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Social networks and substance use after transitioning into permanent supportive housing



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ABSTRACT

Background: Substance use disorders are common among persons experiencing homelessness, and research has identified social networks as important correlates of substance use in this population. Permanent supportive housing (PSH), particularly Housing First, which uses a harm reduction model not requiring substance abstinence, is a key solution for ending homelessness. However, conflicting evidence exists regarding the associations between moving into PSH and changes in substance use, and there is limited understanding of how networks may influence such changes.

Methods: Using observational, longitudinal data from 421 persons before they moved in and over their first year in PSH (collected as part of a HIV-risk study), this paper assesses substance use change (alcohol, marijuana, and illicit drugs) and associations between perceived network characteristics and individual substance use.

Results: Substance use remained relatively stable among participants over their first year living in PSH, although illicit substance use reduced somewhat at six months compared to baseline levels (from 18.5%–14.5%) and marijuana use increased slightly at 12 months (from 26.6% at baseline to 32.9%). Substance use among social network members was consistently associated with individual-level substance use, both cross-sectionally and longitudinally. Specific network substance use characteristics, such as proximity, location met, and social support, had differential relationships with particular substance types.

Conclusions: These findings provide longitudinal evidence that changes within substance-using social networks are associated with subsequent changes in individual use and underscore the importance of interventions aimed at promoting positive social relationships for formerly homeless persons and improving PSH's social environments.

1. Introduction

Substance use disorders are the most common mental health conditions among persons experiencing homelessness (Fazel et al., 2008), and engaging in substance use is associated with worse outcomes for this population, including chronic homelessness (Fichter and Quadflieg, 2006; Kuhn and Culhane, 1998; Lipton et al., 2000), morbidity (Shannon et al., 2006), and mortality (Bejter et al., 2011). Permanent supportive housing (PSH), which combines stable housing with health and other supportive services, is an evidence-based, long-term solution for ending chronic homelessness (Byrne et al., 2014; Rog et al., 2014; Smelson et al., 2016). PSH programs typically follow a Housing First (HF) model, using a harm reduction approach to substance use, wherein

abstinence is not required for housing and interventions, and emphasis is on minimizing consequences associated with substance use (Tidderington et al., 2013; Tsemberis et al., 2004; Watson et al., 2013). Whereas foundational research on the HF model has identified increased uptake of substance abuse treatment among those in HF (Tsemberis et al., 2004) and success in keeping those with substance use disorders housed (Cherner et al., 2017; Tsai et al., 2014; Urbanoski et al., 2018), there is conflicting evidence about how transitioning to PSH impacts substance use among persons with experiences of homelessness.

Studies of substance use among formerly homeless adult populations have explored substance use in relation to housing retention (Collins et al., 2013; Edens et al., 2011; Lipton et al., 2000; Palepu

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et al., 2013; Pearson et al., 2009) or attainment (North et al., 2010), examined the association of particular housing types with substance use (e.g., community-based *scatter-site* vs. single-site buildings specifically for persons with former experiences of homelessness) (Whittaker and Burns, 2015), and identified HF as equally effective for those with and without substance use disorders (Cherner et al., 2017; Tsai et al., 2014; Urbanoski et al., 2018). North et al.'s (2010) findings on housing attainment suggest that housing outcomes may vary based on the type of substance being used. For instance, cocaine use was associated with a lower likelihood of maintaining stable housing, whereas alcohol dependence was not associated with housing outcomes (North et al., 2010). Research focused specifically on whether moving from homelessness into housing is associated with changes in individual substance use has found mixed results, including findings of differential relationships between housing and substance use depending on the type of substance. Kirst et al. (2015) identified reductions in alcohol problems over time among HF residents (as compared with those receiving treatment as usual) but found no relationship between housing and illicit substance use. Several studies found that substance use did not change significantly when persons moved into PSH (Hwang et al., 2011; Mares and Rosenheck, 2011; O'Campo et al., 2016; Somers et al., 2015; Tsemberis et al., 2004), whereas others have identified decreases in substance use during this time (Larimer et al., 2009; Padgett et al., 2011; Tsai et al., 2012). Given these inconsistent findings, there is a need for additional research on how PSH is associated with changes in or sustenance of substance use over time.

Studies examining social contexts among persons experiencing homelessness suggest that network characteristics, such as the proportion of network members who use substances, locations where participants met network members, and social support, are important correlates of individual-level substance use (Rhoades et al., 2011; Song and Wenzel, 2015; Wenzel et al., 2009). For example, previous research with samples of adults experiencing homelessness showed that the presence of substance users within networks and the locations where network members were met (e.g., on the street, at bars, etc.) influenced alcohol, marijuana, and illicit substance use (Rhoades et al., 2011; Song and Wenzel, 2015; Wenzel et al., 2009). Conversely, social support, including tangible, informational, and emotional closeness, has been associated with decreased rates of substance use in this population (Song and Wenzel, 2015; Wenzel et al., 2009). Moving into PSH represents a time of network change for many formerly homeless persons, with the potential for loss and/or gain of social relationships (e.g., ties may be lost if housing limits visitors or is located away from areas where homelessness was experienced, or ties may be gained if family reunification occurs after attaining housing). This network disruption may also create opportunities to develop new neighborhood- and building-based social relationships. Existing findings about the importance of social network composition among persons experiencing homelessness (cited above) suggest that substance use after moving into PSH may be contingent on network change during this time, including whether an individual continues to affiliate with street-based substance-using ties and whether social network members living nearby or within an individual's PSH placement are substance users.

To our knowledge, previous research has not examined how longitudinal changes in social networks among persons experiencing homelessness or formerly homeless persons in PSH may be associated with changes in individual-level substance use behavior. However, extant research examining longitudinal social network changes and personal substance use in other populations suggests that there is a potentially causal relationship wherein changes in substance use within social networks impacts subsequent individual-level substance use. Rosenquist et al. (2010) demonstrated that increased alcohol consumption among social contacts was associated with subsequent increases in individual-level alcohol use. Likewise, Bullers et al. (2001) found that the relationship between social network alcohol use and individual use was comprised of both social selection (i.e., choosing

social networks who have similar substance use characteristics) and social influence (i.e., changes in drinking behaviors among social networks influencing changes in individual alcohol consumption) effects. A similar longitudinal relationship was identified for both alcohol and illicit substance use among men recently released from jail, wherein increases or decreases in substance use among social network members was associated with subsequent increases or decreases individual use (Owens and McCrady, 2014).

The existing literature demonstrates the importance of social network characteristics as correlates of individual-level substance use among persons who have experienced homelessness and has identified conflicting evidence about the relationship between substance use and PSH. Because moving into PSH may be a time of network upheaval, this critical transition provides an opportunity to understand how changes in social relationships relate to substance use, particularly as literature from other populations suggests that there is a social influence relationship between social networks and individual substance use. Within this context, the current study adds to the literature by examining the following: 1) how use of alcohol, marijuana, and illicit substances changes over time when persons move from homelessness into PSH; 2) how substance use within social networks changes during this time, particularly among network members who live nearby or are persistent street-based ties; and 3) the relationship between individual-level substance use and substance use within social networks in this population (including whether this relationship varies based on the proximity and characteristics of network members).

2. Material and methods

2.1. Study

This observational study involved participants initially enrolled as part of a study that focused on HIV risk among persons in PSH. These participants encompassed adults experiencing homelessness moving into PSH in the Los Angeles (LA) area between August 2014 and January 2016. Researchers partnered with 26 housing providers in Los Angeles County to recruit participants moving into housing via agency referrals and direct recruitment at lease-up events. Adults experiencing chronic homelessness are generally placed in PSH in LA County through agencies using the Vulnerability Index Service Prioritization Decision Assistance Tool (VI-SPDAT), which prioritizes the most vulnerable based on VI-SPDAT score and housing voucher type. Clients have higher VI-SPDAT scores if they report a chronic health condition, physical or mental disability, HIV-positive status, or substance abuse (United Way of Greater Los Angeles, 2016).

Participants were initially screened for study eligibility via phone or in person and were eligible if they were moving into PSH with one of the partner agencies, 39 years old or older, spoke English or Spanish, and were not actively parenting minor children. As part of the larger HIV-based focus of this study, the age and non-parenting requirements were implemented to maximize detection of changes in HIV-risk outcomes without the influence of life stages or parenting status. Participants recruited for this study (N = 421) represented the same baseline characteristics as other individuals aged 39 or older without dependent children entered into the Los Angeles County Homeless Management Information System (HMIS; LA Continuum of Care) during the same period as study recruitment. Age and race/ethnicity distributions of both samples were nearly identical (no statistically significant differences between the groups), save for a smaller proportion of women (27.8%) in the study sample compared to the percentage listed within the HMIS (33.4%) (Los Angeles Homeless Services Authority, 2016).

All participants provided written informed consent and were interviewed before or within five days of PSH move-in and at three, six, and 12 months after moving in. Each interview was administered by a trained study interviewer and lasted for one to 1.5 h. Several study

retention techniques were employed to maintain high levels of participation throughout all study timepoints. For instance, at study enrollment, a *locator form* collected the names of family, friends, and staff whom the participant approved as contacts in the event the participant could not be reached. Further, a consistent set of trained research interviewers conducted the study interviews with the same participants throughout the study, barring a few exceptions; when a participant needed to be transferred to a new interviewer, a *warm hand-off* occurred, in which the current interviewer introduced the respondent to their new interviewer. Interviewers reached out to participants monthly to check in and confirm current contact information. If a participant could not be reached, interviewers followed-up with persons listed on the locator form, visited sites known to be frequented by the participant, and sent cards and letters to their housing address. Interviewers also kept in touch with participants by sending greeting cards as interview reminders and for birthdays and holidays. If a participant still could not be reached through the above means, public records databases were checked to see if the participant was incarcerated or had passed away. At baseline, 421 persons were enrolled in the study; 405 completed three months of interviews (96.2% retention), 400 completed six months of interviews (95% retention), and 383 completed 12 months of interviews (91% retention). Reasons for loss at each time point included death, incarceration, withdrawal, and loss of contact. Persons not interviewed at any survey mid-point were eligible for later interviews (excluding those persons who withdrew from the study). The final analyses included a smaller sample of persons due to missing data on substance use and social network outcomes (the number ranges from 376 to 421 people). All study procedures were approved by the authors' university institutional review board. The study received a certificate of confidentiality from the U.S. Department of Health and Human Services to protect participant data from subpoena.

2.2. Measures

Participant demographic characteristics (age, gender, race/ethnicity, and achievement of high school education or GED), three-month history of substance abuse treatment, and incarceration history were assessed using items adopted or adapted from previous research (Hwang, 2001; UCLA Center for Health and Policy Research, 2014; Wenzel, 2005). Participants were asked to identify which chronic mental health conditions they had been diagnosed with in their lifetimes using a list of possible conditions adapted from the National Health Interview Survey (Centers for Disease Control and Prevention, 2015), Bassuk et al. (1998); Hwang (2001), and National Health Care for the Homeless Council (2011); an indicator was created of any lifetime diagnosis.

2.2.1. Substance use

Three-month history of substance use was assessed using items adapted from the National Institute on Drug Abuse (NIDA) Modified ASSIST assessment tool (National Institute on Drug Abuse, 2012). Participants were asked how often in the past month they had used several substances (response options ranged from *never* to *daily/almost daily*), including marijuana, cocaine/crack, prescription stimulants, sedatives, opioids, methamphetamines, hallucinogens, and street opioids (e.g., heroin). If respondents indicated use of prescription stimulants, sedatives, or opioids, a follow-up item assessed whether that substance had been misused, defined as taking it without a prescription or in a larger or more frequent dose than prescribed. Binge drinking was assessed by asking how frequently the respondent had consumed four (for women) or five (for men) drinks within a two-hour period in the past three months (National Institute on Alcohol Abuse and Alcoholism, 2004). Indicators of any use were created for binge drinking, marijuana, and illicit substances (illicit substance use included prescription drug misuse, street opioids, methamphetamines, cocaine/crack, or hallucinogens).

2.2.2. Social network variables

Social network interviews (SNIs) asked participants to name (using only first names or nicknames to protect privacy) all persons with whom they had interacted in the past three months. Network size was operationalized as the total number of network members named by the participant. Subsequent questions asked which persons within the respondent's network had particular characteristics, such as alcohol intoxication, use of marijuana, cocaine, crack, meth, or heroin, or prescription drug use without a prescription, during the past three months (a single item represented perceived use of all illicit substances). Research has shown that perceptions of network-level behavior by persons experiencing homelessness are related to individual-use behavior (Tucker et al., 2009; Wenzel et al., 2012, 2010); in fact, social network influence may be driven *more* by perceptions of behavior than by the actual behavior of network members (Barman-Adhikari et al., 2018, 2017; Iannotti and Bush, 1992). Additional items assessed whether network members lived nearby (operationalized as either in the respondent's building or somewhere the respondent could easily get to within 15 min) or had been originally met on the street. Whether the network member provided social support in the past three months was measured with four items: two measures of emotional closeness ("Who have you felt emotionally close to most of the time" and "Who can you count on to listen to you when you need to talk, or is someone you can confide in?"), one measure of tangible support ("Who has provided you with food, money, or clothes?"), and one measure regarding advice ("Who has given you advice or information to help you solve a problem?"). Support items were combined to create an overall sum of network members providing any of these types of support. All network member characteristic variables were included in the models as the sum total of persons with that characteristic within an individual's network.

2.3. Analysis

Generalized linear mixed models (GLMM) were used to examine (1) change over time in all individual-level and social network variables and (2) each type of individual-level substance use outcome and the corresponding SNI characteristic (e.g., when respondent's marijuana use is the outcome, the primary predictor is the sum score of perceived marijuana users within the respondent's network). By allowing the regression coefficients to vary randomly from individual to individual, the GLMM accounted for the correlated observations within the same subject (i.e., repeated measurements) with the introduction of random effects. All available data points were included in the analysis (data from respondents who provided information on all included variables for at least one of the interviews were modeled). Although multiple imputation is equally popular in analyzing data with missingness, maximum likelihood methods are preferred whenever the software is available because it is more efficient and involves less uncertainty (Allison, 2012). The maximum likelihood estimation method was used by choosing the adaptive Gaussian quadrature with 50 quadrature points (Fitzmaurice et al., 2011). When missing data occurs, maximum likelihood estimation provides valid inferences when data are missing at random.

All outcomes in this study are dichotomous measures (yes/no), so GLMM with a logit link function was specified. Because previous literature identifies location where social network members were met as a correlate of substance use for persons experiencing homelessness (Rhoades et al., 2011; Wenzel et al., 2009) and physical proximity to network members is likely to impact interactions in a similar manner, particularly during the transition to housing (and is highly correlated with location met), an additive interaction variable was developed for this study to further explore location met and proximity. This variable indicates whether network members perceived to use substances were (1) met on the street but did not live nearby, (2) not met on the street and live nearby, (3) met on the street and live nearby, or (4) neither met on the street nor live nearby.

Table 1
Demographic characteristics (baseline; n = 421).

Age at baseline, mean (SD)	54.4 (7.5)
Female, n (%)	120 (28.5)
High school graduate, n (%)	324 (77.0)
Race, n (%)	
African American	235 (56.0)
White	100 (23.8)
Other	85 (20.2)
Past 3-month substance use treatment, n (%)	47 (11.2)
Lifetime diagnosis of chronic mental illness, n (%)	310 (73.6)
Lifetime incarceration, n (%)	317 (94.1)
Social network size, mean (SD)	7.7 (4.5)

To differentiate the cross-sectional and longitudinal effect of time-varying covariates in the models examining individual-level outcomes with SNI exposures, SNI variables were decomposed as two parts: the within-person mean and the deviation from the mean at each time point. The two decomposed parts were simultaneously modeled in each GLMM; the parameter estimates associated with the within-person mean were interpreted as the between-subject effect (cross-sectional), and the estimated coefficients for the deviation yielded an estimate of the within-subject (longitudinal) effect (Fitzmaurice et al., 2011). All models examining change in substance use as associated with perceived network characteristics were adjusted for demographic characteristics that may impact substance use, such as age, gender, race/ethnicity, education, network size, lifetime incarceration, past substance abuse treatment, and any lifetime diagnosis of a chronic mental health disorder.

3. Results

As shown in Table 1, the average age of the 421 participants at baseline was 54 years (SD = 7.53), 29% were women, and 77% had completed high school or an equivalent level of education. African Americans accounted for 56% of the study sample, with the remaining sample represented as White (24%) and other races/ethnicities (20%). The average network size at baseline was 7.7 (SD = 4.5) persons. Ninety-four percent had ever been incarcerated, 11% reported a past three-month experience of substance abuse treatment, and 74% had a diagnosis of a chronic mental health disorder.

Frequencies of individual-level and social network-level substance use are summarized in Table 2. The figures in bold are statistically significant in the GLMM models examining whether these variables changed over time as compared with baseline levels; these models controlled for network size. Individual-level binge drinking did not change after persons moved into permanent housing, with past three-month rates remaining stable at 15–17% across all time points. Illicit substance use was reported at 18–20% at most time points, albeit a statistically significant decrease to 15% at the six-month interview was demonstrated. This decrease rebounded to 20% by 12 months. Marijuana use appeared to increase slightly over time among this sample, with rates going from 27% at baseline to 33% at both the six- and 12-month interviews.

Across all substances, the number of perceived substance users within the network who were met on the street decreased over time, regardless of whether those persons currently lived nearby. For example, there was an average of 0.24 network members perceived to use marijuana who were met on the street and lived nearby at an individual's baseline, but this average reduced to only 0.05 of these network members at 12 months. In contrast, network members who were perceived to be substance users and lived nearby but not originally met on the street increased over time. For example, there was an

average of 0.16 network members perceived to be using marijuana and living nearby but not met on the street at baseline, but that average increased to 0.29 at 12 months. We found no statistically significant change in the number of perceived substance users who were neither met on the street nor lived nearby within respondents' social networks. Regarding social support, there was a decrease over time in social network members who provided social support and were not perceived to use substances and no change in social support-providing network members who were perceived to use substances.

Odds ratios (ORs) from GLM models examining within-subject and between-subject associations of social network characteristics with individual-level outcomes are presented in Table 3. First, across all substances, there was both a within-subject and between-subject relationship between perceived network-level substance use and individual-level substance use. These findings suggest that for binge drinking (OR = 2.07, 95% CI = 1.62–2.64), marijuana (OR = 6.41, 95% CI = 3.88–10.58), and illicit drugs (OR = 7.47, 95% CI = 4.38–12.73), a greater number of social network members perceived to use these substances was associated with an increased likelihood that the individual respondent would also use that substance (between-subjects effects) and that when the number of network members perceived to use alcohol to intoxication (OR = 1.18, 95% CI = 1.04–1.35), marijuana (OR = 1.42, 95% CI = 1.17–1.73), or illicit drugs (OR = 2.17, 95% CI = 1.61–2.93) changed over time, the likelihood that an individual would use that substance changed, as well (within-subjects effects).

Subsequent models only focused on the relationship between perceptions of certain types of substance users within social networks and individual-level substance use. These models identified unique relationships for each type of substance measured. For binge drinking, having more social network members who were perceived to use alcohol to intoxication was statistically significantly associated with individual binge drinking, both cross-sectionally and longitudinally, if they were met on the street but did not currently live nearby (within-subjects effect: OR = 2.06, 95% CI = 1.31–3.21; between-subject effect: OR = 6.75, 95% CI = 2.39–19.09). Cross-sectionally, having more social network members who provided support and were perceived to have used alcohol to intoxication was associated with an increased likelihood of individual binge drinking (OR = 2.51, 95% CI = 1.78–3.53), whereas the inclusion of more network members who provided support and were *not* perceived to use alcohol to intoxication was associated with a decreased likelihood of individual binge drinking (OR = 0.71, 95% CI = 0.61–0.84).

Further, within the cross-sectional analysis, perceiving the presence of more marijuana users within a respondent's social network was associated with a greater likelihood that the individual would report marijuana use across almost all network variables; the exception was members who were met on the street and did not currently live nearby. Having social network members who provided support and were not perceived to use marijuana was cross-sectionally protective against individual-level marijuana use (OR = 0.65, 95% CI = 0.51–0.83).

Within the longitudinal analysis, having, respectively, an increasing number of network members who were met on the street and currently lived nearby (OR = 2.40, 95% CI = 1.36–4.22) and network members perceived to use marijuana who provided social support (OR = 1.30, 95% CI = 1.01–1.69) were associated with a corresponding increased likelihood that the individual would use marijuana.

Relating to illicit drug use, the type of network member did not seem to matter; rather, there were both cross-sectional and longitudinal relationships between perceived network-level illicit substance use and individual substance use regardless of where the network member was met and whether they lived nearby. Similarly, the inclusion of social network members who provided support and were perceived to use illicit drugs was associated with an increased likelihood of individual-level illicit drug use, both cross-sectionally (OR = 18.65, 95% CI = 7.63–45.60) and longitudinally (OR = 2.64, 95%

Table 2
Over time changes in individual-level substance use and social network substance use and other characteristics.

	Baseline (before housing)		3 months		6 months		12 months	
	Total n	n (%)	Total n	n (%)	Total n	n (%)	Total n	n (%)
Individual behavior								
Binge drinking	421	67 (15.91)	405	59 (14.57)	400	67 (16.75)	383	57 (14.88)
Marijuana	421	112 (26.60)	405	119 (29.38)	400	130 (32.50)	383	126 (32.90)
Illicit drugs	421	78 (18.53)	405	71 (17.53)	400	58 (14.50)	383	75 (19.58)
Network behavior (sum totals)								
	n	mean (SD)	n	mean (SD)	n	mean (SD)	n	mean (SD)
Drank alcohol to intoxication	416	1.01 (1.91)	400	1.04 (1.75)	396	0.89 (1.49)	380	0.87 (1.43)
Used marijuana	413	0.98 (1.75)	401	0.88 (1.61)	396	0.86 (1.48)	378	0.84 (1.49)
Used illicit drugs	416	0.45 (1.47)	401	0.35 (0.93)	395	0.34 (0.91)	378	0.36 (1.07)
Indicators of substance use with proximity and location met								
Marijuana users								
Met on street, do not live nearby	413	0.15 (0.57)	400	0.08 (0.32)	395	0.05 (0.25)	378	0.07 (0.38)
Not met on street, live nearby	413	0.16 (0.59)	400	0.25 (0.73)	395	0.26 (0.73)	378	0.29 (0.74)
Met on street and live nearby	413	0.24 (0.86)	400	0.12 (0.51)	395	0.09 (0.38)	378	0.05 (0.24)
Neither met on street nor live nearby	413	0.42 (1.05)	400	0.43 (1.08)	395	0.46 (1.11)	378	0.44 (1.03)
Illicit drug users								
Met on street, do not live nearby	416	0.11 (0.53)	400	0.04 (0.23)	394	0.02 (0.19)	378	0.03 (0.21)
Not met on street, live nearby	416	0.05 (0.25)	400	0.10 (0.43)	394	0.13 (0.60)	378	0.16 (0.61)
Met on street and live nearby	416	0.17 (0.84)	400	0.07 (0.44)	394	0.06 (0.28)	378	0.04 (0.27)
Neither met on street nor live nearby	416	0.13 (0.66)	400	0.14 (0.52)	394	0.13 (0.53)	378	0.14 (0.58)
Have used alcohol to intoxication								
Met on street, do not live nearby	416	0.21 (0.73)	399	0.12 (0.40)	395	0.04 (0.22)	380	0.06 (0.26)
Not met on street, live nearby	416	0.14 (0.60)	399	0.24 (0.65)	395	0.26 (0.72)	380	0.31 (0.78)
Met on street and live nearby	416	0.22 (0.77)	399	0.14 (0.60)	395	0.11 (0.47)	380	0.06 (0.25)
Neither met on street nor live nearby	416	0.45 (1.22)	399	0.54 (1.25)	395	0.47 (1.07)	380	0.45 (0.96)
Social support								
Alcohol to intoxication								
Use and provide support	416	0.54 (1.21)	400	0.57 (1.18)	396	0.51 (1.09)	377	0.52 (1.09)
Do not use and provide support	416	4.24 (3.29)	400	3.49 (2.98)	396	3.37 (2.88)	377	3.50 (3.15)
Illicit drug users								
Use and provide support	416	0.19 (0.79)	401	0.13 (0.46)	395	0.15 (0.62)	376	0.15 (0.64)
Do not use and provide support	416	4.59 (3.46)	401	3.90 (3.21)	395	3.73 (3.04)	376	3.86 (3.31)
Marijuana users								
Use and provide support	413	0.58 (1.15)	401	0.47 (1.01)	396	0.48 (1.00)	376	0.53 (1.18)
Do not use and provide support	413	4.22 (3.23)	401	3.57 (3.06)	396	3.40 (2.88)	376	3.49 (3.18)

All models control for network size; bold cells are significantly different from baseline at $p < 0.05$.

Table 3
General linear mixed models of associations between network-level characteristics and individual-level behavior.

		Binge drinking		Marijuana		Illicit drugs	
		Odds ratio (95% CI)					
		Within	Between	Within	Between	Within	Between
Model 1	Network variables (sum totals)	(n = 415)		(n = 412)		(n = 415)	
	Each corresponding substance	1.18 (1.04–1.35)	2.07 (1.62–2.64)	1.42 (1.17–1.73)	6.41 (3.88–10.58)	2.17 (1.61–2.93)	7.47 (4.38–12.73)
Model 2	Users of each substance, with met on street and proximity	(n = 415)		(n = 412)		(n = 415)	
	Met on street, do not live nearby	2.06 (1.31–3.21)	6.75 (2.39–19.09)	1.28 (0.69–2.38)	7.53 (0.97–58.52)	2.06 (1.05–4.03)	6.98 (1.29–37.82)
	Not met on street, live nearby	1.30 (0.98–1.71)	1.83 (0.94–3.58)	1.49 (1.00–2.21)	12.72 (4.07–39.74)	2.72 (1.56–4.73)	4.17 (1.32–13.17)
	Met on street and live nearby	0.80 (0.54–1.16)	2.29 (0.97–5.41)	2.40 (1.36–4.22)	27.63 (4.42–172.78)	2.54 (1.32–4.88)	9.61 (2.50–37.01)
	Neither met on street nor live nearby	1.12 (0.91–1.37)	1.77 (1.22–2.56)	1.24 (0.96–1.61)	3.59 (1.75–7.37)	1.76 (1.10–2.79)	10.98 (3.68–32.7)
Model 3	Social support	(n = 415)		(n = 412)		(n = 415)	
	Uses and provides support	0.97 (0.81–1.17)	2.51 (1.78–3.53)	1.30 (1.01–1.69)	10.50 (5.22–21.12)	2.64 (1.69–4.14)	18.65 (7.63–45.60)
	Does not use and provides support	0.91 (0.82–1.02)	0.71 (0.61–0.84)	0.93 (0.82–1.05)	0.65 (0.51–0.83)	0.93 (0.82–1.04)	0.80 (0.66–0.96)

Models adjusted for age, gender, race/ethnicity, education, network size, substance use treatment history, any chronic mental illness, and lifetime incarceration. Bold cells are statistically significant at $p < 0.05$.

CI = 1.69–4.14). Having more social network members who provided support and were *not* perceived to use illicit drugs was protective against individual illicit drug use (OR = 0.80, 95% CI = 0.66–0.96) only at the cross-sectional level.

4. Discussion

This study identified relatively stable overall substance use in the first year after persons formerly experiencing homelessness moved into

PSH, which is consistent with several previous studies (Hwang et al., 2011; Mares and Rosenheck, 2011; O’Campo et al., 2016; Somers et al., 2015) and with the tenets of harm reduction within HF. The small changes that occurred included a slight, consistent increase in marijuana use over the first year in housing and a temporary decrease in illicit substance use at the six-month interview. Overall, participants’ reports of substance use within their social networks did not demonstrate statistically significant changes over time; however, there were considerable changes in the perceived presence of substance users with

particular proximity and relational characteristics. These findings suggest that moving into PSH is, indeed, a time of network change, as residents' network members perceived to be using substances within PSH became increasingly composed of those who lived nearby and were not originally met on the streets and disconnected from street-met network members regardless of their current proximity.

This study also shows that the presence of network members perceived to be using substance, across all substances, is associated with individual use of that substance. This study's findings support existing evidence regarding the cross-sectional link between individual-level use and network-level use among those experiencing homelessness (Rhoades et al., 2011; Song and Wenzel, 2015; Wenzel et al., 2009). Further, these findings add significantly to the literature by providing evidence of the longitudinal relationship between perceived changes within social networks and subsequent changes in individual-level substance use. To our knowledge, this is the first research to identify a potential social influence effect when examining networks and substance use among persons experiencing or formerly experiencing homelessness. Combined with the finding that substance use networks of people living in PSH tend to increasingly consist of those who live nearby and become disconnected from street-met networks, persistence in substance use for these individuals may be partially attributed to networks newly-composed of substance users living in their building or new neighborhood.

Both longitudinal and cross-sectional associations between perceived network-level and individual-level substance use varied by substance type, with network member characteristics and proximity appearing to be most important in relation to alcohol and least important for illicit substance use. Whereas individual-level binge drinking was associated cross-sectionally with only street-based network members currently living nearby who were perceived to drink to intoxication, strong cross-sectional relationships were present across nearly all categories of network members for marijuana use and illicit substance use. Longitudinally, binge drinking was associated only with changes in street-met network members not living nearby, whereas marijuana use was associated with changes in both those met on the street and living nearby and with substance users who provided support. Illicit substance use was longitudinally associated with changes in nearly all categories of network members.

Despite only small overall changes in aggregate substance use over the course of this study, the strength of these longitudinal findings demonstrates that, at the individual level, social networks are likely important mechanisms for substance use behavior change. Because increases in perceived substance-using social network members are associated with subsequent increases in individual-level use over time, the idea that substance use within the context of PSH may spread, at least in part, because of social influence or social contagion is supported (Christakis and Fowler, 2013). As such, facilitating change in the larger social-risk environment of PSH may be key to creating sustained change in individual substance use behavior. This change may be achieved through interventions focused on improving positive social integration or changing social norms around substance use within this environment.

4.1. Limitations

These findings may not be representative of all persons in PSH in the Los Angeles area. Whereas similarities were identified across several demographic domains with the larger population of those who moved into PSH in this area (Los Angeles Homeless Services Authority, 2016), how these populations compare on other domains, including histories of homelessness experiences and substance use, is unknown. Additionally, given the dense, urban context of Los Angeles, participants in this study may not be representative of those in PSH in other regions. Further, the exclusion of persons younger than 39 and those living with minor children reduces the generalizability of these data. Finally,

substance use in this study was measured by self-report, which may contain inherent bias; however, there is evidence that self-reported substance use is highly correlated with objective measures among individuals experiencing homelessness (Nyamathi et al., 2001). Some findings in this study could not be fully explored and warrant additional research. In particular, questions remain about how substance abuse treatment is associated with use in this population, as well as about the context of relationships with street-based networks not currently living nearby (e.g., How is contact with these persons maintained? What is it about street-based networks that continues to influence alcohol and illicit substance use even post-housing and at a distance?). Further, participants in this study came from 26 housing organizations throughout the county and, therefore, represent a wide array of housing models and geographic regions. The context of housing type and neighborhood characteristics may impact both substance use and social relationships in ways we were not able to fully explore in this study. Finally, because medical marijuana has been legal in California for many years, the marijuana use findings in this study may be unique to this particular context.

5. Conclusions

This study provides corroborating evidence of the cross-sectional relationship between social networks and individual-level substance use among persons who have experienced homelessness and expands existing findings providing longitudinal evidence that changes within substance-using social networks are associated with subsequent changes in individual-level substance use. These findings underscore the importance of interventions within housing aimed at promoting positive social integration and pro-social relationships and improving the social ecological context of PSH.

Because of differential relationships between specific substance use and corresponding network influence, interventions aimed at curbing substance use by reducing it within the social network may need to be substance-tailored. For example, social network-based interventions that aim to end illicit substance use may need to be more abstinence-focused, as all categories of illicit substance users in the network were longitudinally associated with personal illicit substance use, as compared with marijuana use, in which interventions may be most effective if they focus on proximal marijuana-using networks. Despite the use of the term *abstinence* with regard to illicit substances, such recommendations are meant to be compatible with the principles of harm reduction; programs aimed at reducing substance use in the social environment and improving recovery outcomes among those motivated and ready for treatment should follow harm reduction's emphasis on nonjudgment and ensure that individual substance use remains unrelated to housing eligibility. Further, any intervention attempting to reduce individual-level and network-level substance use within PSH should consider the feasibility of implementation in these settings, including time and financial constraints of service providers, as well as applicability and logistical concerns based on housing type and resident composition (e.g., scatter-site vs. single-site housing).

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Contributors

All authors contributed substantially to the research project and manuscript preparation, and all authors have approved the final article.

Conflict of interest

No conflict declared.

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