Diffusion of Intervention Effects: The Impact of a Family-Based Substance Use Prevention Program on Friends of Participants

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Abstract:

Purpose

We tested whether effects of the Strengthening Families Program for Youth 10–14 (SFP10-14) diffused from intervention participants to their friends. We also tested which program effects on participants accounted for diffusion.

Methods

Data are from 5,449 students (51% female; mean initial age = 12.3 years) in the PROmoting School-community-university Partnerships to Enhance Resilience community intervention trial (2001–2006) who did not participate in SFP10-14 (i.e., nonparticipants). At each of five waves, students identified up to seven friends and self-reported past month drunkenness and cigarette use, substance use attitudes, parenting practices, and unsupervised time spent with friends. We computed two measures of indirect exposure to SFP10-14: total number of SFP-attending friends at each wave and cumulative proportion of SFP-attending friends averaged across the current and all previous post-intervention waves.

Results

Three years post-intervention, the odds of getting drunk (odds ratio = 1.4) and using cigarettes (odds ratio = 2.7) were higher among nonparticipants with zero SFP-attending friends compared with nonparticipants with three or more SFP-attending friends. Multilevel analyses also provided evidence of diffusion: nonparticipants with a higher cumulative proportion of SFP-attending friends at a given wave were less likely than their peers to use drugs at that wave. Effects from SFP10-14 primarily diffused through friendship networks by reducing the amount of unstructured socializing (unsupervised time that nonparticipants spent with friends), changing friends' substance use attitudes, and then changing nonparticipants' own substance use attitudes.

Conclusions

Program developers should consider and test how interventions may facilitate diffusion to extend program reach and promote program sustainability.

Keywords: Social networks | Diffusion | Intervention effects | Alcohol use | Cigarette use | Friendship

Article:

Implications and Contributions

The results of this study suggest that effects from a family-based prevention program can impact nonparticipating adolescents by diffusing through school-based friendship networks. Intervention developers should target processes that might facilitate diffusion, such as unstructured socializing, as interventions are scaled up for broad implementation in community contexts.

Most tests of behavioral interventions evaluate only whether participants are impacted by the intervention. Yet, nonparticipants may also benefit from indirect exposure to the intervention as attitudes, knowledge, and behaviors diffuse through friendship networks [1] and [2]. When diffusion occurs during evaluation studies—such as when individuals assigned to a comparison group are affected by an intervention via friends—it is viewed as "contamination." In real-world implementations of these interventions, however, diffusion is a desirable process. For example, given the typically low participation rates in family-based behavioral interventions [3], diffusion can extend the intervention's reach to the nonparticipants who comprise most of the population. This study explores whether and how diffusion occurs when an effective family-based prevention program is delivered to a small fraction of the targeted population.

We define diffusion as influence that occurs when nonparticipants are indirectly exposed to an intervention through friendships with intervention participants. In this study, our first goal was to test whether nonparticipants' indirect exposure to an intervention is associated with their substance use. By contrast, previous studies often inferred diffusion from school-wide effects of an intervention delivered to a subset of students [4] or from successful deployment of trained peer leaders as disseminators of intervention content [5], [6] and [7]. A few studies have found better outcomes among nonparticipants who were fewer network "steps" from peer leaders [8] or situated within a peer leader's clique [9]. These studies, however, did not test whether diffusion depended on amount of indirect exposure to the intervention, and to our knowledge, no studies have directly assessed naturalistic diffusion processes. Our second goal was to test which proximal program effects could account for (i.e., mediate) diffusion of intervention effects from participants to their friends. Specifically, we test whether program effects on intervention participants' parenting practices, unstructured socializing with friends, substance use attitudes, or substance use account for indirect program effects on nonparticipants.

We use data from the PROmoting School-community-university Partnerships to Enhance Resilience (PROSPER) trial [10]. As part of PROSPER, intervention communities implemented the Strengthening Families Program for Youth 10–14 (SFP10-14), an effective substance use

prevention program with sessions for adolescents and parents [4], [11], [12] and [13]. All sixth graders and their parents were invited to participate in SFP10-14, but 83% did not attend any sessions [14]. We argue that these nonparticipants can benefit from SFP10-14 when they are indirectly exposed to it through friendships with participants. Because peer influence is an ongoing process that can have enduring effects, the beneficial effects of having SFP-attending friends likely accumulate over time. Thus, we expected that nonparticipants' substance use would be associated with cumulative exposure to SFP-attending friends over time (i.e., cumulative indirect exposure).

SFP10-14's effectiveness has been demonstrated through a randomized control trial, with effects maintained 10 years past baseline [13]. Thus, data from a high-fidelity implementation of SFP10-14 provide a perfect test case for evaluating whether indirect exposure can reduce substance use among nonparticipants. Such diffusion occurs when an intervention first influences participants' attitudes and behaviors, which then influence the attitudes and behaviors of participants' friends. Proximal program effects of SFP10-14 on participants include enhanced parenting practices, reduced unstructured socializing with friends, and altered attitudes toward substance use, with distal program effects on participants' substance use [12] and [15]. These proximal and distal program effects may diffuse and impact nonparticipants' substance use attitudes and behaviors (Figure 1).

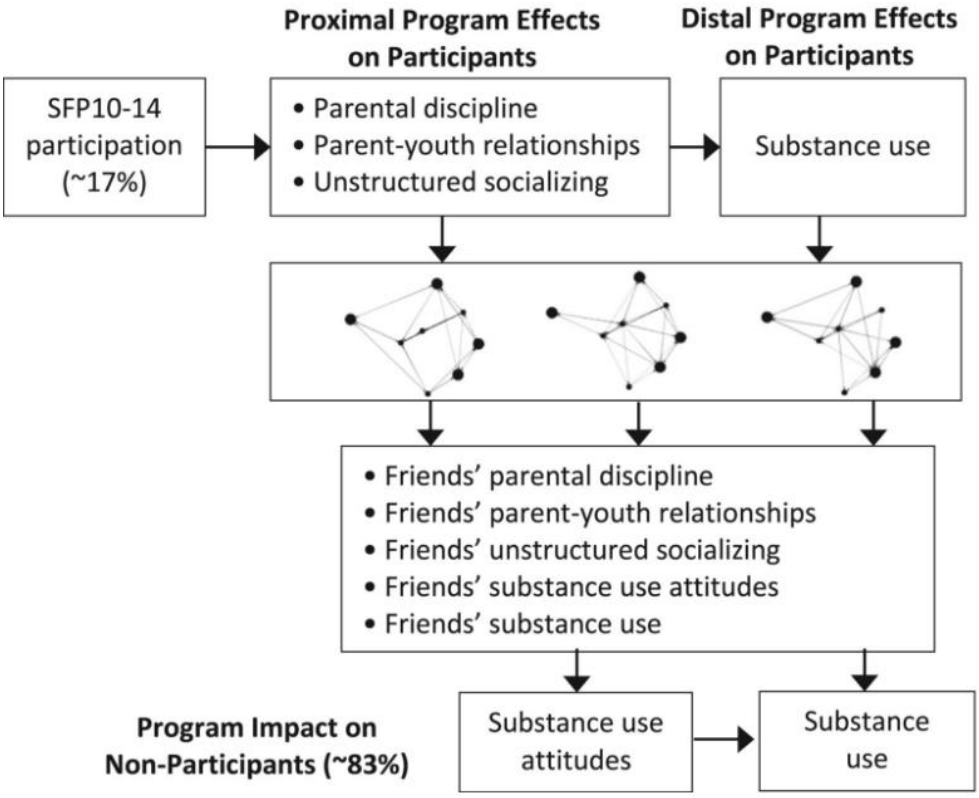

Figure 1. Hypothesized process through which intervention effects diffuse from the students who participated in SFP10-14 to intervention nonparticipants. First, SFP10-14 has proximal and distal effects on program participants (top row). Then, nonparticipants are exposed to intervention participants (larger nodes) through their friendship networks (second row); some

nonparticipants have many SFP-attending friends, whereas others have few SFP-attending friends. The varying degrees of cumulative indirect exposure to SFP10-14 via friendship networks then impact the average characteristics of non-participants' friends (third row). In turn, these friends' characteristics impact nonparticipants' own anti-substance use attitudes and substance use (bottom row).

One potential pathway for diffusion is through proximal effects on parenting practices in participating families. We previously demonstrated that friends' parents influence adolescents' substance use [16] and [17]. SFP10-14 promotes supportive parent–youth relationships and consistent parental discipline. Participating parents may model these positive parenting practices for other youth through interactions with their own adolescent and may engage directly in more positive interactions with nonparticipants. Both modeling and direct interaction may increase nonparticipants' social bonding and reduce their deviant behavior [18].

A second potential pathway for diffusion is through proximal effects on participating adolescents' unstructured socializing with friends, which leads to less substance use [19], [20] and [21]. Past studies found that individual- and aggregate-level parental monitoring are associated with unstructured socializing [22]. Therefore, if SFP10-14 enhances parents' monitoring of adolescents' activities, participating adolescents should engage in less unsupervised, unstructured socializing with friends. In turn, nonparticipants with many SFP-attending friends should spend less unsupervised time with friends, thus having fewer opportunities to use substances.

A third potential pathway for diffusion is through proximal effects on participating adolescents' substance use attitudes (e.g., resistance skills, normative beliefs). Adolescents who believe that drug use is common or that their friends approve of substance use are more likely to use drugs [23], [24], [25] and [26]. Strengthening participants' anti-substance use attitudes could change the normative context within their peer group: if participants become less approving of substance use, their nonparticipating friends may adopt similar attitudes and be less likely to use drugs.

The most critical pathway for diffusion may be through SFP10-14's distal effects on participants' substance use, followed by peer influence on nonparticipant friends' substance use. Whether friends use drugs is one of the strongest predictors of adolescent substance use [27]. This association partly reflects substance-using adolescents selecting substance-using peers as friends, but it also reflects influence from friends [2], [28], [29], [30] and [31]. Further evidence for this pathway for diffusion comes from evidence that the impact of friends' parents on adolescent substance use is partially mediated by friends' behaviors [16] and [17].

Finally, we also examine whether nonparticipants' own substance use attitudes mediate the effect of other variables on their substance use. For example, past studies have demonstrated that individual's own attitudes can mediate the link between friends' attitudes and the individual's own alcohol use [26].

Methods

The PROSPER intervention trial included adolescents from 28 rural communities in Pennsylvania and Iowa who began sixth grade in 2001 (Cohort 1) or 2002 (Cohort 2) [10]. Communities were eligible to participate if their school districts enrolled 1,300–5,200 students and if 15% or more of students were eligible for free or reduced-price lunch. Additional study information is provided elsewhere [10], [14], [32], [33], [34] and [35]. Institutional review boards at Pennsylvania State University and Iowa State University approved all study protocols.

We focused on adolescents in the 13 intervention communities that collected friendship nominations at each wave. Early in Spring of sixth grade, community prevention teams invited all students and their families to participate in the 7-week SFP10-14 program [10] and [11]. Community teams used multiple recruitment strategies and incentives for participation (e.g., small gifts; light meals; child care) [33]. Each week, parents and adolescents met separately for an hour, then together for an hour. Parent sessions addressed establishing rules, discipline, the potential for positive parental influence, and parent–youth communication. Adolescent sessions addressed peer resistance and social skills. Family sessions addressed facilitating family communication and cohesiveness. In seventh grade, all students participated in a school-based substance use prevention program.

All assenting students whose families did not return a form exempting them from the study completed a baseline survey at school in Fall of sixth grade and post-intervention follow-up surveys in Spring of sixth, seventh, eighth, and ninth grade. We primarily use post-intervention data and only include students who did not participate in SFP10-14 (nonparticipants). We excluded 800 students who never named friends and 75 students whose friends never completed a survey. Of the 5,449 students in the final analytic sample, 61.1% completed surveys at all four waves, 28.7% completed surveys at two or three waves, and 10.2% completed a survey at one wave. Although our analytic sample was nonparticipants, we used available data from 889 intervention participants and the excluded nonparticipants to calculate friends' characteristics.

Measures

Substance use

Students reported how often in the past month they had been drunk and smoked cigarettes. Because data were highly skewed, with most students reporting no use, we recorded responses for each substance into no past month use and used at least once in the past month.

Anti-substance use attitudes

We computed the average of four standardized subscales: moral attitudes, expectations, refusal intentions, and refusal efficacy (Appendix Table 1).

Friends' characteristics

Students named up to two best friends and up to five other close friends who were in the same grade at their school. From these data, described in more detail elsewhere [36], we computed two indirect exposure measures. For descriptive purposes, we computed total number of friends who participated in SFP10-14 ("SFP-attending friends") at each wave. To capture cumulative indirect exposure to SFP10-14, we averaged the current proportion of SFP-attending friends with the proportion of SFP-attending friends at each previous postintervention wave. We used cumulative proportion, instead of cumulative total, because the latter also reflects how many times students completed surveys.

Students also indicated how often they "hung out" with each friend outside school without adults around. We operationalized unstructured socializing as the cumulative average unsupervised time reported across friends. We operationalized friends' parenting practices as the cumulative average of friends' characteristics based on friends' self-report of parent–youth relationships and parental discipline style. We calculated friends' anti-substance use attitudes based on friends' self-reports of their own attitudes. We operationalized friends' substance use as the cumulative proportion of friends who reported drunkenness or cigarette use.

Analysis approach

After providing demographic information and testing two selection processes, we tested diffusion. We started with descriptive analyses to determine whether there was any preliminary evidence of diffusion and the timing of diffusion. Specifically, we conducted five Pearson $\chi 2$ tests (3 df) to test the association between total number of SFP-attending friends at each wave and past month substance use at that wave. We then conducted multilevel analyses (using HLM version 6.06; Scientific Software International, Inc., Skokie, IL) [37] to test the association between cumulative exposure through a given wave and nonparticipants' substance use at that wave, controlling for multiple covariates. We then added each hypothesized mediator of diffusion separately to test which variables explained this association. Each multilevel model accounted for nesting of time (Level 1) within students (Level 2), who were nested within school cohorts (Level 3). We modeled substance use with a Bernoulli distribution and grand mean centered all measures except wave. Our general model was:

$$\begin{aligned}\text{Logit } (y_{tij}) &= \beta_{000} + \beta_1 \times (\text{Indirect exposure})_{tij} + \beta_m \times (\text{Mediators}_{tij}) \\ &+ \beta_{c1} \times (\text{Level 1 controls}_{tij}) + \beta_{0c2} \times (\text{Level 2 controls}_{ij}) + \beta_{001} \times \text{State}_j \\ &+ \mu_{0ij} + \nu_{00j}\end{aligned}$$

Level 1 controls were wave, receiving free or reduced-price lunch, and network size. We also included nonparticipants' parent–youth relationships and parental discipline as important controls to test the unique contributions of friends' parenting practices. Level 2 controls were indicators for gender and racial groups, including indicators for missing race (n = 27) and missing gender (n = 55) to retain students with missing Level 2 data in the analyses.

To test the statistical significance of each mediated effect, we computed the indirect effect as the product of the a (mediator regressed on indirect exposure) and b (substance use regressed on mediator) paths, [38] then used RMediation [39] to obtain the 95% confidence interval of this

indirect effect. To determine proportion mediated, we used ab/(ab + c'), where c' is the path from indirect exposure to substance use in the final model [38].

Results

Sample characteristics

At baseline, students' average age was 12.3 years (standard deviation = .43). Sample demographics reflected the communities in which the students lived: across waves, 82%–84% of students identified as white, 24%–32% of students received free or reduced-price lunch, and 76%–77% of students lived with two parents (Table 1).

	Post-test	1-Year follow-up	2-Year follow-up	3-year follow-up	Network SD[a]
Total number of students	4,131	4,668	4,702	4,542	94.91
Race					
White	83.5	82.2	81.7	81.8	5.83
Hispanic	4.6	6.1	6.6	6.9	5.12
Black	2.3	2.4	2.4	2.2	2.13
Native American	.7	.5	.5	.5	.56
Asian	1.1	1.1	1.1	1.1	1.29
Other ethnicity	7.7	7.4	7.4	7.1	2.04
Race not reported	.1	.2	.3	.5	.34
Gender					
Female	50.5	50.8	51.0	51.8	4.12
Male	48.3	48.1	48.0	47.2	4.15
Not reported	1.1	1.1	1.0	1.0	1.32
Free/reduced-rice lunch	32.4	29.9	28.8	24.2	8.67
Two-parent family	76.6	77.2	75.9	76.9	4.69
Frequency of church attendance	5.02 (2.61)	4.83 (2.66)	4.58 (2.68)	4.27 (2.68)	.50
Total number of SFP-attending friends					
Zero SFP-attending friends	54.3	55.2	57.2	60.6	18.8
One SFP-attending friends	29.5	29.1	28.6	28.0	8.05
Two SFP-attending friends	11.4	11.3	9.6	8.4	8.12
Three SFP-attending friends	3.6	3.4	3.7	2.2	5.79
Four SFP-attending friends	1.0	.8	.8	.5	1.93
Five SFP-attending friends	.2	.2	.1	.2	1.85
Six SFP-attending friends	.0	.1	.0	.1	.43
Indirect exposure: cumulative proportion of SFP-attending friends[b]	.14 (.20)	.14 (.18)	.14 (.17)	.13 (.16)	.09
Parent–youth relationships	.12 (.45)	.02 (.49)	−.08 (.51)	.19 (.51)	.07
Parental discipline	3.61 (1.01)	3.64 (.97)	3.58 (.93)	3.55 (.89)	.17
Unstructured socializing	3.02 (1.24)	2.98 (1.16)	3.01 (1.10)	3.04 (1.08)	.19
Anti-substance use attitudes	.21 (.62)	.09 (.73)	−.09 (.85)	−.32 (.93)	.07
Past month drunkenness	2.4	4.6	10.1	18.6	1.08
Past month cigarette use	5.1	8.3	12.3	18.0	2.19

Table 1. Sample demographics and descriptive statistics (% or mean [SD]) for key study variables

SD = standard deviation; SFP = Strengthening Families Program.
a SD of each measure at baseline across networks (i.e., the n = 26 community cohorts).
b SFP for Youth 10–14.

Selection effects

Before testing our hypotheses, it was critical to determine whether selection processes were confounded with differences in exposure to our putative causal variable (i.e., exposure to SFP-attending friends). We tested whether nonparticipants who would later have many SFP-attending friends were initially different from other nonparticipants. We correlated mean proportion of SFP-attending friends across waves with all baseline measures of all variables in Table 1 plus self-reported grades in school, school bonding, delinquency, and sensation seeking. Of these 15 variables, only frequency of attending religious services was significantly, although very weakly, correlated with mean proportion of SFP-attending friends across waves ($r = .03$, $p = .044$); we adjusted for this measure in our multilevel analyses.

A second selection issue is whether post-intervention differences between SFP-attending friends and nonparticipant friends reflect program effects, rather than differential selection of participants into SFP10-14. Such selection bias would be indicated by differences between nonparticipants and participants before program delivery. Of the 15 variables tested, only three differences emerged: participants had higher grades ($M_{participants} = 4.25$, $M_{nonparticipants} = 4.19$, $p = .046$), were more likely to be from a two-parent family ($M_{participants} = 80.5\%$, $M_{nonparticipants} = 77.1\%$, $p = .026$), and attended religious services more often ($M_{participants} = 5.87$, $M_{nonparticipants} = 5.01$, $p < .001$).

Diffusion of Strengthening Families Program for Youth 10–14 effects

Descriptive analyses, using wave-specific $\chi 2$ tests, indicated that total number of SFP-attending friends was unrelated to drunkenness (Figure 2A) or cigarette use (Figure 2B) at baseline or immediate post-test. There were, however, significant differences in drunkenness at the 1-year and 3-year follow-ups and in cigarette use at all three yearly follow-ups. These results were consistent with diffusion; there were no differences before SFP10-14 was implemented or before intervention effects had time to diffuse, but behavioral differences emerged over time, with lower rates of substance use among nonparticipants who had more SFP-attending friends.

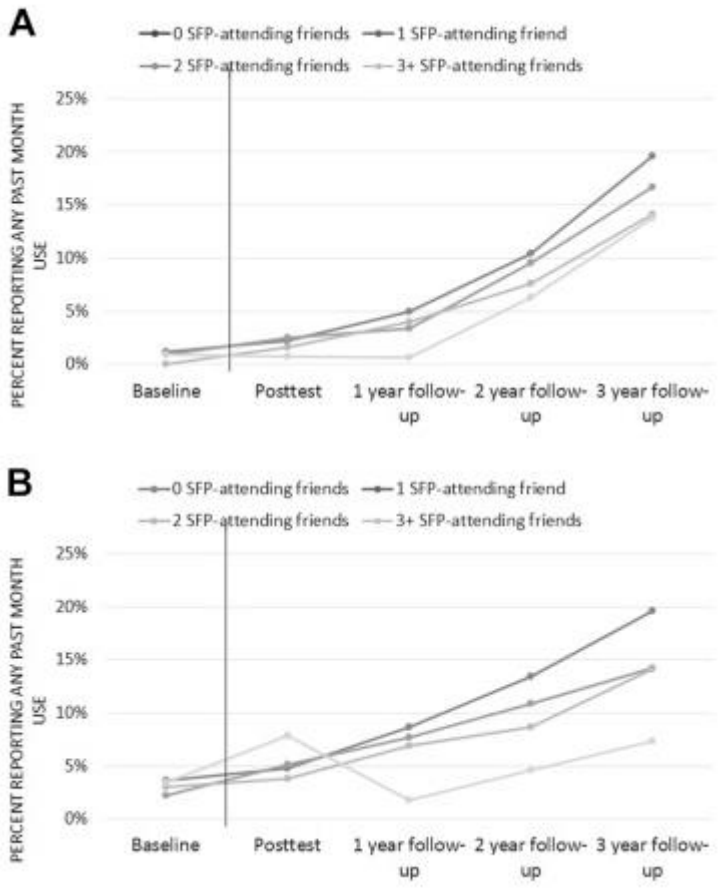

Figure 2. The percent of nonparticipants at each wave who reported (A) past month drunkenness and (B) past month cigarette use as a function of the total number of their friends who attended SFP10-14. The vertical line indicates when SFP10-14 was implemented. Before (baseline) and shortly after (post-test) SFP10-14 were implemented, there were no significant differences in drunkenness or cigarette use. Significant differences emerged 1 year after SFP10-14 was implemented. At each follow-up, students with no SFP-attending friends had the highest rates of substance use, whereas students with three or more SFP-attending friends had the lowest rates of use.

We then tested whether cumulative indirect exposure was associated with substance use after including covariates. In our initial multilevel models (Tables 2 and 3, Model 1), indirect exposure was significantly associated with drunkenness (odds ratio [OR] = .57) and cigarette use (OR = .49). These results supported our preliminary descriptive analyses: Students with more SFP-attending friends were less likely to get drunk or smoke.

	Diffusion effect	Mediation via proximal program effects					Mediation via distal program effects	Combined mediation
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Indirect exposure to SFP 10-14								
Cumulative proportion of SFP-attending friends averaged across current and all previous post-intervention waves	.57** (.41–.80)	.59** (.42–.83)	.61** (.44–.86)	.70* (.49–.99)	.68* (.49–.95)	.79 (.56–1.11)	.79 (.57–1.11)	.89 (.62–1.29)
Friends' parenting practices								
Friends' parental discipline		.74*** (.66–.84)				1.05 (.89–1.25)	1.05 (.88–1.25)	1.17* (1.01–1.35)
Friends' parent–youth relationships			.45*** (.38–.55)			1.25 (.95–1.64)	1.31* (1.00–1.71)	1.26 (.91–1.76)
Unstructured socializing								
Unsupervised time with friends				1.62*** (1.51–1.73)		1.51*** (1.42–1.62)	1.51*** (1.41–1.62)	1.41*** (1.34–1.49)
Friends' attitudes								
Friends' anti-substance use attitudes					.36*** (.30–.43)	.37*** (.30–.46)	.51*** (.41–.64)	.82 (.67–1.01)
Friends' substance use								
Friends' drunkenness							5.50*** (3.50–8.65)	4.81*** (2.83–8.20)
Individual attitudes								
Target adolescent's anti-substance use attitudes								.24*** (.23–.27)

Table 2. Association between indirect exposure to the SFP 10-14 and past-month drunkenness: PROSPER Peers Study, 2001–2006

Table entries indicate adjusted odds ratios (with 95% confidence interval). All models adjusted for gender, race, network size (natural log), wave, whether the nonparticipant received free or reduced-price lunch, and the nonparticipants' frequency of church attendance, family discipline, and parent–youth relationships.

PROSPER = PROmoting School-community-university Partnerships to Enhance Resilience; SFP = Strengthening Families Program for parents and youth 10-14.

*$p < .05$; **$p < .01$; ***$p < .001$.

	Diffusion effect	Mediation via proximal program effects					Mediation via distal program effects	Combined mediation
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Indirect exposure to SFP 10-14								
Cumulative proportion of SFP-attending friends averaged across current and all previous post-intervention waves	.49** (.31–.77)	.49** (.31–.79)	.51** (.32–.81)	.58* (.37–.90)	.58** (.38–.87)	.68* (.46–.99)	.68* (.47–.92)	.72 (.51–1.00)
Friends' parenting practices								
Friends' family discipline		.58*** (.52–.65)				.85** (.73–.99)	.82* (.71–.95)	.84* (.71–1.00)
Friends' parent–youth relationships			.32*** (.26–.41)			1.06 (.72–1.55)	1.18 (.82–1.69)	1.12 (.82–1.54)
Unstructured socializing								
Unsupervised time with friends				1.52*** (1.42–1.63)		1.41*** (1.31–1.51)	1.39*** (1.30–1.49)	1.28*** (1.19–1.37)
Friends' attitudes								
Friends' anti-substance use attitudes					.26*** (.22–.33)	.29*** (.23–.39)	.53*** (.43–.67)	.87 (.74–1.01)
Friends' substance use								
Friends' cigarette use							11.82*** (7.40–18.89)	13.90*** (8.82–21.91)
Individual attitudes								
Target adolescent's anti-substance use attitudes								.18*** (.16–.20)

Table 3. Association between indirect exposure to the SFP 10-14 and past month cigarette use: PROSPER Peers Study, 2001–2006

Table entries indicate adjusted odds ratios (with 95% confidence interval). All models adjusted for gender, race, network size (natural log), wave, whether the nonparticipant received free or reduced-price lunch, and the nonparticipants' frequency of church attendance, family discipline, and parent-youth relationships.
PROSPER = PROmoting School-community-university Partnerships to Enhance Resilience; SFP 10-14 = Strengthening Families Program for parents and youth 10-14.
*$p < .05$; **$p < .01$; ***$p < .001$.

Mediators of diffusion

When we added each proximal effect (Table 2, Models 2–5), the association between indirect exposure and drunkenness weakened (OR range = .59–.70). Both friends' parental discipline and unstructured socializing were significant mediators (Appendix Table 2). When we combined all proximal effects into one model (Model 6), indirect exposure was no longer significantly associated with drunkenness (OR = .79, p = .178) and both parenting practices measures became nonsignificant. Adding friends' drunkenness (Model 7) weakened the effects of friends' substance use attitudes but did not affect the other predictors. Adding nonparticipant's own substance use attitudes (Model 8) further weakened the association between indirect exposure and drunkenness (OR = .89). Combined, all the mediators in Model 8 accounted for 63% of the total relationship between indirect exposure and drunkenness. Unstructured socializing and friends' drunkenness were still positively associated with drunkenness, and nonparticipants' own anti-substance use attitudes were still negatively associated with drunkenness.

We found similar results for cigarette use (Table 3; Appendix Table 3). The association between indirect exposure and cigarette use was generally weaker in Models 2–5 (OR range = .49–.58) and weakened further when we combined all proximal effects in Model 6 (OR = .66). Adding friends' cigarette use (Model 7) reduced the effect of friends' substance use attitudes but had little impact on the other predictors. After adding students' substance use attitudes (Model 8), indirect exposure was no longer significantly associated with cigarette use (OR = .72). Combined, all the mediators in Model 8 accounted for 45% of the total relationship between indirect exposure and cigarette use. Unstructured socializing and friends' cigarette use were positively associated with cigarette use, whereas nonparticipants' anti-substance use attitudes and friends' parental discipline were negatively associated with cigarette use.

Discussion

Our study builds on past research [4] and [13] documenting the effectiveness of SFP10-14 by demonstrating that effects from this family-based substance use prevention program can diffuse through friendship networks. Although only 17% of families attended SFP10-14, the reach of the intervention's effects was much greater. At each wave, almost half of nonparticipants had at least one SFP-attending friend, providing indirect exposure to SFP10-14 and setting the stage for diffusion. As expected, indirect exposure to SFP10-14 through SFP-attending friends was associated with less substance use. Three years after families completed SFP10-14, the odds of getting drunk and using cigarettes were higher among nonparticipants with no SFP-attending friends compared with nonparticipants with three or more SFP-attending friends (OR = 1.4 and 2.7, respectively). Notably, our findings clarified which of several plausible mechanisms could explain how this diffusion occurred.

The most compelling evidence of mediation was via the proximal effect on unstructured socializing (i.e., unsupervised time with friends), which was the only significant mediator in the final models. When entered as the only mediator, the proportion mediated by unstructured socializing was .10 for drunkenness and .16 for cigarette use. Our finding that unstructured socializing significantly predicted nonparticipants' substance use in the final model, even after adjusting for friends' substance use, is consistent with studies that found an association between unsupervised time with peers and deviant behavior, regardless of friends' behaviors [19] and [20]. Interventions should promote limits on unstructured, unsupervised time that adolescents

spend with peers, both because of the direct benefits for participants [19] and [20] and to facilitate the diffusion of intervention effects leading to reduced substance use among nonparticipants.

The proximal effect on participants' substance use attitudes was another potentially important mediator of diffusion. Although its mediation estimate did not reach statistical significance, when entered alone, friends' substance use attitudes mediated a higher proportion of the total relationship than any of the other proximal mediators (.19 for drunkenness and .23 for cigarette use). Once nonparticipants' own substance use attitudes were added to the model, however, the proportion mediated by friends' substance use attitudes dropped to .06 for drunkenness and .02 for cigarette use. By contrast, the proportion mediated by nonparticipants' own substance use attitudes was .41 for drunkenness and .27 for cigarette use. These results suggest that shifting norms within the peer context represents a second pathway for facilitating diffusion. That is, nonparticipants whose friends either disapprove of substance use or do not use substances due to participating in SFP10-14 are more likely to develop negative attitudes toward substance use, thus reducing the likelihood that they will use substances.

By contrast, neither the proximal effects on friends' parenting practices (i.e., friends' parent–youth relationships; friends' parental discipline) nor the distal effect on friends' substance use accounted for much of the diffusion effect. Although both parenting practices variables were significantly associated with nonparticipants' substance use (consistent with past studies [16] and [17]) and friends' parental discipline was a significant mediator when entered alone, the proportion of the total relationship mediated was <.05. Furthermore, both mediators became nonsignificant after adding unstructured socializing to the model. Therefore, friends' parenting practices impacted nonparticipants' substance use primarily by limiting opportunities for substance use. Although the proportion mediated by friends' substance use was .08–.11 when included as the sole mediator (not reported), these effects were fully accounted for by including parenting practices, unstructured socializing, and participants' substance use attitudes in the model. In sum, diffusion of SFP10-14 appears to operate by reducing opportunities for substance use and changing participants' substance use attitudes.

We focused on diffusion of effects to nonparticipants, but the same mechanisms may maintain or enhance program effects on participants. For example, participants with many SFP-attending friends likely spend less unsupervised time with their peers, as both their parents and their friends' parents may limit unstructured socializing, whereas participants with few SFP-attending friends may experience more peer encouragement of substance use. Future studies should explore how friends impact participants' likelihood of adopting attitudes and behaviors promoted by the intervention.

Limitations

Our study included adolescents from two cohorts in 13 rural communities with relatively stable and majority-white populations; thus, the generalizability of our findings may be limited to similar communities. Studies in high-turnover communities are important given the potential for diffusion processes to benefit students who move into a school after an intervention was implemented. Students only nominated same-grade peers who attended their school, precluding

an analysis of whether diffusion extended to neighborhood friends, younger friends, or siblings. Given the low base rates of substance use in middle school, we examined any substance use versus no use. As a result, our analyses do not provide information about frequency of use and confound the potentially different processes involved in substance use onset and maintenance [19]. Although we expect that factors that contribute to substance use and peer influence processes have remained stable over time, future studies should replicate the results with more recent samples than our data from 2001 to 2006.

Neither program participation nor friendships were randomly assigned; thus, the association between indirect exposure and substance use could reflect unmeasured selection processes or shared environmental factors [2]. Because participation in SFP10-14 was voluntary, differences between participants and nonparticipants in post-treatment behavior could have reflected pre-existing differences. In that case, participants' influence on their friends might reflect diffusion but not diffusion of program effects. The effectiveness of SFP10-14, however, is supported by a randomized control trial that used intent-to-treat analyses to account for selection biases [4] and [13]. Furthermore, we found little difference between participants and nonparticipants with respect to baseline characteristics, consistent with studies that found time pressures, not family or child characteristics, predict engagement in family-based interventions [2]. Second, the more important threat of selection would be the selection of SFP-attending friends by students who were less likely to use drugs. However, there is little evidence that adolescents who would later select SFP-attending friends were initially different than their peers; proportion of SFP-attending friends was unrelated to baseline substance use or other risk factors of substance use. Furthermore, we adjusted for frequency of attending religious services, the one variable that was significantly, albeit very weakly, related to proportion of SFP-attending friends at baseline. To reduce environmental confounding, we also adjusted for nonparticipants' gender, race, family discipline, parent–youth relationships, and also whether they received free or reduced-price lunch.

In sum, our findings provide evidence that intervention effects can diffuse to nonparticipants through their friendships with participants and that the key mediators of this process are spending less unsupervised time with friends and changing attitudes about substance use. By identifying mechanisms that facilitate diffusion at the individual level, our findings extend those from another study, which found that network-level characteristics impact diffusion [40]. In that study, less clustering of youth into cliques, greater overall structural network cohesion, and more even distribution of intervention participants across the network all facilitated diffusion. Future studies should explore the interplay between network- and individual-level processes that facilitate diffusion.

Intervention developers strive to reduce “contamination” in evaluation studies, but they should also consider how interventions may facilitate diffusion. For example, when diffusion occurs, more people adopt positive attitudes and behaviors, potentially shifting contextual norms, limiting opportunities for deviant behaviors to occur, and promoting conditions that could maintain intervention effects. This line of research holds promise for identifying ways that intervention developers can facilitate diffusion to expand the scope of program benefits to nonparticipants and enhance the persistence of intervention effects.

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SUPPLEMENTARY DATA OMITTED FROM THIS FORMATTED DOCUMENT

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