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Measuring Peer Socialization for Adolescent Substance Use: A Comparison of Perceived and Actual Friends' Substance Use Effects

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ABSTRACT. Objective: There has been an increase in the use of social network analysis in studies of peer socialization effects on adolescent substance use. Some researchers argue that social network analyses provide more accurate measures of peer substance use, that the alternate strategy of assessing perceptions of friends' drug use is biased, and that perceptions of peer use and actual peer use represent different constructs. However, there has been little research directly comparing the two effects, and little is known about the extent to which the measures differ in the magnitude of their influence on adolescent substance use, as well as how these two effects may be redundant or separate constructs. **Method:** Using Waves I and II of the National Longitudinal Study of Adolescent Health (Add Health) saturated subsample, we directly compared effects of perception of friends' use (PFU) and actual friends' use (AFU) on alcohol, cigarette, and marijuana initiation and persistence of use 1 year later. We also examined potential moderating effects of friendship quality and individual use on the relationship between perceived and actual friends' substance use and outcomes. **Results:** Results indicated that, overall, PFU effects were larger than AFU effects; however, these effects did not significantly differ in magnitude for most models. In addition, interaction effects differed for different substances and usage outcomes, indicating the meaning of PFU and AFU constructs (and thus, different types of peer socialization) may change based on substance and type of use. **Conclusions:** These results highlight the multifaceted nature of peer influence on substance use and the importance of assessing multiple aspects of peer socialization while accounting for distinct contexts related to specific substances and use outcomes. (*J. Stud. Alcohol Drugs, 76,* 267–277, 2015)

ONE OF THE BIGGEST INFLUENCES on adolescent substance use is affiliation with substance-using peers, particularly via peer socialization (e.g., Bauman & Ennett, 1996; Brechwald & Prinstein, 2011). Peer socialization effects are most commonly measured by examining the amount that peers use substances, typically through adolescent perceptions of peers' (e.g., friends, schoolmates) substance use (i.e., frequency/quantity of friends' use). Some researchers argue that this method produces biased results and that social network analysis provides more accurate estimation of peer socialization effects (Bauman & Ennett, 1996). Social network analysis studies indicate that peer socialization effects might have been overestimated by measures of perceived friends' substance use (PFU) (e.g., Kiuru et al., 2010; Knecht et al., 2011; Kobus & Henry, 2010). This has led researchers to argue that social network analysis, which allows for estimation of actual friends' substance use (AFU), should be used whenever possible (Henry et al., 2011) because of potential biases related to PFU measures and differences in the meaning between AFU and PFU effects. However, few studies have directly compared these two methods as substance use predictors (e.g., Iannotti & Bush, 1992).

Perception of friends' use bias

One potential source of bias in PFU measures is projection, which Bauman and Ennett (1996) detail in their seminal paper on peer socialization measurement strategies. This is known as a false consensus effect (Ross et al., 1977), in which individuals assume that friends engage in behaviors at levels similar to their own (Marks & Miller, 1987). Substance users tend to overestimate—and nonusers underestimate—friend and peer substance use (Henry et al.,

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2011; Martens et al., 2006; Prinstein & Wang, 2005). Such a bias could explain the overestimation of peer effects for PFU measures. The few studies examining PFU and AFU simultaneously indicate that PFU effects appear to be larger than AFU effects (Bauman & Fisher, 1986; Iannotti & Bush, 1992; Urberg et al., 1990). To date, there has been no formal test of whether the effects of PFU or AFU on adolescent substance use significantly differ from each other. In other words, although PFU may overestimate the importance of peer influence, how substantial is this overestimation?

Contextual differences influencing effects of actual and perceived friends' use

AFU and PFU effects may differ by substance and use outcome. Researchers examining multiple substances find differences in peer effects (Ennett et al., 2006; Kiuru et al., 2010; Kobus & Henry, 2010), perhaps because of specific substance-related characteristics. For example, alcohol is often consumed within social contexts (Kuntsche et al., 2005) and is seen as a high-status behavior (Osgood et al., 2013). Tobacco and marijuana use are more related to selection (i.e., friend selection and friendship group foundation) rather than socialization influences (de la Haye et al., 2013; Kiuru, 2010). Differences in socialization effects based on the specific substance may lead to differences in the importance of AFU and PFU as predictors.

There may also be differences based on substance use outcome (e.g., initiation, experimentation, persistence). As adolescents tend to select peers homophilous for substance use (de la Haye et al., 2013; Knecht et al., 2011; Valente et al., 2004), those engaging in at least some substance use may be more at risk for socialization effects than nonusers. Friend norms and modeling behavior effects within higher–substance-using friendship groups may reinforce substance use behavior (behavioral maintenance) and strengthen active substance use behavior. Nonusers tend to choose more nonusing friends, thereby reducing exposure and susceptibility to peer socialization (Osgood et al., 2013). Socialization effects have been found for substance use initiation (i.e., substance-using peers influencing initiation in nonusers; Light et al., 2013), although not as strongly as for persistence (D'Amico & McCarthy, 2006). Thus, another important question is whether AFU and PFU effects differ in predicting different substance use outcomes.

Differential meanings of actual and perceived friends' use

Bauman and Ennett (1996) argue that, even if PFU is more closely related to adolescent substance use than is AFU, only AFU is a true peer influence variable (the cause of AFU is attributed to the friend, whereas PFU is an internal construct). However, AFU has a strong influence on (and is strongly related to) PFU (Urberg et al., 1990). One way to examine the distinctness between AFU and PFU is by testing whether AFU and PFU effects are differentially moderated by individual or relationship characteristics related to later use.

Previous research indicates that errors in the estimation of friends' behaviors relate to individual behavior and friendship quality (Henry et al., 2011; Prinstein & Wang, 2005). Results from social network analysis studies demonstrate that friendship quality (closer affiliation with peers) influences AFU effects on individual use (Ennett et al., 2006; Kobus & Henry, 2010). It is possible that, regardless of PFU, closer friendships provide stronger reinforcement of use or nonuse based on the increased amount of time individuals spend with a friend (increasing exposure to AFU). Conversely, adolescent personal use may moderate PFU more than AFU, as it may be more of a reflection of false consensus or norms with which an adolescent self-identifies (Brechwald & Prinstein, 2011; Prinstein & Wang, 2005).

Current study

Based on previous studies regarding AFU and PFU measures, we had three research questions. First, we were interested in examining the following: (a) whether AFU and PFU have individual effects on adolescent substance use 1 year later and (b) if these effects were similar in magnitude, or if PFU had a stronger effect on individual substance use, indicating potential bias related to the false consensus effect. Second, we examined whether AFU and PFU acted similarly for different substances (alcohol, cigarette, and marijuana use) and different outcomes (initiation and persistence). Third, we tested the extent to which AFU and PFU might represent separate constructs of peer socialization two different ways: interaction with two specific contexts (individual use status and friendship quality) and interaction with each other.

Based on previous work regarding false consensus bias, we expected that PFU, rather than AFU, would interact with individual use; higher individual substance use would increase the effect of PFU. Based on work regarding social context effects within peer networks, we expected that AFU, rather than PFU, would interact with friendship quality; as the quality of the friendship increased (e.g., closer friendships), the effect of AFU would become stronger. We also hypothesized that there would be a significant interaction between AFU and PFU in predicting substance use 1 year later, providing further evidence that AFU and PFU represent individual constructs of socialization.

Method

Participants

Participants were from Waves I (WI) and II (WII) of the in-home survey of the National Longitudinal Study of

Adolescent Health (Add Health) (see Blum et al., 2000, for sampling design and procedure information). The present study used the saturated subsample, in which all students within 16 schools were interviewed to obtain complete network information (Harris, 2013). The full sample was used for estimating AFU (via peer nomination) at WI. The sample used for models predicting peer socialization effects was restricted to students in Grades 7–11 who completed in-home WI and WII interviews and who attended the same school at both waves, restricting the sample to 2,701 participants. Only adolescents who nominated three or more (in-school) friends were included in the sample so the AFU measure would match the PFU measure (see details below), restricting the final sample to 1,192 participants.

Analyses were conducted to examine if individuals from the saturated subsample who were excluded were significantly different from those included in the sample. The only significant difference between the groups was that, compared with those who reported having three or more friends, those who reported fewer than three friends or no in-school friends smoked significantly more cigarettes at WI. Average age at WI was 15.71 years. The sample was 50% male, 59% White/European American, 8.85% Black/African American, 7% Latino, 13.74% Asian American, 1% Native American, and 10.71% biracial.

Measures

Drinking initiation. Drinking initiation was assessed at WI and WII by the question, "Have you ever had a drink of beer, wine or liquor—not just a sip or a taste of someone else's drink—more than two or three times (in your life [WI]; since month of last interview [WII])?" Answers were coded with a binary score (0 = no/no use, 1 = yes/have used).

Drinking frequency. WI and WII drinking frequency was assessed with the question, "During the past 12 months, on how many days did you drink alcohol?" using a 7-point scale from 0 (*never*) to 6 (*every day* or *almost every day*). Because of the skewness of results, this variable (at WI and WII) was recoded into a 5-point scale, in which any score of 4 or higher (score of 4 = *one or two days a week*) was re-coded to a score of 4. A score of 4 was used as the cutoff because 91.74% of the sample at WI and 87.70% at WII scored a 3 or below.

Smoking initiation. WI and WII smoking initiation was assessed by the question, "Have you ever tried cigarette smoking, even just one or two puffs (WI) (since month of last interview [WII])?" This question was used as a WII initiation question for WI nonsmokers. Answers were coded with a binary (0 = no/no use, 1 = yes/have used).

Smoking frequency. WI and WII smoking frequency were assessed with the question, "During the past 30 days, on how many days did you smoke cigarettes?" and measured using a continuous scale. This measure was recoded to reflect number of days smoked per week, on an 8-point scale from 0 (*no days a week*) to 7 (*7 days a week*).

Marijuana initiation. WI marijuana use initiation was assessed by the question, "How old were you when you tried using marijuana for the first time?" (0 = never used). This was recoded into a dichotomous WI ever-used score (0 = no, 1 = yes). WII marijuana use status was assessed by the question, "Since month of last interview, have you tried or used marijuana?" This question was used as a WII initiation question for WI nonusers. Answers were coded with a binary (0 = no/no use, 1 = yes/have used).

Marijuana use frequency. WI and WII frequency of marijuana use were assessed with the question, "During the past 30 days, how many times have you used marijuana?" Frequency was assessed with responses ranging from 0 to 500. This variable was recoded such that individuals who reported using marijuana five or more times were scored as 5 because of the sparse numbers of marijuana users reporting using marijuana more than five times at WI (14%) and WII (25%).

Number of friends nominated (outdegree). At WI, all participants were asked to nominate up to 10 friends (five male, five female), starting with their "best friend." Participant ID numbers from nominated participants were entered as the friendship nominations. Youth with romantic partners were asked to list their partners as the first friend nominee. Romantic partners were coded with a "5555555" instead of their identification (ID) number and were therefore precluded from the friendship social networks. Nominated individuals who were not in the sample schools were also specially coded and precluded from the friendship networks because of a lack of an ID number. Neither romantic partners nor friends from other schools were counted in each participant's ego network.

Perceived friends' substance use. Adolescents were asked how many of their "three best friends" smoked at least one cigarette a day (i.e., were daily smokers), drink alcohol at least once a month, and use marijuana at least once a month at WI. Scores ranged from 0 (*no friends*) to 3 (*three friends*) for each question. Each substance was scored separately.

Actual friends' substance use. AFU substance use assessment included up to five best male friends and five best female friends (i.e., substance use behavior of all friends nominated). Additional steps were taken to align the AFU and PFU scores by selecting the top three friends that each adolescent nominated. The top three friends were selected by choosing the three friends who had the highest friendship quality scores. In the case of a tie, rank order of friends (i.e., the order in which the friends were nominated) was used to break the tie.

To assess average substance use of the three best friends, we converted the friendship nomination data into a matrix data set and then used the R package statnet (Handcock et al., 2003) to assess ego networks (the three

best friends nominated) and their covariates. Ego network–level covariates (e.g., how much an individual's three best friends drink) were computed by multiplying the original binary social network matrix, *A,* with the variable of interest, *v,* to obtain the sum vector $Av_{n \times 1}$. (Note: Because *A* is an $n \times n$ matrix of binary relationships and *v* is an $n \times 1$ variable vector, $Av_{n \times 1}$ will be an $n \times 1$ vector of sums.) AFU scores were recoded to align with the measurement used for the PFU scores.

Personal report of cigarette use was recoded as a binary variable measure that matched perceived friends' cigarette daily smoking status. Those who scored a "7" (daily smoker for the past 30 days) were coded with a "1," whereas those who reported 6 or less on the individual cigarette score (nondaily smoker/nonsmoker) were coded with a "0". This variable was summed for the three best friends within each adolescent's ego network. Personal report of drinking was recoded as a binary variable measure that matched the perceived friends' drinking question. Individuals who reported drinking "2 or 3 days a month" or more were coded with a "1," whereas those who reported drinking "once a month or less" were coded with a 0. This variable was summed for the three best friends within each adolescent's ego network. Personal report of marijuana use (ever using marijuana in the past 30 days) was similar enough to the PFU marijuana use question that no recoding was needed. The original variable was summed for the three best friends within each adolescent's ego network.

Friendship quality. Respondents reported for each friend they nominated if they had met after school to hang out, spent time over the weekend, discussed a problem, or talked on the phone in the past 7 days (male: $\alpha = .70$; female: $\alpha = .72$) at WI. Each item was scored on a binary yes/no (1/0) scale and was then were averaged over the five items. Scores relating to the nominated three best friends were summed into an aggregate friendship quality score (range of scores: 0–3). Although this measure most directly assesses friend "closeness," the term "quality" is used to avoid confusion with the social network analysis definition of closeness.

School average of substance use behaviors. Assessment of all students at WI in each school allowed for the accurate representation of school means. Average reported initiations (ever having used) and frequencies of individual smoking, drinking, and marijuana use were separately calculated for each school at WI and were used as the school-level variables for their respective models.

Analytic plan

Multilevel models (individuals nested within schools) were estimated using Mplus 7 (Muthén & Muthén, 1998–2012) type TWOLEVEL RANDOM COMPLEX, allowing for estimation of a random intercept accounting for interdependence within schools and accurate modeling of complex data. Group-mean centering (Enders & Tofighi, 2007) was used in persistence models to accurately estimate individual (Level 1) within-school effects of individual substance use at WI, as individuals were nested within schools (Level 2). A robust maximum likelihood estimator was used to account for data missing at random. For models predicting initiation of alcohol, cigarette, and marijuana use, binary logistic regressions were estimated and restricted to individuals who reported never using alcohol ($n = 482$), cigarettes ($n = 483$), or marijuana ($n = 798$) at WI. These models had three steps: an AFU-only model (Step 1), adding PFU (Step 2), and adding interactions between AFU and PFU and friendship quality (Step 3).

Multivariate logistic regression models predicting persistence of alcohol and cigarette use and a zero-inflated Poisson regression model predicting persistence of marijuana use (WII frequency of use controlling for WI frequency of use) were restricted to individuals who reported using alcohol ($n = 707$), cigarettes ($n = 707$), or marijuana ($n = 389$) by WI. A zero-inflated Poisson was chosen to estimate the marijuana model, as it had a better model fit than a Poisson model ($\Delta AIC = 248.73$, where ΔAIC is the change in Akaike Information Criterion) or a negative binomial model ($\Delta AIC = 94.94$). These models had four steps: an AFU-only model (Step 1), adding PFU (Step 2), adding interactions between AFU and PFU and WI personal use (Step 3), and adding interactions between AFU and PFU and friendship quality (Step 4).

To test if AFU and PFU effects were statistically different from each other, the effects were constrained to be equal. For this analysis, the final models were used. The constraint was tested for every model (all substances and both outcomes). A rescaled log-likelihood test for nested model comparisons was used to compare the initial model (unconstrained parameters) with the nested model (constrained parameters). Last, the interaction between PFU and AFU was examined in each main effects model to examine if they contributed separately to peer socialization or if they were redundant.

Results

Descriptive analyses

Table 1 displays means and standard deviations of all variables for individuals who reported using or not using alcohol, cigarettes, and marijuana at WI. Table 2 displays partial correlations, accounting for nesting of schools, between all variables.

Initiation of alcohol, cigarette, and marijuana use

Table 3 displays results for the binary logistic regression models estimating alcohol, cigarette, and marijuana use initiation. AFU of marijuana was positively related to marijuana

TABLE 1. Means and standard deviations of model variables for adolescents reporting ever used and never used alcohol, cigarettes, and marijuana by Wave I (WI)

	Alcohol		Cigarettes		Marijuana	
Variable	Used by WI (n = 707) M (SD)	Never used by WI (n = 482) M (SD)	Used by WI (n = 707) M (SD)	Never used by WI (n = 483) M (SD)	Used by WI (n = 389) M (SD)	Never used by WI (n = 798) M (SD)
Frequency of drinking WI	1.86 (1.37)	–	1.58 (1.46)	0.41 (0.93)	2.13 (1.49)	0.60 (1.02)
Frequency of drinking WII	1.80 (1.63)	0.41 (1.00)	1.65 (1.65)	0.62 (1.22)	2.14 (1.75)	0.79 (1.28)
Frequency of smoking WI	1.56 (2.02)	0.28 (1.00)	1.97 (2.06)	–	2.25 (2.16)	0.41 (1.14)
Frequency of smoking WII	1.62 (2.05)	0.42 (1.20)	1.78 (2.10)	0.18 (0.72)	2.28 (2.18)	0.58 (1.34)
Frequency of marijuana use WI	0.84 (1.65)	0.08 (0.50)	0.80 (1.62)	0.13 (0.70)	1.63 (1.99)	–
Frequency of marijuana use WII	0.89 (1.73)	0.19 (0.87)	0.89 (1.75)	0.19 (0.81)	1.53 (2.09)	0.17 (0.77)
School frequency of drinking WI	0.97 (0.65)	0.76 (0.60)	0.98 (0.65)	0.75 (0.60)	1.02 (0.67)	0.82 (0.62)
School frequency of smoking WI	1.27 (0.61)	0.98 (0.62)	1.28 (0.61)	0.98 (0.63)	1.34 (0.59)	1.07 (0.63)
School frequency of marijuana use WI	0.69 (0.25)	0.55 (0.29)	0.67 (0.25)	0.57 (0.29)	0.75 (0.18)	0.57 (0.29)
Perceived friends' drinking	1.52 (1.16)	0.46 (0.82)	1.42 (1.18)	0.60 (0.93)	1.81 (1.11)	0.74 (1.01)
Perceived friends' smoking	1.08 (1.17)	0.47 (0.85)	1.12 (1.17)	0.41 (0.80)	1.45 (1.21)	0.53 (0.89)
Perceived friends' marijuana use	0.93 (1.01)	0.27 (0.68)	0.92 (1.10)	0.29 (0.69)	1.47 (1.12)	0.27 (0.64)
Actual friends' drinking	0.65 (0.81)	0.29 (0.57)	0.63 (0.80)	0.32 (0.62)	0.81 (0.88)	0.35 (0.61)
Actual friends' smoking	0.39 (0.69)	0.17 (0.46)	0.42 (0.72)	0.13 (0.39)	0.57 (0.80)	0.17 (0.46)
Actual friends' marijuana use	0.67 (0.82)	0.26 (0.56)	0.67 (0.83)	0.27 (0.55)	0.94 (0.86)	0.30 (0.60)
Disparity between perceived and actual friends' drinking (absolute value)	1.12 (0.96)	0.45 (0.69)	1.06 (0.96)	0.53 (0.75)	1.24 (0.97)	0.65 (0.83)
Disparity between perceived and actual friends' smoking (absolute value)	0.78 (0.93)	0.38 (0.71)	0.81 (0.93)	0.34 (0.69)	0.99 (0.96)	0.44 (0.76)
Disparity between perceived and actual friends' marijuana use (absolute value)	0.71 (0.80)	0.34 (0.65)	0.71 (0.80)	0.34 (0.64)	0.97 (0.84)	0.36 (0.63)
Friendship quality	1.83 (.71)	1.58 (0.75)	1.83 (0.71)	1.58 (.76)	1.94 (0.70)	1.63 (0.74)
No. of friends nominated	4.95 (1.75)	4.88 (1.77)	4.96 (1.75)	4.88 (1.76)	4.90 (1.75)	4.94 (1.75)
Age, in years	15.96 (1.25)	15.54 (1.51)	15.92 (1.29)	15.60 (1.47)	16.17 (1.08)	15.61 (1.46)
Gender	0.48 (0.50)	0.52 (0.50)	0.52 (0.50)	0.47 (0.49)	0.45 (0.49)	0.53 (0.50)
Race	0.45 (0.50)	0.39 (0.49)	0.49 (0.50)	0.36 (0.48)	0.43 (0.49)	0.38 (0.49)

Notes: Gender coded as boys = 0, girls = 1. Race coded as 0 = White/European American, 1 = non–White/European American.

initiation 1 year later; however, the AFU effect disappeared when accounting for PFU. PFU had a positive relationship with both alcohol and cigarette initiation and held for alcohol use even when accounting for a Bonferroni correction. Friendship quality did not moderate PFU and AFU for alcohol or cigarette use. However, friendship quality moderated PFU of marijuana, such that the effect of PFU of marijuana was a stronger predictor of marijuana use initiation 1 year later when friends were not as close.

AFU and PFU effects were constrained to be equal for each substance use main effect model (Step 2). Log-likelihood tests indicated that, for alcohol use initiation, model fit of the main effect model (see Step 2) did not get significantly worse when AFU and PFU effects were constrained to be equal, $\Delta\chi^2(1) = 0.37$, $p > .05$, indicating that the two effects were not significantly different from each other in magnitude. However, model fit did become worse for the cigarette, $\Delta\chi^2(1) = 24.84$, $p < .05$, and marijuana, $\Delta\chi^2(1) = 4.83$, $p < .05$, initiation, indicating that PFU had a significantly stronger effect than AFU on cigarette use initiation and AFU had a stronger effect than PFU for marijuana use initiation. Last, interactions between AFU and PFU for all three substances were examined. Interactions between AFU and PFU for smoking (odds ratio [OR] = 0.78, 95% CI [0.56, 1.09], $p > .05$), alcohol (OR = 1.04, 95% CI [0.74, 1.45], $p > .05$), and marijuana (OR = 0.93, 95% CI [0.72, 1.21], $p > .05$) initiation were not significant.

Persistence of alcohol, cigarette, and marijuana use

Table 4 displays results for the multinomial logistic regression models for alcohol and cigarette use persistence and the zero-inflated Poisson models for marijuana use persistence. AFU of marijuana use was related to an increase in individual use 1 year later. This effect disappeared when PFU was added to the marijuana model, although PFU itself was not significantly related to persistence. PFU was related to an increase in cigarette and alcohol use 1 year later, and this relationship held for alcohol use even when accounting for a Bonferroni correction.

For marijuana use, there was an interaction between AFU and individual use at WI, such that the effect of AFU was

TABLE 2. Partial correlations controlling for interdependence of school for all model variables

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.
1. Ever drank alcohol WI	–																									
2. Ever drank alcohol WII	.50	–																								
3. Frequency of drinking WI	.69	.52	–																							
4. Frequency of drinking WII	.47	.80	.60	–																						
5. Ever smoked WI	.50	.41	.50	.39	–																					
6. Ever smoked WII	.41	.45	.43	.43	.62	–																				
7. Frequency of smoking WI	.34	.31	.42	.35	.54	.50	–																			
8. Frequency of smoking WII	.36	.38	.41	.40	.52	.64	.72	–																		
9. Ever used marijuana WI	.44	.36	.54	.42	.51	.42	.47	.46	–																	
10. Ever used marijuana WII	.36	.41	.42	.44	.41	.47	.42	.47	.53	–																
11. Frequency of marijuana use WI	.27	.21	.43	.32	.29	.29	.42	.37	.56	.41	–															
12. Frequency of marijuana use WII	.24	.27	.32	.35	.28	.31	.43	.43	.43	.66	.52	–														
13. School frequency of drinking WI	.20	.27	.28	.27	.29	.32	.30	.28	.18	.25	.18	.20	–													
14. School frequency of smoking WI	.26	.23	.26	.26	.29	.29	.33	.33	..23	.22	.16	.20	.89	–												
15. School frequency of marijuana use WI	.26	.23	.25	.25	.24	.20	.24	.19	.31	.26	.19	.22	.85	.64	–											
16. Perceived friends drinking	.47	.41	.59	.50	.40	.20	.39	.38	.44	.33	.36	.30	.32	.30	.26	–										
17. Perceived friends' smoking	.29	.27	.36	.31	.39	.37	.58	.54	.41	.34	.33	.34	.30	.32	.21	.43	–									
18. Perceived friends' marijuana use	.33	.30	.42	.36	.36	.36	.42	.40	.57	.42	.57	.40	.27	.22	.30	.54	.52	–								
19. Actual friends' drinking	.25	.27	.34	.34	.24	.26	.28	.27	.28	.26	.22	.22	.27	.27	.20	.41	.40	.32	–							
20. Actual friends' smoking	.18	.18	.29	.21	.29	.28	.47	.39	.30	.25	.26	.28	.26	.30	.18	.29	.52	.32	.35	–						
21. Actual friends' marijuana use	.25	.26	.33	.28	.30	.30	.41	.34	.38	.35	.34	.33	.31	.26	.33	.34	.38	.46	.48	.42	–					
22. Friendship quality	.18	.21	.22	.21	.17	.21	.20	.21	.21	.22	.17	.19	.29	.27	.30	.21	.16	.15	.19	.15	.17	–				
23. No. of friends nominated	.02	.09	.05	.08	.03	.09	.02	.03	-.01	.07	.03	.03	.15	.22	.10	.12	-.01	.05	.12	.03	.10	.29	–			
24. Age	.15	.17	.15	.19	.11	.03	.07	.05	.19	.09	.09	.05	.28	.08	.41	.21	.11	.15	.20	-.08	.16	.16	-.05	–		
25. Gender	-.03	-.06	-.06	-.12	.04	.05	.04	.01	-.04	.02	-.04	.03	-.02	-.01	-.03	-.11	.02	-.07	-.04	.02	-.06	.11	-.01	-.06	–	
26. Race	-.09	-.09	-.12	-.11	-.17	-.23	-.22	-.23	-.06	-.08	-.06	-.10	-.28	-.65	-.08	-.14	-.20	-.06	-.15	-.21	-.08	-.13	-.18	.20	-.02	–

Notes: Gender coded as boys = 0, girls = 1. Race coded as 0 = White/European American, 1 = non–White/European American. W = wave.
Correlations above $r = |.06|$ are significant at the $p < .05$ level.

TABLE 3. Odds ratios and confidence intervals for models predicting alcohol, cigarette, and marijuana use initiation by Wave II for adolescents reporting no use by Wave I

	Alcohol			Cigarettes			Marijuana		
Variable	Step 1	Step 2	Step 3	Step 1	Step 2	Step 3	Step 1	Step 2	Step 3
Age	1.02 [0.98, 1.23]	1.11 [0.93, 1.33]	1.12 [0.91, 1.38]	0.75 [0.57, 0.98]	0.76 [0.58, 1.00]	0.76 [0.59, 1.00]	0.96 [0.76, 0.1.22]	0.94 [0.75, 1.17]	0.93 [0.75, 1.16]
Gender	1.22 [0.84, 1.76]	1.22 [0.74, 2.05]	1.25 [0.76, 2.04]	1.24 [0.62, 2.50]	1.36 [0.70, 2.28]	1.26 [0.70, 2.28]	1.26 [0.80, 1.97]	1.30 [0.76, 2.23]	1.39 [0.83, 2.33]
Race	0.87 [0.65, 1.16)	0.75* [0.59, 0.96]	0.76 [0.88, 1.00]	1.33 [0.52, 3.35]	1.57 [0.67, 3.65]	1.53 [0.64, 3.66]	0.91 [0.69, 1.18]	0.69**† [0.56, 0.87]	0.68* [0.52, 0.88]
No. of friends	1.08 [0.91, 1.27]	1.09 [0.90, 1.32]	1.10 [0.90, 1.33]	1.05 [0.88, 1.25]	1.06 [0.88, 1.29]	1.06 [0.87, 1.28]	1.05 [0.96, 1.15]	1.02 [0.93, 1.11]	1.00 [0.90, 1.11]
Friendship quality	1.22 [1.03, 1.43]	1.01 [0.74, 1.38]	0.96 [0.61, 1.51]	1.59 [0.85, 3.99]	1.66 [0.91, 3.05]	1.56 [0.70, 3.48]	0.97 [0.55, 1.73]	1.10 [0.66, 1.84]	1.12 [0.74, 1.69]
Average school substance use (Level 2 group variable)	4.56 [0.88, 23.75]	3.02 [0.57, 16.02]	2.80 [0.52, 14.92]	3.86 [0.33, 44.61]	1.41 [0.09, 22.19]	1.45 [0.09, 23.02]	18.32* [2.36, 142.05]	7.82* [1.20, 50.74]	7.43* [1.19, 47.86]
Actual friend substance use	1.70^ [1.00, 2.88]	1.36 [0.78, 2.38]	1.40 [0.90, 2.19]	1.86 [0.90, 3.86]	0.88 [0.63, 1.24]	0.87 [0.63, 1.19]	2.28* [1.16, 4.47]	1.46 [0.86, 2.50]	1.31 [0.72, 2.39]
Perceived friend substance use	–	1.67**† [1.48, 1.89]	1.65**† [1.51, 1.78]	–	2.27**† [1.58, 3.28]	2.45**† [1.58, 3.82]		2.29**† [2.04, 2.57]	2.33**† [2.00, 2.71]
AFU × Friendship Quality	–	–	1.33 [0.69, 2.57]	–	–	0.48 [0.09, 2.57]	–	–	1.44 [1.05, 1.97]
PFU × Friendship Quality	–	–	0.84 [0.54, 1.31]	–	–	1.45 [0.96, 2.18]	–	–	0.49**† [0.41, 0.59]

Notes: Effective sample sizes: Alcohol $n = 474$; cigarette $n = 475$; marijuana $n = 786$. Confidence intervals in brackets. "Substance use" variables refer to the respective substance examined as the outcome (e.g., "substance use" variables for the alcohol model refers to alcohol use only). Level 2 average school substance use refers to the average initiation of use status (average number of individuals who reported initiation of using each substance for the respective model) at WI within each school. Gender coded as boys = 0, girls = 1. Race coded as 0 = White/European American, 1 = non–White/European American. ^$p < .06$; *$p < .05$; **$p < .01$; †significant when accounting for Bonferroni adjustment ($p < .02$).

stronger as adolescents reported a higher frequency of use at WI for both alcohol and marijuana. PFU also interacted with WI personal use for alcohol, cigarette, and marijuana use. For alcohol and marijuana use, PFU was weaker as WI personal use increased. For cigarette use, PFU was stronger as WI personal use increased. For cigarette and marijuana persistence, friendship quality moderated AFU. For cigarette persistence, AFU of cigarettes had a stronger effect on increased cigarette use 1 year later when friends were closer. For marijuana use, AFU of marijuana had a stronger effect on increased marijuana use 1 year later when friends were less close. In addition, marijuana PFU was also moderated by friend quality, such that PFU of marijuana had a stronger effect on increased marijuana use 1 year later when friends were less close.

AFU and PFU were not significantly different from each other for any of the models; log-likelihood tests indicated that model fit of the main effect model (Step 2) did not get significantly worse when AFU and PFU effects were constrained to be equal for the alcohol (although there was a trend toward significance), $\Delta\chi^2(1) = 3.82$, $p > .06$; cigarette, $\Delta\chi^2(1) = 0.71$, $p > .05$; or marijuana, $\Delta\chi^2(1) = 0.25$, $p > .05$, models. Last, interactions between PFU and AFU were examined. Interactions for the smoking (OR = 0.97, 95% CI [0.88, 1.09], $p > .05$), alcohol (OR = 0.92, 95% CI [0.78, 1.08], $p > .05$), and marijuana ($b = .01$, 95% CI [-.01, .03], $p > .05$) persistence models were not significant.

Discussion

This study highlights potential differences AFU and PFU can have on adolescent substance use as well as how effects may change because of both friendship quality and individual substance use. Results demonstrate that, whereas PFU appears to overestimate the effect of direct peer use on individual substance use, as other researchers have established, PFU and AFU effects are typically not significantly different from each other. Ultimately, the results indicate that there is a substantial amount of redundancy between AFU and PFU measures, although the distinct aspects of AFU and PFU may be influenced by different contexts.

Although PFU appeared to be a stronger effect in some models, there were only two instances in which effects significantly differed from each other. The effect of PFU was significantly stronger than AFU for cigarette and marijuana initiation, indicating, as other researchers have argued (e.g., Bauman & Ennett, 1996; Henry et al., 2011), that PFU is a biased measure that overestimates peer socialization effects. In addition, the interaction between AFU and PFU was not significant for any of the six models, indicating a high level of redundancy between the measures.

This does not mean that PFU is always a sufficient proxy variable for AFU; similarity between the two seems to depend on substance type and use outcome. The importance of PFU for cigarette and marijuana use initiation indicates

TABLE 4. Odds ratios and confidence intervals from multinomial logistic regression models predicting frequency of alcohol and cigarette use, and zero-inflated Poisson estimates and confidence intervals for models predicting frequency of marijuana use, at Wave II for individuals reporting use by Wave I

	Alcohol[a]				Cigarettes[a]				Marijuana[b]			
Variable	Step 1	Step 2	Step 3	Step 4	Step 1	Step 2	Step 3	Step 4	Step 1	Step 2	Step 3	Step 4
Age	1.05	1.00	1.01	1.00	0.97	0.95	0.97	0.96	-0.06	-0.07*	-0.11**†	-0.10**†
	[0.97, 1.14]	[0.82, 1.16]	[0.89, 1.45]	[0.89, 1.14]	[0.88, 1.06]	[0.86, 1.05])	[0.89, 1.07]	[0.85, 1.09]	[-0.11, -0.01]	[-0.11, -0.04]	[-0.13, -0.08]	[-0.13, -0.07]
Gender	0.67**†	0.65**†	0.64**†	0.65**†	0.97	0.95	0.94	0.94	0.11	0.10	0.06	0.05
	[0.55, 0.82]	[0.52, 0.83]	[0.52, 0.80]	[0.51, 0.83]	[0.72, 1.30]	[0.69, 1.31]	[0.70, 1.27]	[0.71, 1.26]	[0.01, 0.22]	[-0.01, 0.21]	[-0.04, 0.15]	[-0.04, 0.15]
Race	0.97	1.04	1.02	1.00	0.48	0.65	0.50	0.48	-0.16*	-0.16*	0.20**†	-0.20***
	[0.69, 1.37]	[0.72, 1.50]	[0.72, 1.45]	[0.70, 1.44]	[0.18, 1.33]	[0.21, 1.97]	[0.19, 1.31]	[0.18, 0.28]	[-0.28, -0.05]	[-0.27, -0.05]	[-0.32, -0.08]	[-0.32, -0.08]
No. of friends	1.06**†	1.05**†	1.06**	1.06**†	0.93	0.93	0.93	0.95	-0.02*	-0.03	-0.02	-0.02
	[1.02, 1.09]	[1.01, 1.09]	[1.02, 1.10]	[1.02, 1.09]	[0.85, 1.02]	[0.85, 1.03]	[0.86, 1.01]	[0.88, 1.01]	[-0.07, 0.02]	[-0.06, 0.01]	[-0.05, 0.01]	[-0.04, 0.01]
Friendship quality	1.26	1.28**†	1.28**	1.33*	1.39	1.25	1.36	1.33	0.01	0.01	-0.01	-0.08*
	[1.04, 1.52]	[1.06, 1.53]	[1.06, 1.55]	[1.02, 1.73]	[0.90, 2.15]	[0.84, 1.88]	[0.92, 2.00]	[0.91, 1.85]	[0.03, 0.04]	[-0.02, 0.04]	[-0.05, 0.02]	[-0.13, -0.02]
Substance use at Wave I	2.20**†	1.89**†	2.02**	2.02**†	2.15**†	1.98**†	1.94**†	1.94**†	0.14**†	0.12**†	0.16**†	0.17**†
	[1.74, 2.77]	[1.42, 2.51]	[1.30, 3.14]	[1.59, 2.56]	[2.07, 2.23]	[1.78, 2.21]	[1.79, 2.09]	[1.80, 2.10]	[0.12, 0.16]	[0.12, 0.13]	[0.14, 0.18]	[0.14, 0.19]
Average school substance use (Level 2 group variable)	2.20**†	1.91	1.93	1.91	2.78	1.78	2.38	2.49	0.21	0.22	0.32	0.31
	[1.05, 4.65]	[0.92, 2.28]	[0.94, 3.99]	[0.94, 3.86]	[0.78, 9.96]	[0.74, 4.31]	[0.73, 7.87]	[0.78, 8.02]	[-0.40, 0.81]	[-0.39, 0.83]	[-0.26, 0.90]	[-0.27, 0.89]
Actual friend substance use	1.20	1.14	1.07	1.09	1.06	0.98	1.02	0.99	0.11*	0.10	0.03	0.08
	[1.02, 1.39]	[0.84, 1.53]	[0.71, 1.62]	[0.81, 1.48]	[0.75, 1.51]	[0.69, 1.39]	[0.66, 1.57]	[0.74, 1.32]	[0.02, 0.19]	[0.01, 0.19]	[-0.06, 0.12]	[-0.01, 0.15]
Perceived friend substance use	–	1.47**†	1.54**	1.55**†	–	1.21*	1.18*	1.19*	–	0.07	0.11	0.10
		[1.38, 1.56]	[1.40, 1.70]	[1.40, 1.74]		[1.02, 1.43]	[1.03, 1.31]	[1.01, 1.33]		[-0.05, 0.18]	[0.01, 0.22]	[-0.01, 0.21]
AFU × Personal Use	–	–	1.10	1.10	–	–	0.96	0.94	–	–	0.04**†	0.04**
			[0.96, 1.26]	[0.96, 1.28]			[0.84, 1.09]	[0.83, 1.07]			[0.03, 0.05]	[0.03, 0.05]
PFU × Personal Use	–	–	0.88*	0.88*	–	–	1.09	1.10*	–	–	-0.05**†	-0.05**†
			[0.78, 0.99]	[0.78, .99]			[0.95, 1.26]	[1.01, 1.20]			[-0.07, 0.02]	[-0.08, -0.03]
AFU × Friendship Quality	–	–	–	0.95	–	–	–	1.65**†	–	–	–	-0.08**†
				[0.67, 1.34]				[1.31, 2.08]				[-0.10, -0.05]
PFU × Friendship Quality	–	–	–	0.95	–	–	–	0.97	–	–	–	0.09**†
				[0.86, 1.05]				[0.74, 1.27]				[-.04, 0.14]

Notes: Effective sample sizes: Alcohol $n = 695$; cigarette $n = 522$; marijuana $n = 361$. Confidence intervals in brackets. "Substance use" variables refer to the respective substance examined as the outcome (e.g., "substance use" variables for the alcohol model refers to alcohol use only). Level 2 average school substance use refers to the average frequency of use at WI within each school. Gender coded as boys = 0, girls = 1. Race coded as 0 = White/European American, 1 = non–White/European American; AFU = actual friend substance use; PFU = perceived friend substance use. [a]multivariate logistic odds ratios; [b]zero-inflated Poisson estimates.

*$p < .05$; **$p < .01$; †significant when accounting for Bonferroni adjustment ($p < .012$).

that the way in which peers influence substance use (i.e., exposure to substance-using peers or group cultivation of peer normative values regarding use) may be different for specific substances and different outcomes, which may explain differences found in studies examining multiple substances (Ennett et al., 2006; Kiuru et al., 2010; Kobus & Henry, 2010). However, results indicated that, overall, although PFU may tend to overestimate peer socialization effects, the effects for AFU and PFU may be somewhat comparable, and findings in previous studies using PFU measures should not be wholly discounted as they may, in part, reflect genuine AFU effects.

We also investigated whether AFU and PFU represent separate aspects of peer influence by examining if they were differentially moderated by specific contexts. Differences in how much AFU or PFU were moderated when predicting specific outcomes or substances highlighted the different characteristics that AFU and PFU may have depending on substance and behavioral outcome. AFU and PFU effects for marijuana and cigarette use seemed to be more influenced by specific contexts (e.g., friendship quality, personal use) than with alcohol use. In addition, AFU and PFU effects appeared to be moderated more when examining persistence compared with onset.

As hypothesized, AFU had an interaction with friendship quality for cigarette persistence; AFU was stronger when friends were closer. The more time individuals spend with substance-using friends, the more likely they are to be exposed to friends' substance use behavior, enhancing socialization effects. Although AFU and friendship quality also interacted for marijuana use persistence, this relationship was negative, such that AFU was stronger when friends were less close. A potential explanation for this lies in the "peer influence paradox," such that adolescents who tend to be strong socialization agents for more deviant behavior (e.g., illicit substance use) also tend to have poorer-quality friendships with others (e.g., Bagwell & Coie, 2004; Piehler & Dishion, 2007; Poulin et al., 1999). Conversely, there were also interactions between PFU and friendship quality for marijuana initiation and persistence, such that the effect of PFU increased as friends were closer. This difference highlights the need to examine more detailed facets of peer behavior and norm transmission, such as the amount of time spent with friends in which they either (a) both engage in substance use or (b) observe friends engaging in substance use.

In addition, as hypothesized, PFU interacted with personal use for marijuana and alcohol use persistence; however, the direction was contrary to what was expected, such that PFU effects were weaker when personal marijuana or alcohol use was higher. Although it was expected that the false consensus bias would influence PFU (such that PFU would increase as individual use increased), it is possible that friends' use becomes less influential as personal alcohol or marijuana use increases, as other factors are more important in influencing persistence of higher levels of substance use.

Contrary to hypotheses, there was an interaction between AFU and personal marijuana use, such that the effect of AFU increased as personal use increased. Given that the moderation between AFU and friendship quality was negative, these contrary interactions indicate that relations among personal use, friendship quality, and friends' use may be more complex than can be explained by simple socialization theories (e.g., social learning, primary socialization theory) and should be probed further by examining characteristics of personal use and use with friends. Last, it is important to note that many of these potential explanations are speculative, and more research is needed to understand underlying mechanisms behind peer socialization (and the multiple ways in which peer socialization can be conceptualized) and adolescent substance use.

Limitations

The main limitation of this study is the potential mismatch between the three best friends used to calculate AFU scores and the "three best friends" participants thought about when answering PFU questions. AFU and PFU were also measured differently; and asking participants to determine their friends' substance use based on the same measures used to report their own substance use might have yielded different results. Like all social network analysis, models could not account for peer influence outside of the bounded network (the school), which may be problematic if an adolescent considered one or more of his or her three best friends to be someone outside of the bounded network.

We did not model potential dependencies resulting from cross-nesting individuals within peer networks because we wanted to have the highest degree of comparison between AFU and PFU effects (as we would not be able to account for these dependencies for the PFU measure) and because we did not use the full network (in which any cross-nesting effects would be incomplete). However, unmodeled dependencies might have influenced standard errors of the model parameters. In addition, because of the complexity of the model, there might not have been a large enough sample to provide sufficient power for some of the tests, particularly interactions. There is also a variety of ways in which "peers" are operationalized in literature; this study focused on "best friends," but other studies account for other types of peers (e.g., Kobus & Henry, 2010, Martens et al., 2006), and results might have differed if other peers were examined. These results may not generalize to adolescents who may not have close friends. Such individuals can be at particularly high risk for substance use (Kobus & Henry, 2010).

Last, the cutoff point for PFU/AFU was a moderate amount of substance use (e.g., less than one cigarette a day coded as "no use") and did not distinguish between "no use"

and "use." Using these measures was unavoidable because of the nature of secondary data analysis. It is possible that PFU or AFU effects might vary depending on quantity of use; measures assessing a broader range of substance use (e.g., little use vs. heavy use) might have yielded different results.

Conclusions and future directions

Despite limitations, this study provides evidence that PFU may give similar estimates to AFU of the magnitude of peer socialization effects on adolescent substance use and that PFU measures may not be overly biased. However, although there is a high degree of overlap between PFU and AFU and their relations to substance use outcomes, they may be representing different peer socialization aspects. It may be beneficial to include both AFU and PFU effects in future studies, when possible, to better capture the nature of peer socialization influences.

Although this study examined some ways in which AFU and PFU may be different constructs by examining if they are differentially moderated by specific contexts, examining how AFU and PFU may be distinct constructs should be further probed with more in-depth studies, such as examining the amount of time adolescents spend exposed to friends' drug use, engage in drug use with particular friends, or perceive their own drug use relative to their friends' drug use. This may be helpful in disentangling the seemingly contradictory roles that friendship quality played in effects of AFU and PFU on marijuana use. Such questions could also help enhance PFU measures for researchers who are not able to obtain social network analysis data. As this study indicates, PFU measures can be used without greatly overestimating peer socialization effects. Adding questions that further probe peer contexts and perceptions of drug use in PFU measures could qualify the extent of the bias inherent in PFU or clarify the nature of the relationship between adolescents and their peers regarding drug use. Given the importance of peer effects in adolescent substance use, improving PFU measures may provide many benefits to future peer socialization research.

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