), 500-515.

Montgomery, S., Hyde, J., De Rosa, C. J., Rohrbach, L. A., Ennett, S., Harvey, S. M., . . . Kipke, M. D. (2002). Gender differences in HIV risk behaviors among young injectors and their social network members. *The American journal of drug and alcohol abuse, 28*(3), 453-475.

Moss, A. R., Vranizan, K., Gorter, R., Bacchetti, P., Watters, J., & Osmond, D. (1994). HIV seroconversion in intravenous drug users in San Francisco, 1985-1990. *AIDS, 8*(2), 223-232.

Muthén, B. O., & Satorra, A. (1989). Multilevel aspects of varying parameters in structural models. In D. R. Brock (Ed.), *Multilevel analysis of educational data* (pp. 87-99). San Diego, CA: Academic Press.

Muthen, L. (2010). ML with Numerical Integration vs. WLSMV. Retrieved October, 2, 2014, from http://www.statmodel.com/discussion/messages/23/408.html?1349455760

Muthen, L., & Muthen, B. (2012). Mplus User's Guide. Seventh Edition. Los Angeles, CA: Muthén & Muthén.

Muthen, L., & Muthen, B. (2014). Chi-Square Difference Testing Using the Satorra-Bentler Scaled Chi-Square. Retrieved July 29, 2014, from http://www.statmodel.com/chidiff.shtml

Neaigus, A., Friedman, S. R., Curtis, R., Des Jarlais, D. C., Terry Furst, R., Jose, B., . . . Ward, T. (1994). The relevance of drug injectors' social and risk networks for understanding and preventing HIV infection. *Social Science & Medicine, 38*(1), 67-78.

Neaigus, A., Friedman, S. R., Goldstein, M., Ildefonso, G., Curtis, R., & Jose, B. (1995). Using dyadic data for a network analysis of HIV infection and risk behaviors among injecting drug users. *NIDA research monograph, 151*, 20-37.

Needle, R. H., Coyle, S., Cesari, H., Trotter, R., Clatts, M., Koester, S., . . . Bluthenthal, R. N. (1998). HIV risk behaviors associated with the injection process: multiperson use of drug injection equipment and paraphernalia in injection drug user networks. *Substance use & misuse, 33*(12), 2403-2423.

Neighbors, C., Walters, S. T., Lee, C. M., Vader, A. M., Vehige, T., Szigethy, T., & DeJong, W. (2007). Event-specific prevention: Addressing college student drinking during known windows of risk. *Addictive Behaviors, 32*(11), 2667-2680.

Nelson, P. K., Mathers, B. M., Cowie, B., Hagan, H., Des Jarlais, D., Horyniak, D., & Degenhardt, L. (2011). Global epidemiology of hepatitis B and hepatitis C in people who inject drugs: results of systematic reviews. *The Lancet, 378*, 571-583.

Niccolai, L. M., Toussova, O. V., Verevochkin, S. V., Barbour, R., Heimer, R., & Kozlov, A. P. (2010). High HIV prevalence, suboptimal HIV testing, and low knowledge of HIV-positive serostatus among injection drug users in St. Petersburg, Russia. *AIDS and Behavior, 14*(4), 932-941.

Noor, S. W., Ross, M. W., Lai, D., & Risser, J. M. (2014). Use of Latent Class Analysis Approach to Describe Drug and Sexual HIV Risk Patterns among Injection Drug Users in Houston, Texas. *AIDS and Behavior*, 1-8.

O'Connell, J. M., Kerr, T., Li, K., Tyndall, M. W., Hogg, R. S., Montaner, J. S. G., & Wood, E. (2005). Requiring help injecting independently predicts incident HIV infection among injection drug users. *JAIDS Journal of Acquired Immune Deficiency Syndromes, 40*(1), 83-88.

O'Shaughnessy, M. V., Hogg, R. S., Strathdee, S. A., & Montaner, J. S. G. (2012). Deadly public policy: what the future could hold for the HIV epidemic among injection drug users in Vancouver. *Current HIV/AIDS Reports, 9*(4), 394-400.

Ober, A. J., Shoptaw, S., Wang, P., Gorbach, P. M., & Weiss, R. E. (2009). Factors associated with event-level stimulant use during sex in a sample of older, low-income men who have sex with men in Los Angeles. *Drug and Alcohol Dependence, 102*(1), 123-129.

Ouellet, L. J., Jimenez, A. D., Johnson, W. A., & Wiebel, W. W. (1991). Shooting galleries and HIV disease: Variations in places for injecting illicit drugs. *Crime & Delinquency, 37*(1), 64-85.

Page, J., Shapshak, P., Duran, E. M., Even, G., Moleon-Borodowski, I., & Llanusa-Cestero, R. (2006). Detection of HIV-1 in Injection Paraphernalia: Risk in an Era of Heightened Awareness. *AIDS Patient Care & STDs, 20*(8), 576-585.

Page, K., Hahn, J. A., Evans, J., Shiboski, S., Lum, P., Delwart, E., . . . Cooper, S. (2009). Acute hepatitis C virus infection in young adult injection drug users: a prospective study of incident infection, resolution, and reinfection. *Journal of Infectious Diseases, 200*(8), 1216-1226.

Paintsil, E., He, H., Peters, C., Lindenbach, B. D., & Heimer, R. (2010). Survival of hepatitis C virus in syringes: implication for transmission among injection drug users. *Journal of Infectious Diseases, 202*(7), 984-990.

Paintsil, E., Verevochkin, S. V., Dukhovlinova, E., Niccolai, L. M., Barbour, R., White, E., . . . Heimer, R. (2009). Hepatitis C virus infection among drug injectors in St Petersburg, Russia: social and molecular epidemiology of an endemic infection. *Addiction, 104*(11), 1881-1890.

Palmateer, N., Kimber, J., Hickman, M., Hutchinson, S., Rhodes, T., & Goldberg, D. (2010). Evidence for the effectiveness of sterile injecting equipment provision in preventing hepatitis C and human immunodeficiency virus transmission among injecting drug users: a review of reviews. *Addiction, 105*(5), 844-859.

Paquette, D. M., Bryant, J., & De Wit, J. (2011). Use of respondent-driven sampling to enhance understanding of injecting networks: A study of people who inject drugs in Sydney, Australia. *The International journal on drug policy, 22*(4), 267-273.

Paterson, L., & Goldstein, H. (1991). New statistical methods for analysing social structures: an introduction to multilevel models. *British Educational Research Journal, 17*(4), 387-393.

Patterson, T. L., Semple, S. J., Staines, H., Lozada, R., Orozovich, P., Bucardo, J., . . . Amaro, H. (2008). Prevalence and Correlates of HIV Infection among Female Sex Workers in 2 Mexico—US Border Cities. *Journal of Infectious Diseases, 197*(5), 728-732.

Perdue, T., Hagan, H., Thiede, H., & Valleroy, L. (2003). Depression and HIV risk behavior among Seattle-area injection drug users and young men who have sex with men. *AIDS Education and Prevention, 15*(1), 81-92.

Petry, N. M. (2001). Reliability of Drug Users' Self-reported HIV Risk Behaviors using a Brief, 11-item Scale. *Substance use & misuse, 36*(12), 1731-1747.

Pineda, J. A., Romero-Gómez, M., Díaz-García, F., Girón-González, J. A., Montero, J. L., Torre-Cisneros, J., . . . Aguilar-Guisado, M. (2005). HIV coinfection shortens the survival of patients with hepatitis C virus-related decompensated cirrhosis. *Hepatology, 41*(4), 779-789.

Pollini, R. A., Brouwer, K. C., Lozada, R. M., Ramos, R., Cruz, M. F., Magis-Rodriguez, C., . . . Frost, S. D. (2008). Syringe possession arrests are associated with receptive syringe sharing in two Mexico–US border cities. *Addiction, 103*(1), 101-108.

Pouget, E. R., Deren, S., Fuller, C., Blaney, S., McMahon, J. M., Kang, S., . . . Vlahov, D. (2005). Receptive syringe sharing among injection drug users in Harlem and the Bronx during the New York State Expanded Syringe Access Demonstration Program. *JAIDS Journal of Acquired Immune Deficiency Syndromes, 39*(4), 471-477.

Pouget, E. R., Hagan, H., & Des Jarlais, D. C. (2012). Meta-analysis of hepatitis C seroconversion in relation to shared syringes and drug preparation equipment. *Addiction, 107*(6), 1057-1065.

Prejean, J., Song, R., Hernandez, A., Ziebell, R., Green, T., Walker, F., . . . Lansky, A. (2011). Estimated HIV incidence in the United States, 2006–2009. *PloS one, 6*(8), 1-13. doi: 10.1371/journal.pone.0017502

Prendergast, M. L., Urada, D., & Podus, D. (2001). Meta-analysis of HIV risk-reduction interventions within drug abuse treatment programs. *Journal of Consulting and Clinical Psychology, 69*(3), 389-405.

Rácz, J., Gyarmathy, V. A., Neaigus, A., & Ujhelyi, E. (2007). Injecting equipment sharing and perception of HIV and hepatitis risk among injecting drug users in Budapest. *AIDS Care, 19*(1), 59-66.

Ramirez-Valles, J., Heckathorn, D. D., Vázquez, R., Diaz, R. M., & Campbell, R. T. (2005). From networks to populations: the development and application of respondent-driven sampling among IDUs and Latino gay men. *AIDS and Behavior, 9*(4), 387-402.

Remis, R. S., Bruneau, J., & Hankins, C. A. (1998). Enough sterile syringes to prevent HIV transmission among injection drug users in Montreal? *JAIDS Journal of Acquired Immune Deficiency Syndromes, 18*, S57-S59.

Rhodes, T. (1997). Risk theory in epidemic times: sex, drugs and the social organisation of 'risk behaviour'. *Sociology of Health & Illness, 19*(2), 208-227.

Rhodes, T. (2002). The 'risk environment': a framework for understanding and reducing drug-related harm. *International Journal of Drug Policy, 13*(2), 85-94.

Rhodes, T. (2009). Risk environments and drug harms: A social science for harm reduction approach. *International Journal of Drug Policy, 20*(3), 193-201.

Rhodes, T., Davis, M., & Judd, A. (2004). Hepatitis C and its risk management among drug injectors in London: renewing harm reduction in the context of uncertainty. *Addiction, 99*(5), 621-633.

Rhodes, T., Mikhailova, L., Sarang, A., Lowndes, C. M., Rylkov, A., Khutorskoy, M., & Renton, A. (2003). Situational factors influencing drug injecting, risk reduction and syringe exchange in Togliatti City, Russian Federation: a qualitative study of micro risk environment. *Social Science & Medicine, 57*(1), 39-54.

Rhodes, T., Platt, L., Sarang, A., Vlasov, A., Mikhailova, L., & Monaghan, G. (2006). Street Policing, Injecting Drug Use and Harm Reduction in a Russian City: A Qualitative Study of Police Perspectives. *Journal of Urban Health, 83*(5), 911-925.

Rhodes, T., Singer, M., Bourgois, P., Friedman, S. R., & Strathdee, S. A. (2005). The social structural production of HIV risk among injecting drug users. *Social Science & Medicine, 61*(5), 1026-1044.

Roca, B., Suarez, I., Gonzalez, J., Garrido, M., de la Fuente, B., Teira, R., . . . Galindo, M. J. (2003). Hepatitis C virus and human immunodeficiency virus coinfection in Spain. *Journal of Infection, 47*(2), 117-124.

Rockstroh, J. K., & Spengler, U. (2004). HIV and hepatitis C virus co-infection. *The Lancet Infectious Diseases, 4*(7), 437-444.

Samuels, J. F., Vlahov, D., Anthony, J. C., & Chaisson, R. E. (1992). Measurement of HIV risk behaviors among intravenous drug users. *British Journal of Addiction, 87*(3), 417-428.

Santibanez, S. S., Garfein, R. S., Swartzendruber, A., Purcell, D. W., Paxton, L. A., & Greenberg, A. E. (2006). Update and overview of practical epidemiologic aspects of HIV/AIDS among injection drug users in the United States. *Journal of Urban Health, 83*(1), 86-100.

Scott, G. (2011). Getting Off Right ... and Left and Sideways: Drug Injections in the Real World, the Persistence of Hepatitis C, and the Failure of "Total Hygiene" Interventions. *Harm Reduction Communication, 16*, 3-9.

Seear, K., Gray, R., Fraser, S., Treloar, C., Bryant, J., & Brener, L. (2012). Rethinking safety and fidelity: The role of love and intimacy in hepatitis C transmission and prevention. *Health Sociology Review, 21*(3), 272-286.

Shain, R. N., Piper, J. M., Newton, E. R., Perdue, S. T., Ramos, R., Champion, J. D., & Guerra, F. A. (1999). A randomized, controlled trial of a behavioral intervention to prevent sexually transmitted disease among minority women. *New England Journal of Medicine, 340*(2), 93-100.

Sharma, M., Burrows, D., & Bluthenthal, R. (2007). Coverage of HIV prevention programmes for injection drug users: confusions, aspirations, definitions and ways forward. *International Journal of Drug Policy, 18*(2), 92-98.

Sharma, M., Oppenheimer, E., Saidel, T., Loo, V., & Garg, R. (2009). A situation update on HIV epidemics among people who inject drugs and national responses in South-East Asia Region. *AIDS, 23*(11), 1405-1413.

Shaw, S. Y., Shah, L., Jolly, A. M., & Wylie, J. L. (2007). Determinants of injection drug user (IDU) syringe sharing: the relationship between availability of syringes and risk network member characteristics in Winnipeg, Canada. *Addiction, 102*(10), 1626-1635.

Sherman, S. G., Latkin, C., & Gielen, A. C. (2001). Social factors related to syringe sharing among injecting partners: a focus on gender. *Substance use & misuse, 36*(14), 2113-2136.

Shiffman, S., Stone, A. A., & Hufford, M. R. (2008). Ecological momentary assessment. *Annu. Rev. Clin. Psychol., 4*, 1-32.

Simmons, J., Rajan, S., & McMahon, J. M. (2012). Retrospective accounts of injection initiation in intimate partnerships. *International Journal of Drug Policy, 23*(4), 303-311.

Small, W., Kerr, T., Charette, J., Schechter, M. T., & Spittal, P. M. (2006). Impacts of intensified police activity on injection drug users: Evidence from an ethnographic investigation. *International Journal of Drug Policy, 17*(2), 85-95.

Small, W., Rhodes, T., Wood, E., & Kerr, T. (2007). Public injection settings in Vancouver: Physical environment, social context and risk. *International Journal of Drug Policy, 18*(1), 27-36.

Smith, B. D., Jewett, A., Burt, R. D., Zibbell, J. E., Yartel, A. K., & DiNenno, E. (2013). "To share or not to share?" Serosorting by hepatitis C status in the sharing of drug injection equipment among NHBS-IDU2 participants. *Journal of Infectious Diseases, 208*(12), 1934-1942.

Spittal, P. M., Craib, K. J. P., Wood, E., Laliberte, N., Li, K., Tyndall, M. W., . . . Schechter, M. T. (2002). Risk factors for elevated HIV incidence rates among female injection drug users in Vancouver. *Canadian Medical Association Journal, 166*(7), 894-899.

Staples, C., Rimland, D., & Dudas, D. (1999). Hepatitis C in the HIV (human immunodeficiency virus) Atlanta VA (Veterans Affairs Medical Center) Cohort Study (HAVACS): the effect of coinfection on survival. *Clinical Infectious Diseases, 29*(1), 150-154.

Stein, M., Maksad, J., & Clarke, J. (2001). Hepatitis C disease among injection drug users: knowledge, perceived risk and willingness to receive treatment. *Drug and Alcohol Dependence, 61*(3), 211-215.

Stein, M., Solomon, D. A., Herman, D. S., Anderson, B. J., & Miller, I. (2003). Depression severity and drug injection HIV risk behaviors. *American Journal of Psychiatry, 160*(9), 1659-1662.

Strathdee, S. A., Galai, N., Safaiean, M., Celentano, D. D., Vlahov, D., Johnson, L., & Nelson, K. E. (2001). Sex differences in risk factors for HIV seroconversion among injection drug users: a 10-year perspective. *Archives of internal medicine, 161*(10), 1281-1288.

Suh, T., Mandell, W., Latkin, C., & Kim, J. (1997). Social network characteristics and injecting HIV-risk behaviors among street injection drug users. *Drug and Alcohol Dependence, 47*(2), 137-143.

Sulkowski, M. S. (2008). Viral hepatitis and HIV coinfection. *Journal of Hepatology, 48*(2), 353-367.

Sulkowski, M. S., Ray, S. C., & Thomas, D. L. (2002). Needlestick transmission of hepatitis C. *JAMA: The Journal of the American Medical Association, 287*(18), 2406-2413.

Sulkowski, M. S., & Thomas, D. L. (2003). Hepatitis C in the HIV-infected person. *Annals of Internal Medicine, 138*(3), 197-207.

Suryaprasad, A. G., White, J. Z., Xu, F., Eichler, B., Hamilton, J., Patel, A., . . . Fisher, C. (2014). Emerging Epidemic of Hepatitis C Virus Infections Among Young Non-Urban

Persons who Inject Drugs in the United States, 2006–2012. *Clinical Infectious Diseases*, 10-23. doi: 10.1093/cid/ciu643

Syvertsen, J. L., Robertson, A. M., Strathdee, S. A., Martinez, G., Rangel, M. G., & Wagner, K. D. (2014). Rethinking risk: Gender and injection drug-related HIV risk among female sex workers and their non-commercial partners along the Mexico–US border. *International Journal of Drug Policy, 25*(5), 836–844.

Tavitian-Exley, I., Boily, M., & Vickerman, P. (2013). HIV Risk in People Who Inject Different Drugs: Systematic Review and Meta-Analysis. *Sexually Transmitted Infections, 89*(Suppl 1), A179-A179.

Tempalski, B., Cooper, H. L., Friedman, S. R., Des Jarlais, D. C., Brady, J. E., & Gostnell, K. (2008). Correlates of syringe coverage for heroin injection in 35 large metropolitan areas in the US in which heroin is the dominant injected drug. *International Journal of Drug Policy, 19, Supplement 1*(0), 47-58. doi: http://dx.doi.org/10.1016/j.drugpo.2007.11.011

Tempalski, B., Lieb, S., Cleland, C. M., Cooper, H., Brady, J. E., & Friedman, S. R. (2009). HIV Prevalence Rates among Injection Drug Users in 96 Large US Metropolitan Areas, 1992–2002. *Journal of Urban Health, 86*(1), 132-154.

Tempalski, B., & McQuie, H. (2009). Drugscapes and the role of place and space in injection drug use-related HIV risk environments. *International Journal of Drug Policy, 20*(1), 4-13.

Thiede, H., Hagan, H., Campbell, J. V., Strathdee, S. A., Bailey, S. L., Hudson, S. M., . . . Garfein, R. S. (2007). Prevalence and correlates of indirect sharing practices among young adult injection drug users in five US cities. *Drug and Alcohol Dependence, 91*, 39-47.

Thomas, D. L., Vlahov, D., Solomon, L., Cohn, S., Taylor, E., Garfein, R., & Nelson, K. E. (1995). Correlates of hepatitis C virus infections among injection drug users. *Medicine, 74*(4), 212-220.

Thorpe, L. E., Ouellet, L. J., Hershow, R., Bailey, S. L., Williams, I. T., Williamson, J., . . . Garfein, R. S. (2002). Risk of Hepatitis C Virus Infection among Young Adult Injection Drug Users Who Share Injection Equipment. *American Journal of Epidemiology, 155*(7), 645-653.

Tobin, K., Davey-Rothwell, M., & Latkin, C. (2010). Social-level correlates of shooting gallery attendance: A focus on networks and norms. *AIDS and Behavior, 14*(5), 1142-1148.

Tobin, K., Kuramoto, S., Davey-Rothwell, M., & Latkin, C. (2011). The STEP into Action study: a peer-based, personal risk network-focused HIV prevention intervention with injection drug users in Baltimore, Maryland. *Addiction, 106*(2), 366-375. doi: 10.1111/j.1360-0443.2010.03146.x

Tortu, S., McMahon, J. M., Hamid, R., & Neaigus, A. (2003). Women's drug injection practices in East Harlem: An event analysis in a high-risk community. *AIDS and Behavior, 7*(3), 317-328.

Trotter, R., Baldwin, J. A., & Bowen, A. (1995). Network structure and proxy network measures of HIV, drug and incarceration risks for active drug users. *Connections, 18*(1), 89-104.

Tseng, V., & Seidman, E. (2007). A systems framework for understanding social settings. *American Journal of Community Psychology, 39*(3), 217-228.

Tyndall, M. W., Currie, S., Spittal, P. M., Li, K., Wood, E., O'Shaughnessy, M. V., & Schechter, M. T. (2003). Intensive injection cocaine use as the primary risk factor in the Vancouver HIV-1 epidemic. *AIDS, 17*(6), 887-893.

Unger, J. B., Kipke, M. D., De Rosa, C. J., Hyde, J., Ritt-Olson, A., & Montgomery, S. (2006). Needle-sharing among young IV drug users and their social network members: The influence of the injection partner's characteristics on HIV risk behavior. *Addictive Behaviors, 31*(9), 1607-1618.

USDHHS. (2013a). *National Survey on Drug Use and Health, 2012*. Retrieved from: http://doi.org/10.3886/ICPSR34933.v1

USDHHS. (2013b). *National Survey on Drug Use and Health: 10-Year Substate R-DAS (2002 to 2011)*. Retrieved from: http://doi.org/10.3886/ICPSR34947.v1

Valdiserri, R., Khalsa, J., Dan, C., Holmberg, S. D., Zibbell, J. E., Holtzman, D., . . . Compton, W. M. (2014). Confronting the Emerging Epidemic of HCV Infection Among Young Injection Drug Users. *American Journal of Public Health*(0), e1-e6.

Valente, T. W., & Vlahov, D. (2001). Selective risk taking among needle exchange participants: implications for supplemental interventions. *American Journal of Public Health, 91*(3), 406-411.

Vickerman, P., Hickman, M., Rhodes, T., & Watts, C. (2006). Model projections on the required coverage of syringe distribution to prevent HIV epidemics among injecting drug users. *JAIDS Journal of Acquired Immune Deficiency Syndromes, 42*(3), 355-361.

Vlahov, D., Muñoz, A., Anthony, J. C., Cohn, S., Celentano, D. D., & Nelson, K. E. (1990). Association of drug injection patterns with antibody to human immunodeficiency virus type 1 among intravenous drug users in Baltimore, Maryland. *American Journal of Epidemiology, 132*(5), 847-856.

Vlahov, D., Robertson, A. M., & Strathdee, S. A. (2010). Prevention of HIV infection among injection drug users in resource-limited settings. *Clinical Infectious Diseases, 50*(Supplement 3), S114-S121.

Vosburgh, H. W., Mansergh, G., Sullivan, P. S., & Purcell, D. W. (2012). A review of the literature on event-level substance use and sexual risk behavior among men who have sex with men. *AIDS and Behavior, 16*(6), 1394-1410.

Wagner, K. D., Lankenau, S. E., Palinkas, L. A., Richardson, J. L., Chou, C. P., & Unger, J. B. (2010). The perceived consequences of safer injection: An exploration of qualitative findings and gender differences. *Psychology, health & medicine, 15*(5), 560-573.

Wagner, K. D., Lankenau, S. E., Palinkas, L. A., Richardson, J. L., Chou, C. P., & Unger, J. B. (2011). The influence of the perceived consequences of refusing to share injection equipment among injection drug users: Balancing competing risks. *Addictive Behaviors, 36*(8), 835–842.

Wagner, K. D., Unger, J. B., Bluthenthal, R. N., Andreeva, V. A., & Pentz, M. A. (2010). Cognitive behavioral theories used to explain injection risk behavior among injection drug users: a review and suggestions for the integration of cognitive and environmental models. *Health Education & Behavior, 37*(4), 504-532.

Watson, C.-A., Weng, C. X., French, T., Anderson, B. J., Nemeth, C., McNutt, L.-A., & Smith, L. C. (2013). Substance abuse treatment utilization, HIV risk behaviors, and recruitment among suburban injection drug users in Long Island, New York. *AIDS and Behavior*, 1-11.

Wejnert, C., Pham, H., Oster, A., DiNenno, E., Smith, A., Krishna, N., & Lansky, A. (2012). HIV Infection and HIV-Associated Behaviors Among Injecting Drug Users - 20 Cities, United States, 2009 (pp. 133-138). Atlanta: U.S. Center for Disease Control.

Williams, C., Liu, W., & Levy, J. A. (2011). Crossing Over: Drug Network Characteristics and Injection Risk Along the China-Myanmar Border. *AIDS and Behavior, 15*(5), 1011-1016.

Williams, M., Zhuo, Z., Siegal, H. A., Robles, R. R., Trotter, R. T., & Jones, A. (1995). A comparison of drug use networks across three cities. *NIDA research monograph, 151*, 109-130.

Willig, C. (1997). The limitations of trust in intimate relationships: Constructions of trust and sexual risk taking. *British Journal of Social Psychology, 36*(2), 211-221.

Wingood, G. M., & DiClemente, R. J. (2000). Application of the theory of gender and power to examine HIV-related exposures, risk factors, and effective interventions for women. *Health Education & Behavior, 27*(5), 539-565.

Witte, S. S., El-Bassel, N., Gilbert, L., Wu, E., Chang, M., & Hill, J. (2006). Promoting female condom use to heterosexual couples: findings from a randomized clinical trial. *Perspectives on Sexual and Reproductive Health, 38*(3), 148-154.

Wodak, A., & Cooney, A. (2005). Effectiveness of sterile needle and syringe programmes. *International Journal of Drug Policy, 16, Supplement 1*(0), 31-44. doi: http://dx.doi.org/10.1016/j.drugpo.2005.02.004

Wodak, A., & Cooney, A. (2006). Do needle syringe programs reduce HIV infection among injecting drug users: a comprehensive review of the international evidence. *Substance use & misuse, 41*(6-7), 777-813.

Wodak, A., & McLeod, L. (2008). The role of harm reduction in controlling HIV among injecting drug users. *AIDS (London, England), 22*(Suppl 2), S81-S92.

Wood, E., Kerr, T., Marshall, B. D. L., Li, K., Zhang, R., Hogg, R. S., . . . Montaner, J. S. G. (2009). Longitudinal community plasma HIV-1 RNA concentrations and incidence of HIV-1 among injecting drug users: prospective cohort study. *BMJ: British Medical Journal, 338-342*.

Wood, E., Li, K., Small, W., Montaner, J. S. G., Schechter, M. T., & Kerr, T. (2005). Recent incarceration independently associated with syringe sharing by injection drug users. *Public Health Reports, 120*(2), 150-156.

Wood, E., Tyndall, M. W., Spittal, P. M., Li, K., Hogg, R. S., Montaner, J. S. G., . . . Schechter, M. T. (2002). Factors associated with persistent high-risk syringe sharing in the presence of an established needle exchange programme. *AIDS, 16*(6), 941-943.

Wood, E., Tyndall, M. W., Stoltz, J., Small, W., Lloyd-Smith, E., & Zhang, R. (2005). Factors associated with syringe sharing among users of a medically supervised safer injecting facility. *American Journal of Infectious Diseases, 1*(1), 50-54.

Wood, E., Tyndall, M. W., Zhang, R., Stoltz, J., Lai, C., Montaner, J. S. G., & Kerr, T. (2006). Attendance at supervised injecting facilities and use of detoxification services. *New England Journal of Medicine, 354*(23), 2512-2514.

Wright, T. L., Hollander, H., Pu, X., Held, M. J., Lipson, P., Quan, S., . . . Scharschmidt, B. F. (1994). Hepatitis C in HIV-infected patients with and without AIDS: Prevalence and relationship to patient survival. *Hepatology, 20*(5), 1152-1155.

Yang, C., Tobin, K., & Latkin, C. (2011). Perceived serosorting of injection paraphernalia sharing networks among injection drug users in Baltimore, MD. *AIDS and Behavior, 15*(1), 16-21.

Zibbell, J. E. (2012). Safer Injection 2.0: Beyond the Point. *Harm Reduction Communication, 17*, 4-11.

Zorn, C. J. (2001). Generalized estimating equation models for correlated data: A review with applications. *American Journal of Political Science*, 470-490.

Zule, W. A. (1992). Risk and reciprocity: HIV and the injection drug user. *Journal of psychoactive drugs, 24*(3), 243-249.