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Neighborhood Moderation of Sensation Seeking Effects on Adolescent Substance Use Initiation

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Abstract

Adolescent substance use carries a considerable public health burden, and early initiation into use is especially problematic. Research has shown that trait sensation seeking increases risk for substance use initiation, but less is known about contextual factors that can potentially unmask this risk. This study utilized a diverse longitudinal subsample of youth (N=454) from a larger study of familial alcoholism (53.1% female, 61% non-Hispanic Caucasian, 27.8% Hispanic, 11.2% other ethnicity). Study questions examined sensation seeking in early adolescence (mean age= 12.16) and its relations with later substance use initiation (mean age=15.69), and tested whether neighborhood disadvantage moderated sensation seeking's effects on initiation of alcohol, tobacco, and marijuana use. Neighborhood disadvantage significantly moderated the relation between sensation seeking and all three forms of substance use. For the most part, sensation

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Author Affiliations and Research Interests

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Authors' Contributions

MJ conceived of the study, conducted statistical analyses, interpreted data, and coordinated and drafted the manuscript; LC is the principal investigator of the parent project, oversaw parent study design and data collection, contributed to the conceptual framework for the study, and assisted with data interpretation and drafting the manuscript; NG contributed to the conceptual framework for the study and assisted with data interpretation and drafting the manuscript. All authors have read and approved the final manuscript.

Conflicts of Interest

The authors report no conflicts of interest.

Informed Consent

At every interview, written informed consent was obtained from adults and the parents of minors, and adolescents gave assent. During telephone interviews verbal consent/assent was audio recorded.

Ethical Approval

This study was approved by the Institutional Review Board of Arizona State University.

seeking effects were weakened as neighborhood disadvantage increased, with the most advantaged neighborhoods exhibiting the strongest link between sensation seeking and substance use initiation. These results highlight the importance of focusing on relatively advantaged areas as potentially risky environments for the sensation seeking pathway to substance use.

Keywords

Sensation seeking; neighborhood; substance use; adolescence

Introduction

Adolescent substance use is a pressing public health concern, linked with increased risk of substance use disorder (SUD) and the leading causes of adolescent death (DeWit et al. 2000; Grant and Dawson 1998; Centers for Disease Control and Prevention 2010). Substance use in adolescence is common, with 45.2% of high school students reporting lifetime use of alcohol, 21.1% having ever tried cigarettes, and 30% having tried marijuana (Johnston et al. 2016). The high prevalence of adolescent substance use, combined with the potential consequences of such use, underscore the importance of prevention of early onset adolescent alcohol and other drug use. An understanding of the etiology of adolescent substance use is necessary for the development and improvement of preventive interventions.

Sensation Seeking Risk for Adolescent Substance Use

Sensation seeking (also referred to as novelty seeking, excitement seeking, and fun seeking) is a personality trait characterized by attraction to novel, intense, stimulating experiences, and a disposition to take risks in service of experiencing these sensations (Zuckerman 1994, 1979). Sensation seeking is one facet under the broader umbrella of disinhibition (characterized by difficulty constraining behavior and impulses) thought to represent an endophenotype for transmission of genetic liability via the “externalizing pathway” to substance use and problem behavior (Zucker et al. 2011; Iacono et al. 2008). Research consistently shows that sensation seeking is related to higher rates of adolescent experimentation with alcohol, tobacco, marijuana, and other illicit drugs (Andrucci et al. 1989; Malmberg et al. 2010). It is likely that this disposition toward excitement seeking results in more adolescent substance use experimentation due to a combination of the allure of the experience of pleasurable intoxication effects, excitement of rule breaking, and the fact that alcohol and drug use are often coupled with rewarding peer interactions. A recent meta-analysis concluded that of all disinhibition facets considered, sensation seeking and positive urgency were the most strongly related to adolescent alcohol consumption and binge drinking, both in cross sectional and prospective designs, whereas alcohol related *problems* and alcohol use disorders were more strongly predicted by the trait of urgency and not sensation seeking (Stautz and Cooper 2013). This is consistent with human and animal research suggesting that disinhibition and sensation seeking tendencies are most associated with early-stage alcohol and drug use and experimentation, whereas the progression to problem abuse and dependence may be more strongly influenced by other factors (Winstanley et al. 2010; Smith et al. 2007; Riggs et al. 2016). The associations between sensation seeking and early stage use make it of particular interest during the adolescent

developmental period when youth are just beginning to experiment with alcohol and drug use.

Neighborhood Effects

Sensation seeking risk for substance use initiation emerges within broader community environments, which can potentially work to facilitate or constrain adolescent substance use behavior. Traditionally, economically disadvantaged communities have been conceptualized as high risk ecologies for development of delinquency and substance use, operating through mechanisms like exposure and social disorganization (Elliott et al. 1996; Jencks and Mayer 1990; Sampson et al. 2002). However, empirically, the decades of work on neighborhood effects have failed to consistently support social disorganization theory in the relation between neighborhood disadvantage and substance use (Karriker-Jaffe 2011). Studies suggesting positive associations between neighborhood disadvantage and substance use (Abdelrahman et al. 1998; Crum et al. 1996; Hoffmann 2002; Smart et al. 1994; Briggs 1997; Leventhal and Dupéré 2011) must be balanced by investigations that either fail to find the hypothesized disadvantage-substance use link (Brenner et al. 2011; Buu et al. 2009; Allison et al. 1999; Esbensen and Huizinga 1990) or conclude that adolescents in the most *advantaged* neighborhoods are at increased risk for substance use (Ennett et al. 1997; Snedker et al. 2009; Luthar and D'Avanzano 1999; Fagan et al. 2015). Luthar has posited two primary mechanisms for increased risk for substance use among affluent communities: stress from pressure to achieve and isolation from adults, which reduces support and adult supervision (Luthar and Latendresse 2005). The present study seeks to clarify this very mixed pattern of findings by considering the hypothesis that there are complex, nonlinear processes at work, with both highly disadvantaged communities and highly advantaged communities imparting risk for adolescent substance use. A contribution of the current study is that it tests the potential quadratic relation between neighborhood disadvantage and adolescent substance use experimentation.

Sensation Seeking Risk in Context

There has been increased interest in the expression of individual risk for problem behaviors within neighborhood contexts, though few studies focus on substance use. Inquiry into the potential for neighborhood contexts to modify the manifestation of personality risk for problem behaviors and delinquency has been shaped by three lines of theorizing and hypothesis testing (all of which have had some empirical support). The first two types of hypotheses are shaped by the classical sociological theory that "weak situations", characterized by lack of explicit behavioral norms, will allow for expression of individual personality dispositions, whereas "strong situations" will pull for certain behaviors regardless of individual differences (Mischel 1977). Within this theoretical framework, some studies hypothesize that economically *advantaged* neighborhoods are "strong situations" in which established community bonds and informal social control proscribe disinhibited behaviors, thus suppressing the behavioral expression of sensation seeking so that it is not manifested in substance use or other problem behaviors and thus, the effects of sensation seeking should be minimal. In contrast, disadvantaged neighborhoods would be "weak situations" that unmask individual vulnerability. Consistent with this theory, Lynam et al. (2000) found that a multi-method impulsivity composite was more strongly related to

criminal offending in neighborhoods with lower socioeconomic status (SES), whereas in more affluent neighborhoods impulsivity had little effect. A similar pattern has been seen in which thrill/adventure seeking and impulsivity effects on delinquency are strongest in those neighborhoods in which the participants perceive lower levels of informal social control and collective efficacy, which social disorganization theory posits are mediators of neighborhood disadvantage effects (Jones and Lynam 2009; Meier et al. 2008). In contrast, within these theories about "strong situations," it has also been suggested that disadvantaged, low-income communities, characterized by criminogenic culture and prevalent social pressure for delinquency, are "strong situations" that create environmental risk for problem behaviors that mask the effects of individual-level risk factors. These studies hypothesize that the effects of sensation seeking would be stronger in advantaged neighborhoods and weaker in disadvantaged neighborhoods. There is also evidence to support this hypothesis, with studies demonstrating stronger effects of impulsivity and impulse control on delinquency in neighborhoods characterized by higher SES and less disorder, whereas impulsivity effects are suppressed in the most disadvantaged, disorganized neighborhoods (Zimmerman 2010; Fine et al. 2016). Most relevant to the current study of substance use, Ray and colleagues (2016) studied a cross-sectional sample of justice-involved youth and found that youth impulse control was negatively related to youth substance use, and that this relation was stronger in the *most* socially organized neighborhoods. Finally, a third hypothesis is consistent with the general theory of crime (Gottfredson and Hirschi 1990), and suggests that low self-control and disinhibition influence delinquency in a manner that is context independent. In support of this hypothesis, some studies have concluded that disinhibition's effects on delinquency do not vary across levels of neighborhood disadvantage or disorganization (Vazsonyi et al. 2006; Barker et al. 2011; Neumann et al. 2010; Ray et al. 2016).

We are left with three seemingly contradictory bodies of evidence regarding the interplay between disinhibition and neighborhood environment in predicting problem behavior, with the only study of substance use concluding that disinhibition effects are heightened in the most organized neighborhoods. One issue with the "weak" and "strong" situations approach is that the majority of studies do not measure or test the social factors (e.g. community level norms) that are thought to characterize "weak" and "strong" situations, and thus either direction of effect can be interpreted as in line with the theory; whichever type of neighborhood facilitates expression of individual vulnerability can be labeled as "weak", and the type of neighborhood which masks the vulnerability as "strong".

The present study takes an alternative approach and instead considers that neighborhood impact on individual risk for *substance use* might differ from neighborhood impact on individual risk for *delinquency* (the outcome that has received the most attention). The most notable difference is that current research suggests that both advantaged *and* disadvantaged neighborhoods see heightened rates of adolescent substance use, a pattern of direct effects which is not paralleled in the delinquency literature. The present study thus considers that advantaged and disadvantaged neighborhoods may *both* pull for substance use (albeit via potentially different mechanisms) and considers three competing hypotheses about how these high risk environments may either unmask or conceal sensation seeking effects on substance use. The first hypothesis is consistent with a vulnerability approach (Mischel

2004; Zimmerman and Farrell 2016) and posits that neighborhood contexts that pull for substance use unmask individual vulnerability, and thus sensation seeking effects will be strongest in the highest risk environments (conceptualized here as both highly advantaged and highly disadvantaged neighborhoods, but not those in between). A second hypothesis is that environments that pull for substance use do so for everyone in the community, regardless of individual vulnerability (high risk environments as strong situations approach), and thus these high risk neighborhoods characterized by both relative advantage and disadvantage should see weaker effects of sensation seeking on substance use, and sensation seeking effects should be strongest in the middle of the disadvantage spectrum. A third hypothesis posits that sensation seeking risk for substance use will not differ across neighborhood environments (the invariance approach).

The Current Study

The present study is the first to examine neighborhood moderation of sensation seeking's effects on adolescent substance use in a longitudinal sample. We hypothesize that adolescent substance use initiation will be predicted by higher youth sensation seeking (a direct linear effect) and residence in both relatively disadvantaged and relatively advantaged neighborhoods (a direct quadratic effect, informed by the literature suggesting risk at both ends of the spectrum). Furthermore, we will test three competing moderation hypotheses (heightened sensation seeking effects in both advantaged and disadvantaged neighborhoods, weakened sensation seeking effects in both advantaged and disadvantaged neighborhoods, and invariance of sensation seeking effects across neighborhoods) by modeling a quadratic interaction. Testing this quadratic interaction also accounts for the possibility that past conflicting findings from the broader literature may be due in part to linear modeling of a non-linear process. Furthermore, modeling the potential direct and interactive quadratic effects of neighborhood are consistent with recent recommendations for avoiding detection of spurious interactions in the related field of gene by environment interactions (Dick et al. 2015).

Method

Participants

The sample of youth (N=454) is drawn from the third generation of participants in an ongoing intergenerational study of familial alcoholism risk, with Time 1 (T1) data used here were collected between the years of 2006–2011. The original study recruited 454 adolescents (second generation; G2) and their parents (first generation; G1) in 1988 (Chassin et al. 1991). The original study recruited families with at least one alcoholic parent (54% of original sample) using court records of DUI arrests, HMO wellness questionnaires, and community telephone screenings. Reverse directories and telephone screenings were used to locate demographically matched control families without an alcohol parent (46% of original sample) from the same neighborhoods as alcoholic families. G2 adolescents and their G1 parents were interviewed annually for three years (Waves 1–3) and then at five year intervals (Waves 4–6). Beginning at Wave 4, biological siblings of G2s who fell within the same target age range were also interviewed and added to the G2 sample. Retention of the original

sample has been excellent, with 90% of original G2s retained at Wave 6. Assessments of the children of G2s (the third generation; G3s) were added at Waves 5 and 6, and extra assessments of just the G3s were administered about 18 months after Wave 6 and about 5 years after Wave 6. The current study's sample is made up of youth who completed a Wave 6 (current study's T1) assessment in early adolescence (aged 10–15; mean age=12.16). The Time 2 (T2) assessment of G3 substance use is drawn from the last follow up assessment for which data were present and at which the G3 had not yet turned 21 (and could thus drink legally; mean age =15.69). The present analyses focusing on initiation of substance use behavior in light of neighborhood factors were restricted to youth who reported lifetime abstinence from any substance use at T1 and had a valid geocoded T1 home address.

Although the original study design explicitly targeted G1 families that lived in the same Arizona neighborhoods, by the third generation youth were no longer necessarily residing in these same communities. At T1, G3 adolescents resided in 22 different states, with 78.2% of the sample residing in Arizona (65% in the Phoenix Metropolitan Statistical Area); 93.4% of adolescents resided in designated metropolitan statistical areas, defined as having an urban core with a population of at least 50,000 people. Furthermore, the intergenerational nature of the larger project resulted in a sample of youth clustered both within families (due to the inclusion of some siblings) and within neighborhoods, resulting in two possible sources of non-independence of observations. A close examination of the sample (after exclusion criteria mentioned above were applied; N=462) revealed that for the most part siblings were nested *within* neighborhoods, though in several families siblings lived in different neighborhoods (termed cross-classification). Sparse clustering in the present sample limits this study's power to estimate a three level and/or cross-classified model, and thus 8 cases were excluded in which a sibling lived in a different neighborhood than his/her other sibling(s), yielding a final sample of N=454 in which all siblings were nested within neighborhoods. The 454 cases were distributed across 257 neighborhoods, with an average of 1.767 adolescents per neighborhood. The number of participants in a neighborhood ranged from 1–8. A total of 132 adolescents were the only participant from the current study in their neighborhoods (singletons; 29% of the sample). At the family level, the 454 adolescents were distributed across 308 families, with an average of 1.45 participants per family. A total of 186 participants were singletons at the family level (41% of the sample). As we would expect, the T2 substance use initiation outcomes demonstrated fairly high ICCs at the neighborhood level ($ICC_{alcohol}$= .241; $ICC_{tobacco}$= .354; $ICC_{marijuana}$= .352) and family cluster level ($ICC_{alcohol}$= .357; $ICC_{tobacco}$= .454; $ICC_{marijuana}$= .617). Sparse clustering and the overlap between family and neighborhood limit the ability to partition variability across both families and neighborhoods (i.e. in a three level model). The clustered nature of the data was thus modeled using a sandwich estimator (Mplus type=complex) with adjusted standard errors due to neighborhood clustering. It is important to keep in mind that neighborhood clusters also subsume some clusters of siblings within the same neighborhoods.

When the included subsample of youth (N=454) was compared with the excluded subsample (N=113) across all study variables, the two groups did not differ significantly on level of sensation seeking, gender composition, or ethnicity. However, excluded adolescents were more likely to be older at T2 ($t(532) = -3.805$, $p < .001$), come from more disadvantaged

neighborhoods (t (513) = − 2.836, p =.005), come from families with lower average annual income (t (488) = 2.383, p .018), be from non-two parent households (χ^2(1)=23.194, p<.001), and were more likely to have reported T2 alcohol (χ^2(1)=67.003, p<.001), tobacco (χ^2(1)=53.175, p<.001), and marijuana use (χ^2(1)=43.938, p<.001).

Procedure

T1 interviews with adolescents and their parents were conducted at the family's residence or Arizona State University, and T2 data is drawn from interviews in the family's residence, at the university, or over the phone (on average 3.4 years later). Written informed consent was obtained from the parents of minors, and adolescents gave assent at every interview. During telephone interviews verbal consent/assent was audio recorded. At every interview informed consent forms described the nature of the information to be asked in the interview, emphasized that participation was voluntary, and described confidentiality and its limits (i.e. risk of harm to self or others). Participants were made fully aware that they would be asked about substance use.

Measures

Sensation seeking—Six items derived from Zuckerman's (1979) Sensation Seeking Scale were employed to measure motivations for exciting and novel situations. Both child report and primary caregiver report on child sensation seeking were obtained. A low correlation between primary caregiver and child report (r=.188), questionable internal consistency for child report (α=.687), concerns about accurate reporting given young age of some respondents at T1 (youngest respondents age 10), and a desire to reduce potential method bias from using the same reporter of primary predictor and outcome, led to the decision to utilize primary caregiver's report on adolescent sensation seeking in all analyses. The primary caregiver was determined by examining parent and child responses on custody and living situation. In instances where both the biological mother and father had custody and contact, the mother was designated as the primary caregiver. The primary caregiver for 95.2% of youth was a mother or other female caregiver, 3.1% of youth had a male primary caregiver, and 1.8% of youth had no designated primary caregiver (e.g. lived with un-interviewed grandparents or in some other custody arrangement). Parents responded using a (1) "Strongly agree" to (5) "Strongly disagree" scale to items about whether their child, "likes wild parties", "likes to do things on the spur of the moment", "likes being where there is something going on all the time", "would do almost anything on a dare", "likes work that has lots of excitement", and "likes to have new experiences, even if they are a little unconventional". Internal consistency for parent report was acceptable (α =.771).

Neighborhood disadvantage—Adolescents' home addresses at T1 were geocoded and matched to a census-defined block group, which typically contain 600–3,000 residents. Census block groups were then matched to the 2000 Census, yielding a number of census-block level measures of structural neighborhood factors which were used to create the neighborhood disadvantage variable. Neighborhood disadvantage was measured as a z-score composite of percentage of families below the poverty line (range 0–46.59%, mean=8.59%), percentage of families on public assistance (range 0–22.86%, mean=2.20%), percentage of residents who did not graduate high school (range 0–65.58%, mean=15.73%), percentage of

female headed households (range 0–69.52%, mean= 20.16%), and percentage of unemployed residents (range 0–14.83%, mean=3.98%). This is consistent with factor analyses suggesting that these neighborhood structural dimensions load on the same factor (Sampson et al. 1997). By way of comparison, there was a comparable range among common indicators of concentrated advantage (Anderson et al. 2014) in the sample of neighborhoods: the percentage of residents with Bachelor's degrees or higher ranged from 0–68.75% and the percentage of residents in managerial and professional positions ranged from 0–100%. Neighborhood disadvantage was also strongly negatively correlated with census measurement of median household income (r=−.763; median household income ranged from $0–$154,521 per year). These neighborhood-level data suggest that there was substantial variability in the types of neighborhoods in which adolescent participants resided. In the T1 sample the composite neighborhood disadvantage score ranged from −6.55 to 16.68 with a mean of zero.

Covariates

Gender—Gender was included as a covariate (0=female, 1=male), with 53.1 % of the sample reporting male gender.

Ethnicity—Adolescents' self-reported ethnicity was re-coded into a three category variable reflecting non-Hispanic Caucasian (61%), Hispanic (27.8%), or any other ethnicity (11.2%). Two dummy codes were included in all models to control for ethnicity.

Age—G3 age was included as a covariate to account for variability in age at the T2 interview.

Biological parent Substance Use Disorder (SUD): Given the nature of the original sampling procedure, familial substance use disorder must be taken into account. DSM-IV criteria (American Psychiatric Association 1994) and the computerized version of the Diagnostic Interview Schedule (Robins et al. 1995) were used to classify interviewed biological parents of the adolescent respondents as having or not having a lifetime alcohol or drug disorder diagnosis. Lifetime diagnosis was established for non-interviewed parents using spousal reports on the Family History Research Diagnostic Criteria (Andreasen et al. 1977). Thus, all adolescents with at least one biological parent with a lifetime history of alcohol or drug disorder diagnosis were classified as having a parental SUD (0= no parental SUD, 1= parental SUD). The majority of participants at T1 had at least one parent with a lifetime history of SUD (56.1%).

Family structure: G3s were categorized as living in a two-parent home (0) or any other living situation (1), regardless of the biological relation of child to parent. The majority (80.4%) of participants at T1 lived in 2 parent homes.

Family income: Primary caregivers reported on their average annual family income, which was included as a covariate in order to parse apart the effects of individual socioeconomic status and neighborhood socioeconomic status. The average family income was $68,488 (SD=$42,000).

Substance use initiation—Youth reported at T2 on the lifetime frequency of substance use behaviors for alcohol, tobacco, marijuana, and seven other classes of illicit drugs. Those substances for which at least 10% of the initially non-using sample endorsed any incidence of lifetime use at T2 were included as binary outcomes (0= no lifetime use, 1= lifetime use). At T2, 17.6% of the sample reported having initiated alcohol use, 10.2% reported having initiated tobacco use, and 12.5% reported having initiated marijuana use.

Data Analysis

All study questions were addressed using structural equation modeling in Mplus 7.2 using FIML to account for missing data (Muthén 1998–2012). All models were tested using MLR estimation and the Type=Complex option, robust to non-normality and with standard errors adjusted for non-independence of observations. The binary nature of substance use initiation was modeled using logistic regression, predicting the log odds of initiating alcohol, tobacco, or marijuana use separately.

Covariates included ethnicity, gender, age at T2, family income, family structure, and family history of substance use disorder. Preliminary analyses tested potential covariate moderation of key paths, examining sensation seeking interactions with each covariate, neighborhood disadvantage interactions with each covariate, and all three way interactions among sensation seeking, neighborhood disadvantage and each covariate. Given the multiple un-hypothesized comparisons involved in testing these covariate by predictor interactions, significance levels were corrected for false discovery rates (FDR; Thissen et al. 2002). These analyses revealed that no interaction reached FDR-corrected significance levels, and thus all covariate by predictor interactions were dropped from further analyses.

The models (Figure 1) included longitudinal relations between T1 sensation seeking, neighborhood disadvantage, neighborhood disadvantage squared, two interaction terms and T2 substance use initiation alongside all covariates. The inclusion of the squared term allowed for a test of the hypothesized quadratic relation between neighborhood disadvantage and substance use initiation such that both the most disadvantaged and most advantaged communities would be associated with increased risk for initiating alcohol, tobacco, and marijuana use. The hypothesized interaction between sensation seeking and neighborhood disadvantage was tested using the “define” command in Mplus to create two interaction terms: sensation seeking by neighborhood disadvantage (a linear interaction term) and sensation seeking by neighborhood disadvantage squared (a quadratic interaction term). The Wald test of parameter constraints was utilized to determine whether the joint contribution of the neighborhood disadvantage quadratic term and the quadratic interaction significantly improved model fit. If the Wald test was non-significant, the quadratic term and quadratic interaction term were dropped (the linear interaction was retained). Interactions which reached statistical significance ($p<.05$) were probed and plotted using the Johnson-Neyman technique for computation of regions of significance with confidence bands for the conditional effect (Johnson and Neyman 1936; Preacher et al. 2006) and simple slopes computed and plotted at the 20^{th}, 40^{th}, 60^{th}, and 80^{th} percentiles of neighborhood disadvantage to aid in interpretation. All predictors included in interaction terms were grand mean centered (Aiken and West 1991).

Results

Correlations

Zero-order correlations (Table 1) between all study variables revealed that T1 sensation seeking was significantly related to a higher likelihood of initiation of alcohol and marijuana use by T2, but was not significantly correlated with likelihood of tobacco initiation by T2. Neighborhood disadvantage was not significantly correlated with any of the three substance use initiation outcomes. All three substance use initiation outcomes were highly correlated with each other. Correlations between covariates and T2 substance use initiation outcomes were largely consistent with what has been seen in the literature regarding risk for substance use initiation. Age at T2 assessment and parent substance use disorder were positively correlated with T2 initiation of all three substances, and higher family income was associated with less initiation across all three classes of substances. Being in any family structure other than a two parent household was associated with higher likelihood of T2 alcohol, tobacco, and marijuana use. Gender, Hispanic ethnicity, and other ethnicity (not Hispanic or Caucasian) were not significantly correlated with T2 substance use initiation. Non-Hispanic Caucasian ethnicity was associated with less initiation of marijuana use but was not significantly correlated with initiation of alcohol or tobacco use. Caucasian youth were more likely to have higher sensation seeking scores, live in less disadvantaged neighborhoods, have lower rates of parent substance use disorder, and have higher family incomes, whereas Hispanic youth were more likely to be male, to be from more disadvantaged neighborhoods, have higher rates of parental substance use disorder, and have lower family incomes.

Covariate Effects

Results can be found in Table 2. Gender, family structure, family income, and Hispanic ethnicity were not significantly associated with initiation of alcohol, tobacco, or marijuana use. Caucasian ethnicity (compared to Hispanic and other ethnicity) was associated with lower likelihood of initiating alcohol use, but was not related to initiation of tobacco or marijuana use. Older age at T2 and having a biological parent with a substance use disorder were consistently associated with higher likelihood of initiating all three forms of substance use.

Interaction of Sensation Seeking and Neighborhood Disadvantage

Although the quadratic interaction was significant or near significant in both the alcohol (β =.024, SE=.011, p=.029) and tobacco (β =.029, SE=.015, p=.063) models, the Wald test of parameter constraints suggested that the inclusion of the quadratic neighborhood disadvantage term and sensation seeking by quadratic neighborhood disadvantage interaction did not jointly significantly improve fits for the alcohol ($\chi^2(2)=4.794$, p=.091) or tobacco ($\chi^2(2)=5.509$, p=.064) models. Thus, these quadratic terms were dropped and results from the more parsimonious linear models presented.

The effects of sensation seeking on alcohol and tobacco initiation were both significantly moderated by level of neighborhood disadvantage in a linear manner, though neighborhood disadvantage was not directly related to either substance use outcome. Regions of

significance plots (left panel Figure 2) demonstrated a similar pattern for both alcohol and tobacco initiation outcomes. The effect of sensation seeking (plotted on the Y-axis) on alcohol and tobacco use was strongest in relatively advantaged neighborhoods, and the magnitude of this effect was reduced as level of neighborhood disadvantage increased (plotted on the X-axis). Conditional slope plots (right panel Figure 2) further clarified that the effect of sensation seeking was nonsignificant at both the 60th and 80th percentile of neighborhood disadvantage in the alcohol initiation model, and nonsignificant in the 80th percentile for the tobacco initiation model. That is, for alcohol initiation, in the most advantaged neighborhoods (20th percentile), a one point increase in sensation seeking was associated with 3.5 times higher odds of initiating alcohol use and 2.7 times higher odds of initiating tobacco use, and the strength of this association was reduced to zero as neighborhood disadvantage increased.

The effect of sensation seeking on marijuana use initiation was moderated by neighborhood disadvantage in a quadratic manner, though the direct effect of neighborhood disadvantage was not related to the likelihood of marijuana use in either a linear or quadratic manner. A plot of the slope of sensation seeking predicting the log odds of initiating marijuana use across levels of neighborhood disadvantage (bottom left panel of Figure 2) revealed a U shaped curve. On the left side of the plot, at the lowest levels of neighborhood disadvantage, sensation seeking was significantly related to a higher likelihood of initiating marijuana use, with the effect growing more strongly predictive of marijuana initiation as neighborhood disadvantage decreased. In economically advantaged neighborhoods (20th percentile), a one point increase in sensation seeking was associated with a 2.8 times higher odds of initiating marijuana use. Upwards of about the 40th percentile (in average and relatively disadvantaged neighborhoods), the effect of sensation seeking decreased to non-significance, but began to grow stronger again above about the 80th percentile. Only at the *very* highest levels of neighborhood disadvantage (outside the bounds of the plotted 2SD region) did the slope of sensation seeking predicting the likelihood of initiating marijuana use return to statistical significance. The bottom right panel of Figure 2 depicts this pattern of simple slopes plotted separately at the 20th, 40th, 60th, and 80th percentiles on neighborhood disadvantage.

Sensitivity Analyses

Sensitivity analyses suggest that findings are robust across alternate modeling techniques and conceptualizations of substance use initiation. Multilevel modeling (MLM) is an alternative approach to handling clustered data. MLM accounts for the nested structure of the data by explicitly modeling variance at both the individual level and the neighborhood level. Alcohol, tobacco, and marijuana use models were also run using the multilevel structural equation modeling method, and the pattern of results was the same as the single level sandwich estimator option.

The current study examined the rates of substance use *initiation* among a sample of youth who had not yet initiated any substance use at T1. This design decision strengthens our confidence in conclusions about temporal precedence of the role of sensation seeking in initiation of use, but excluded the higher risk youth who had already tried alcohol and/or other drugs at T1. In order to address the question of whether sensation seeking and

neighborhood disadvantage impact the extent of experimentation with different substance classes among both users and non-users at T1, an alternate model tested the same hypothesized paths among T1 users and non-users (n=529) on the outcome of number of lifetime substances tried at T2. Number of lifetime substances tried at T1 was included as a covariate. The count nature of the T2 number of substances tried outcome, with a large number of zeros (69.5% reported 0 substances tried, 11.2 % reported 1 substance tried, 6.4% reported 2 substances tried, 7.2% reported 3 substances tried, 5.8% reported four or more substances tried), necessitated zero-inflated Poisson (ZIP) modeling. Thus the T2 number of substances tried outcome was modeled in two parts: the zero-inflation portion of the outcome is a logistic regression predicting the log odds of being a latent structural zero (an abstainer), whereas the Poisson portion models the count of number of substances tried among the latent class of individuals who were able to assume non-zero values. As we would expect, results from the zero-inflation portion of the model (predicting the likelihood of T2 abstinence from substance use) were very consistent with the results for alcohol, tobacco, and marijuana use initiation. The Wald test suggested that inclusion of the neighborhood quadratic term and quadratic interaction improved model fit ($\chi^2(2)=7.670$, $p=.022$) in the prediction of the likelihood of being an abstainer. Neighborhood disadvantage and its square were not directly related to the likelihood of being an abstainer, but neighborhood disadvantage significantly moderated the relation between sensation seeking and likelihood of being an abstainer ($\beta = -.032$, SE=.011, p=003.). The interaction was such that sensation seeking was significantly associated with a lower likelihood of being an abstainer below the median on neighborhood disadvantage, with the strength of the association growing stronger as neighborhood disadvantage decreased. The effect of sensation seeking was non-significant at higher levels of disadvantage, though it returned to statistical significance in the very tail of the distribution of neighborhood disadvantage (well beyond 2SD from the mean). Results from the counts portion of the model suggested lack of improvement in fit from the inclusion of the quadratic neighborhood effect and quadratic interaction ($\chi^2(2)=2.226$, $p=.329$), and in the more parsimonious linear model neither sensation seeking, neighborhood disadvantage, nor their interaction were significantly related to a higher number of substances tried.

Discussion

Sensation seeking is a risk factor for adolescent substance use initiation (Andrucci et al. 1989; Malmberg et al. 2010), but less is known about how neighborhood contexts can potentially modify this risk, for example, by either unmasking or suppressing sensation seeking's effects. Although the traditional social disorganization approach to problem behavior suggests that the most disadvantaged neighborhoods should see the highest rates of youth substance use, a body of research suggests that youth in the most socioeconomically affluent communities are also at risk (e.g. Luthar and D'Avanzano 1999). The only existing study on the interplay between disinhibition and neighborhood factors in substance use demonstrated that disinhibition effects were strongest in the most socially organized communities (Ray et al. 2016); the literature on delinquency more broadly has failed to yield a consensus. This mixed pattern of findings leaves questions unanswered about potential non-linear neighborhood effects (wherein both highly advantaged and highly disadvantaged

communities represent high risk substance use ecologies) and potential non-linear interactions between neighborhood disadvantage and sensation seeking (wherein sensation seeking effects are unmasked or concealed similarly in the high risk neighborhoods at both ends of the disadvantage spectrum).

The present study sought to answer these questions in a longitudinal sample of youth who had not yet initiated any substance use at the beginning of the study. Neighborhood disadvantage did not directly predict adolescent initiation of substance use, but results supported the hypothesized role of neighborhood disadvantage as a *moderator* of sensation seeking effects on adolescent initiation of alcohol, tobacco, and marijuana use outcomes. Results provide fairly robust evidence that relatively advantaged neighborhoods unmasked sensation seeking risk for substance use, whereas the impact of sensation seeking was not evident in more disadvantaged neighborhoods. It was initially hypothesized that sensation seeking effects would manifest similarly in *both* highly advantaged and highly disadvantaged neighborhoods. Results showed some suggestion of this pattern but did not provide clear support. Results from all three models suggested a trend for the slope of sensation seeking to begin to increase again in the most highly disadvantaged neighborhoods, but in the alcohol and tobacco use models this effect in the most highly disadvantaged neighborhoods did not reach statistical significance and fit statistics suggested that modeling this quadratic trend did not improve overall fit. In the marijuana use model, results suggested that neighborhood disadvantage played a nonlinear moderator role, although it must be emphasized that the highly disadvantaged neighborhoods where the sensation seeking effect again reached statistical significance were very much in the tail of the neighborhood distribution, and thus the reliability of these estimates are perhaps untrustworthy.

The lack of direct effects of neighborhood disadvantage is consistent with the findings in the literature that suggest that neighborhood disadvantage may not be the main driver of geographic clustering of substance use rates (Karriker-Jaffe 2011). The finding of heightened sensation seeking risk in the most economically advantaged communities is very much consistent with the only other study examining the interplay between disinhibition and neighborhood context in predicting substance use. Thus, the current results provide a valuable replication and longitudinal extension of Ray et al. (2016)’s cross-sectional study which demonstrated that low impulse control was more strongly related to the probability of being either a soft or a hard drug user (as compared to the abstainers class) in the most organized neighborhoods, but not in those neighborhoods characterized by more disorder. Our results and those of Ray and colleagues are both consistent with the traditional theory that more disadvantaged, disorganized neighborhoods are “strong situations” where social pulls for problem behavior and substance use will mask the effects of individual differences, whereas in advantaged, less criminogenic communities, individual vulnerabilities will be allowed to express themselves. The finding of increased sensation seeking risk in more economically advantaged communities also provides a valuable contribution to a growing body of research which seeks to understand the pathways to substance use among affluent communities, which have traditionally be conceptualized as low risk ecologies. Luthar and colleagues (Luthar and Becker 2002; Luthar and Latendresse 2005) have posited that the stress reduction pathway to substance use, characterized by comorbidities with anxiety and

depression, is of particular relevance in affluent communities characterized by high pressure to achieve and supervisory and emotional isolation from adults. The results of the present study, however, suggest that an alternate *fun seeking* pathway from sensation seeking tendencies to substance use initiation may also be at work in relatively more advantaged communities.

Strengths and Limitations

The current study extends previous research by being the first to test quadratic effects of neighborhood disadvantage and its interaction with sensation seeking as a prospective predictor of substance use initiation, and highlights the role of neighborhood advantage in unmasking sensation seeking risk. This study is strengthened by the use of different reporters of sensation seeking and substance use effects (which minimizes the effects of reporter bias) and appropriate statistical methods which controlled for the clustered nature of the data. However, despite these strengths, there are limitations to consider. First, as in most studies of neighborhood structural characteristics, neighborhood disadvantage is highly conflated with neighborhood level race/ethnicity such that the more advantaged neighborhoods which saw greater sensation seeking risk for substance use initiation were also more likely to be white neighborhoods. This study did control for individual race/ethnicity, which can ameliorate concerns about race/ethnicity effects at the person level, but not the community level. Second, the prospective assessment of neighborhood disadvantage at T1 and substance use at T2 strengthens this study's ability to make causal interpretations of the results, but does not address the possibility that there might be stronger effects of the adolescents' *current* neighborhood environments. Third, the current study did not have direct measures of the neighborhood features that constitute a "strong" or "weak" situation. That is, we had no neighborhood-level measures of substance use norms or access to substances. Models testing the interaction of sensation seeking with these neighborhood level variables are a direction for future research. Finally, the equivocal findings concerning increasingly strong effects of sensation seeking at extremes of neighborhood disadvantage suggest that studies with larger samples, with higher prevalence of substance use initiation that include more extremely disadvantaged neighborhoods, would have greater power to more clearly reveal potential quadratic interactions between neighborhood disadvantage and sensation seeking.

Conclusions

The present study makes an important contribution to our understanding of the ways in which sensation seeking risk for substance use initiation is modified by the neighborhood environment. Results showed that sensation seeking increases risk for initiation of alcohol, tobacco, and marijuana use, but that this effect depends on the level of neighborhood disadvantage. Sensation seeking risk for substance use initiation increased as neighborhoods grew more advantaged. These results highlight the importance of focusing on relatively more advantaged areas as potentially risky environments for the sensation seeking pathway to substance use.

These results have implications for the prevention of adolescent substance use. Many alcohol and drug prevention programs are geared toward youth in impoverished communities that are often perceived as at highest risk. The results presented here highlight that youth from more advantaged neighborhoods are also at risk, specifically for sensation seeking-related substance use. Findings can be used to inform prevention efforts to educate parents from more advantaged communities about their children's risk (Luthar and Latendresse 2005). The present findings could also be used to inform other types of innovative interventions that have exhibited preventive effects on substance use. For instance, a teacher-delivered selective intervention that targets sensation seeking youth has shown promise in reducing alcohol use and misuse (Conrod et al. 2013) and received considerable attention in the popular media of late. Perhaps this sort of intervention would be particularly useful in schools that serve socioeconomically advantaged communities. On a broader level, universal televised messages have demonstrated effects on marijuana use reduction among sensation seeking youth (Palmgreen et al. 2007). The results here suggest that perhaps these media campaigns could be targeted at television markets with higher proportions of affluent viewers in hopes of reducing substance use among this high risk group.

Although the research focus on the importance of neighborhood environments is increasing, there is still a paucity of research, particularly longitudinal studies, on the complex interplay of individual and contextual risks in adolescent development of substance use. More quality research is needed to further increase our understanding of these processes and inform future research, intervention, and policy.

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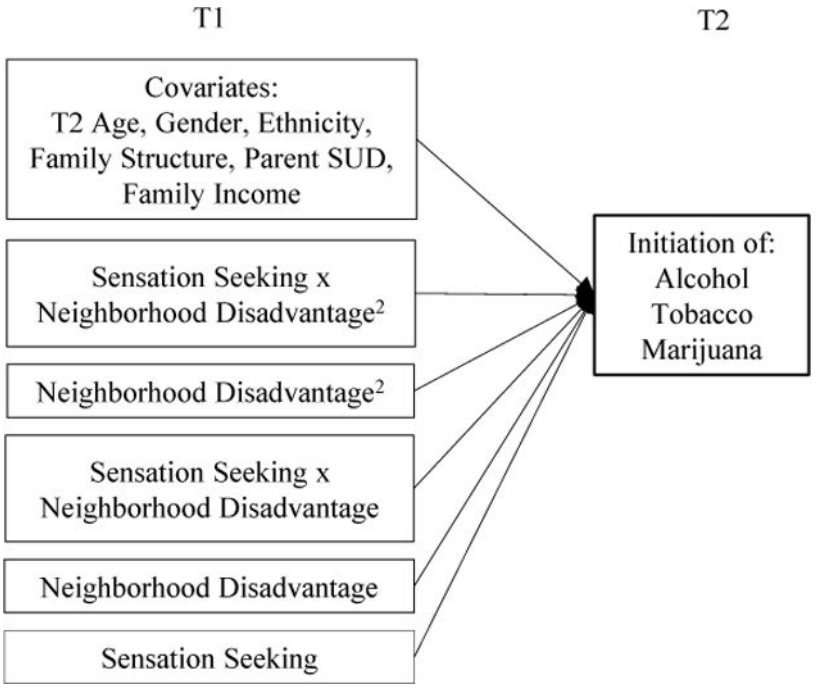

Figure 1.

Statistical Model. Initiation of alcohol use, tobacco use, and marijuana use were each tested in separate logistic regression models. SUD=Substance Use Disorder.

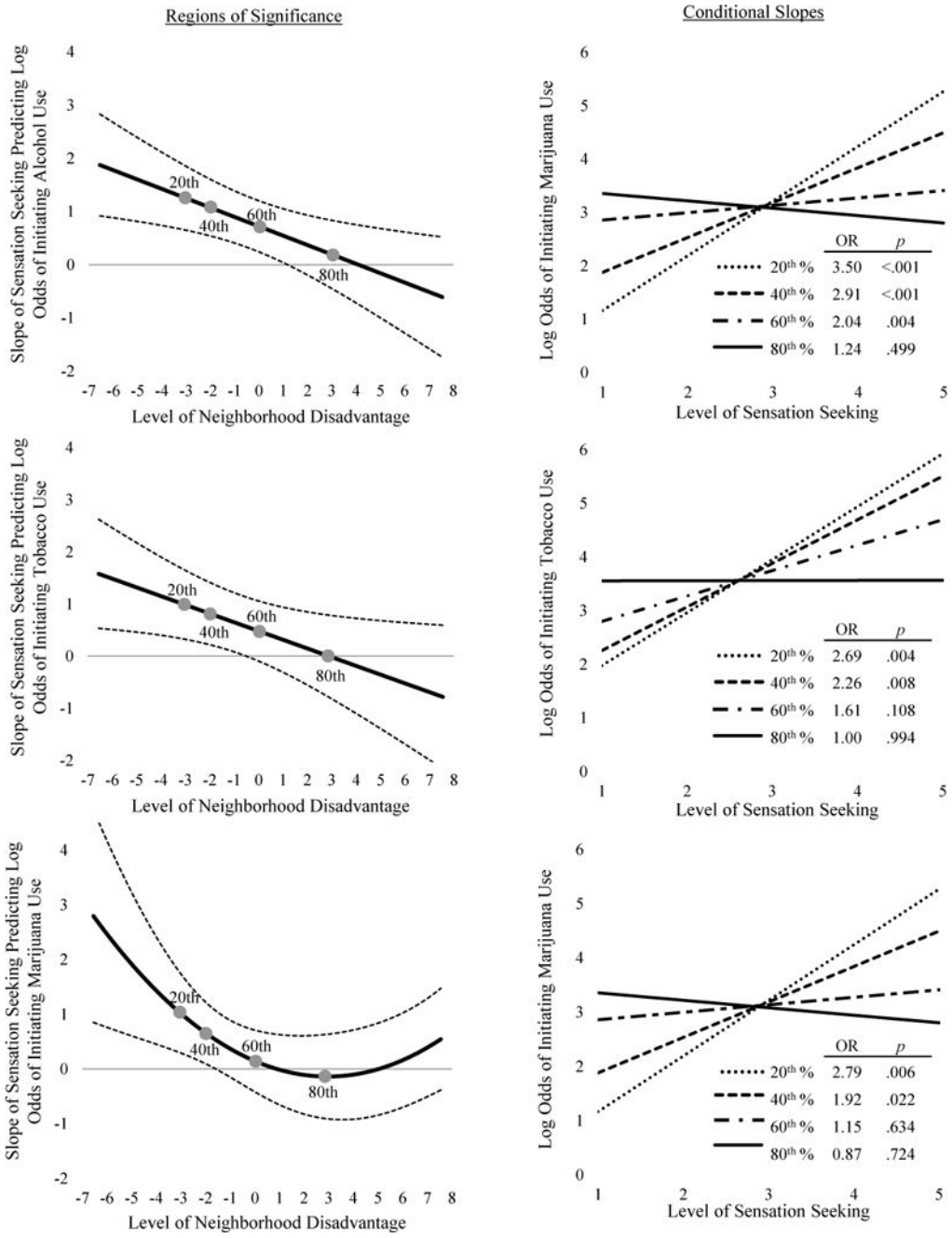

Figure 2.

Regions of significance plots in left panel depict the slope of sensation seeking (dark solid line) predicting the log odds of initiating alcohol, tobacco, and marijuana use (Y-axis) across levels of neighborhood disadvantage out to 2 SD from the mean (X-axis). Dashed lines represent bounds of the 95% confidence interval. Right panel depicts the conditional slopes of sensation seeking predicting the log odds of initiating alcohol, tobacco, and marijuana use at the 20th, 40th, 60th, and 80th percentiles of neighborhood disadvantage. OR=Odds Ratio.

Table 1

Zero Order Correlations

	1. Sensation Seeking	2. Neighborhood Disadvantage	3. Age at T2	4. Gender	5. Caucasian Ethnicity	6. Hispanic Ethnicity	7. Other Ethnicity	8. Family Structure	9. Parent SUD	10. Family Income	11. T2 Alcohol Use Initiation	12. T2 Tobacco Use Initiation	13. T2 Marijuana Use Initiation
Sensation Seeking	–												
Neighborhood Disadvantage	.003	–											
Age at T2	−.035	−.071	–										
Gender (0=female)	.065	.121*	−.057	–									
Caucasian Ethnicity	.102*	−.297*	.043	−.041	–								
Hispanic Ethnicity	−.083	.309*	−.051	.095*	−.775*	–							
Other Ethnicity	−.04	.022	.007	−.071	−.447*	−.219*	–						
Family Structure (0=2 parent)	.108*	.144*	−.012	−.013	−.064	.033	.052	–					
Parent SUD (0=no SUD)	.065	.182*	.079	.019	−.155*	.105*	.089	.263*	–				
Family Income	−.042	−.32*	−.007	−.052	.116*	−.105*	−.03	−.319*	−.093*	1			
T2 Alcohol Use Initiation	.107*	.075	.424*	−.018	−.082	.034	.079	.148*	.18*	−.134*	–		
T2 Tobacco Use Initiation	.08	.009	.244*	.034	−.03	.035	−.002	.151*	.193*	−.124*	.547*	–	
T2 Marijuana Use Initiation	.105*	.046	.228*	.029	−.088*	.069	.038	.194*	.211*	−.124*	.56*	.59*	–
N	419	440	433	454	454	454	454	448	449	397	431	431	431
Sample Mean	3.015	0	15.69	.531	.612	.275	.112	.196	.561	68.488	.176	.102	.125
Standard Deviation	.679	3.771	2.285							42.024			

Note. Correlations calculated using full sample (N=454) in Mplus. N's, sample means, and standard deviations for present data. SUD= Substance Use Disorder. Family income presented in 1,000s of dollars.

*=$p \leq .05$

Table 2

Results

	Alcohol				Tobacco				Marijuana			
	β	**SE**	**OR**	***p* value**	**β**	**SE**	**OR**	***p* value**	**β**	**SE**	**OR**	***p* value**
Gender	−.139	.325	.870	.669	.252	.356	1.286	.479	.102	.319	1.107	.750
Caucasian Ethnicity	**−1.180**	.508	.307	.020	−.334	.569	.716	.557	−.696	.480	.499	.147
Hispanic Ethnicity	−.616	.516	.540	.233	.098	.633	1.103	.877	−.094	.519	.910	.856
Family Structure	.496	.390	1.642	.204	.399	.417	1.500	.339	.738	.422	2.093	.080
Family Income	−.009	.007	.991	.161	−.013	.010	.987	.182	−.008	.007	.992	.270
Parent SUD	**.885**	.384	2.422	.021	**1.367**	.427	3.923	.001	**1.315**	.421	3.724	.002
Age at T2	**.727**	.096	2.069	<.001	**.420**	.097	1.522	<.001	**.401**	.074	1.493	<.001
Sensation Seeking	**.720**	.245	2.054	.003	.481	.294	1.618	.102	.146	.288	1.157	.611
Neighborhood Disadvantage	.038	.048	1.039	.431	−.069	.062	.934	.266	−.026	.069	.975	.710
Neighborhood Disadvantage^2									.002	.007	1.002	.806
SS x Neigh. Disadvantage	**−.176**	.067	.839	.009	**−.167**	.077	.846	.030	−.192	.097	.825	.048
SS x Neigh. Disadvantage^2									**.032**	.012	1.033	.007

Note. SS= Sensation Seeking. Neigh.= Neighborhood. SUD= Substance Use Disorder. Statistically significant paths bolded. β = Unstandardized path coefficient. SE= Standard Error. OR=Odds Ratio.