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Audio-visual integration is strongest for spatially congruent stimuli

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Interplay between Perceived Peer Drinking Norms, the *DRD4* VNTR Polymorphism, and Impulsivity on Young Adult Alcohol Consumption

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Abstract

Young adult alcohol use is a prevalent and significant public health concern, influenced by a complex interplay of genetic, personality, and social factors. Greater descriptive norms (i.e., perceptions of peer drinking behavior) and injunctive norms (i.e., perceptions of peer drinking acceptability) have been associated with increased young adult drinking. Further emerging research suggest that the association between peer norms and alcohol outcomes may be exacerbated by carrying a 7-repeat allele of the *DRD4* VNTR. Presence of a 7-repeat allele has also been associated with greater impulsivity (i.e., novelty-seeking and sensation seeking), but it remains unknown whether such heightened impulsivity explains why carriers drink more than noncarriers at high levels of peer drinking norms. The current study examined whether impulsivity accounted for such *DRD4* VNTR-related differences in susceptibility to perceived peer drinking norms. Participants were 113 Caucasian, moderate to heavy drinking young adults (50% female; mean age = 22 years [*SD* = 2.23]). Generalized negative binomial models revealed that *DRD4* VNTR genotype moderated the relationship between descriptive (although not injunctive) peer norms and frequency of heavy drinking; descriptive norms were more strongly associated with more frequent heavy drinking among carriers of a 7-repeat allele than among noncarriers. Impulsivity was not significantly associated with any alcohol outcomes after accounting for these moderating effects and covariates. Our findings suggest that young adults carrying a high-risk *DRD4* VNTR variant may be more susceptible to the alcohol-promoting influences of perceived peer drinking behavior, although impulsivity may not account for such differences. Future research should examine whether other aspects of personality (e.g., extraversion), alcohol-related cognitions (e.g., drinking motives), or mood (e.g., anxiety) account for such differences in *DRD4* VNTR-related susceptibility to peer drinking norms.

Keywords: DRD4, descriptive peer norms, injunctive peer norms, impulsivity, drinking

Executive Summary

Alcohol use and misuse is a significant public health concern and prevalent among young adults (Slutske, 2004). Individuals in their late teens and early to mid-twenties are more likely to drink heavily, and are at greater risk for alcohol abuse than any other age groups (Naimi, Brewer, Mokdad, Denny, Serdula, & Marks, 2003; Knight, Wechsler, Kuo, Seibring, Weitzman, & Schuckit, 2002). There are many risks associated with heavy drinking, including risky behavior and academic, social, and physical consequences (National Institute on Alcohol Abuse and Alcoholism [NIAAA], n.d.). Young adult alcohol consumption is influenced by many variables, including a complex interplay of genetic, personality, and social factors, and more research on young adult alcohol consumption is necessary to better understand the etiology of young adult drinking to slow such risky behavior.

Descriptive and Injunctive Peer Norms as Perceptions of Peer Drinking and Factors Influencing Individual Drinking. Descriptive norms (defined as perceptions of peer frequency and quantity of drinking) and injunctive norms (defined as perceptions of peer approval of drinking) have been found associated with alcohol use (Borsari & Carey, 2001; Lee, Geisner, Lewis, Neighbors, & Larimer, 2007; Perkins, 2002). Young adults frequently overestimate actual peer drinking rates (Baer, Stacy & Larimer, 1991; Weschler & Kuo, 2000), and research has found that individuals often rate others as more accepting of drinking behaviors than they rate themselves (Borsari & Carey, 2003; Lewis & Neighbors, 2004; Perkins & Berkowitz, 1986b; Thombs et al., 2005). Peer drinking norms may have an influence on alcohol consumption rates and frequency of alcohol use among young adults.

***DRD4* VNTR Genotype: Genetic factor as a Potential Moderator of Influence of Peer Drinking Norms on Young Adult Alcohol Use.** The *DRD4* gene encodes a dopamine D_4

receptor (Benjamin, Li, Patterson, Greenberg, Murphy, & Hamer, 1996). Variations in the *DRD4* gene includes a variable number of tandem repeats (VNTR) sequence, where the genetic code is repeated a varying number of times. Carriers of a 7-repeat allele, specifically, have been more susceptible to perceived peer drinking than noncarriers (Park et al., 2016). Presence of a 7-repeat allele has also been associated with impulsivity (Benjamin et al., 1996), but it remains unknown whether such heightened impulsivity explains why 7-repeat allele carriers drink more than noncarriers when they perceive their peers to be heavy-drinking or approving of heavy-drinking.

Impulsivity as a Potential Mechanisms for Genetic Differences in Susceptibility to Peer Drinking Norms. Impulsivity is a trait that has been correlated with *DRD4* and is characterized by several facets, including novelty-seeking and sensation seeking. Novelty-seeking (i.e., excited responses to novel stimuli; Benjamin et al., 1996) and sensation seeking (i.e., a tendency to seek out and enjoy novel/exciting experiences; Whiteside & Lynam, 2001) have been associated with young adult drinking (Magid & Colder, 2007; Park et al., 2014). Young adults high in sensation seeking have been shown to experience more positive drinking consequences (Park et al., 2014), which may prompt them to continue drinking to experience additional, positive outcomes, and may be a link between impulsivity and *DRD4* VNTR.

Specific Aims. The current study examined interplay between perceived peer drinking, *DRD4* VNTR genotype, and impulsivity on young adult alcohol consumption. Greater perceived peer drinking (i.e., descriptive peer norms) or approval of drinking (i.e., injunctive peer norms) have been associated with increased alcohol consumption, especially among *DRD4* VNTR carriers, and impulsivity may account for carriers' increased susceptibility to perceived peer drinking. To our knowledge, no research has examined possible mechanisms for the reason

behind this increased genetic susceptibility relating to impulsivity. We hypothesized that carriers of a *DRD4* VNTR 7-repeat allele would be more susceptible than noncarriers to the alcohol-promoting peer drinking environment, and impulsivity would account for these *DRD4* VNTR-related differences in susceptibility to perceived peer drinking.

Methods. Participants were recruited from Syracuse University and the Syracuse community through flyers, the university's research participant pool, word of mouth, referrals from another psychology study, and course announcements. Eligible participants were required to be between 21 and 30 years old, Caucasian, and moderate-heavy drinkers. Participants were on average 22 years old (*SD* = 2.18) and 50% female. Participants reported consuming alcohol on over 32 of the past 90 days, drinking about four standard drinks on a typical drinking day and about nine standard drinks on their heaviest-drinking day.

After informed consent, participants provided a saliva sample for genotyping and completed a questionnaire assessing peer norms, impulsivity, and past-90-day alcohol use. Self-reported alcohol use over the past 90 days was collected through the Timeline Follow Back calendars (Sobell & Sobell, 1992), with participant answers recoded into three alcohol outcomes: number of heavy-drinking days, maximum alcohol use on a single day, and frequency of any alcohol use. Descriptive peer norms were assessed with a 5-item measure (e.g., "How many of your close friends would you estimate get drunk at least once a week?"), and injunctive peer norms were assessed with another 5-item measure (e.g., "How do you think your close friends feel [or would feel] about you drinking four or five drinks regularly?"). Regarding impulsivity, novelty-seeking was assessed with a 40-item measure (e.g., "I like to explore new things"), and sensation seeking was assessed with a 12-item measure (e.g., "I quite enjoy taking risks").

Results. Generalized negative binomial models (accounting for over-dispersed distributions of outcome variables) demonstrated that presence of a *DRD4* VNTR 7-repeat allele moderated the relationship between descriptive norms and frequency of heavy drinking over the past 90 days (incidence rate ratio = 1.16, $p = .21$). Descriptive norms were more strongly associated with number of heavy-drinking days among carriers of the 7-repeat allele than among noncarriers. Impulsivity was not associated with any alcohol outcomes and did not account for the significant interaction between descriptive peer norms and *DRD4* on frequency of heavy-drinking.

Conclusions and implications. The present study extended the literature by examining the relationships between perceived peer drinking, *DRD4* VNTR genotype and impulsivity on young adult alcohol use. Young adult carriers of a *DRD4* 7-repeat allele who reported high perceived peer drinking engaged in more frequent heavy-drinking than noncarriers; that is, when young adult carriers perceived their peers to be more heavy-drinking (i.e., high descriptive peer norms), they tended to engage in more heavy-drinking themselves. In contrast, carriers were not more susceptible to perceived peer approval of drinking (i.e., injunctive peer norms) than noncarriers. Impulsivity (either sensation seeking or novelty-seeking) did not account for this heightened susceptibility of *DRD4* carriers to perceived peer drinking. These findings have important clinical implications for reducing young adult heavy drinking. Our results suggest that genetic risks are highest when young adults perceive that their peers drink heavily and research has shown young adults overestimate their peers' drinking. So, we could use interventions to reduce these overestimates of peer drinking (personalized feedback interventions, normative feedback, etc) to reduce perceptions of peer drinking and, thus, genetic risks for heavy drinking. Future, prospective studies are needed to explore alternative mechanisms for *DRD4* VNTR-

related susceptibility to descriptive peer norms as well as the extent to which *DRD4* influences the relationship between injunctive norms and alcohol consumption among young adults.

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Interplay between Perceived Peer Drinking Norms, the *DRD4* VNTR Polymorphism, and Impulsivity on Young Adult Alcohol Consumption

Alcohol use and misuse is prevalent among young adults, especially college students (Slutske, 2004). Research has shown that individuals in their late teens and early to mid-twenties are more likely to drink heavily, and over 30% of college students may meet criteria for alcohol abuse (Naimi, Brewer, Mokdad, Denny, Serdula, & Marks, 2003; Knight, Wechsler, Kuo, Seibring, Weitzman, & Schuckit, 2002). There are many risks associated with heavy drinking, including risky behavior and academic, social, and physical consequences (National Institute on Alcohol Abuse and Alcoholism [NIAAA], n.d.). More research on young adult alcohol consumption is necessary to better understand the etiology of young adult drinking.

Young adult alcohol consumption is affected by many variables, including a complex interplay of genetic, personality and social factors. Young adults drink more when they perceive their peers to be heavy-drinking (i.e., high descriptive peer norms) or approving of heavy-drinking (i.e., high injunctive peer norms; Borsari & Carey, 2003; Perkins, 2002). Young adults frequently overestimate actual peer drinking rates (Baer, Stacy & Larimer, 1991; Weschler & Kuo, 2000), and research has found that individuals often rate others as more accepting of drinking behaviors than they rate themselves (Borsari & Carey, 2003; Lewis & Neighbors, 2004; Perkins & Berkowitz, 1986b; Thombs et al., 2005). Carriers of *DRD4* VNTR have been more susceptible to perceived peer drinking than noncarriers (Park, Kim, Zaso, Glatt, Sher, Scott-Sheldon & Carey, 2016). The *DRD4* gene encodes a dopamine D_4 receptor in the limbic system that responds to dopamine (Benjamin, Li, Patterson, Greenberg, Murphy, & Hamer, 1996). Variations in the *DRD4* gene are possible through a variable number of tandem repeats (VNTR) sequence, where the genetic code is repeated a varying number of times. The 7-repeat allele,

specifically, has been associated with greater susceptibility to alcohol-promoting social environments (Larsen, 2010).

The *DRD4* gene has also been correlated with impulsivity, which is characterized by disinhibition, novelty-seeking, and risk taking. Impulsivity is suggested to include several facets – lack of perseverance, lack of premeditation, sensation seeking, negative urgency, and positive urgency – that have been shown to have differential relationships to alcohol use (Cyders & Smith, 2007; Magid & Colder, 2007). Specifically, individuals high in sensation seeking (defined as the tendency to seek out and enjoy novel and exciting experiences [Whiteside & Lynam, 2001]) have reported greater alcohol use than individuals high in urgency or lack of perseverance (Magid & Colder, 2007). Those high in sensation seeking may indulge in alcohol use for the positive arousal that is associated with drinking (Cyders, Flory, Rainer & Smith, 2009). Further, young adults high in sensation seeking have been shown to experience more positive drinking consequences (Park et al., 2014), which may prompt them to continue drinking to experience additional, positive outcomes. Impulsivity is also characterized by qualities of novelty seeking, or excited responses to novel stimuli (Benjamin, Li, Patterson, Greenberg, Murphy, & Hamer, 1996). Greater novelty seeking has been associated with increased alcohol use among young adults (Magid & Colder, 2007; Park et al., 2014). However, there have been mixed findings on associations between novelty-seeking and the *DRD4* VNTR. Specifically, Benjamin and colleagues (1996) found that mostly male, Caucasian adult *DRD4* VNTR carriers reported higher novelty seeking, Schinka, Letsch, and Crawford (2002) found no relationship between *DRD4* genotype and novelty-seeking in a meta-analysis involving various populations (i.e., Japanese students, American adults, Japanese soldiers, German adults with alcohol use

disorder, and several Israeli and Swedish adult samples). Future research is needed to clarify these mixed findings.

In addition to associations between *DRD4* VNTR genotype and impulsivity, research has also demonstrated associations between *DRD4* and susceptibility to alcohol-promoting social environments. Specifically, *DRD4* VNTR 7-repeat allele carriers may be more susceptible to perceived peer drinking norms than noncarriers. Descriptive norms (i.e., perceptions of peer drinking behavior) and injunctive norms (i.e., perceptions of peer drinking acceptability) have been found to influence alcohol use (Borsari & Carey, 2001; Lee, Geisner, Lewis, Neighbors, & Larimer, 2007; Perkins, 2002), and alcohol-related problems (Larimer, Turner, Mallett, & Geisner, 2004). Further, recent findings suggest that carriers of a risky 7-repeat allele may be more susceptible to both descriptive and injunctive peer norms than noncarriers (Park et al., 2016). The mechanisms of such *DRD4* VNTR-related susceptibility to social environments remain unknown, and it remains to be tested whether impulsive personality traits could account for such genetic differences in susceptibility to perceived peer drinking.

The current study examined interplay between perceived peer drinking, *DRD4* VNTR genotype, and impulsivity on young adult alcohol consumption. Greater perceived peer drinking or approval of drinking has been associated with increased alcohol consumption, especially among *DRD4* VNTR carriers, and impulsivity may account for carriers' increased susceptibility to peer drinking norms. We hypothesized that carriers of a *DRD4* VNTR 7-repeat allele would be more susceptible to the alcohol-promoting influence of peer drinking norms than noncarriers, and impulsivity would account for these *DRD4* VNTR-related differences in susceptibility to perceived peer drinking. Study findings could have important implications for prevention and intervention efforts by identifying those young adults most susceptible to the influences of

perceived peer drinking norms as well as exploring a potential mechanism through which genetic and environmental factors interact to influence young adult drinking.

Method

Participants

One hundred and twenty participants were recruited from Syracuse University and the Syracuse community through flyers, the university's research participant pool, word of mouth, referrals from another psychology study, and course announcements. Eligible participants were Caucasian, as the *DRD4* VNTR genotype is primarily found in this group, and 21 – 30 years of age. As part of a larger study with an alcohol administration component, further eligibility criteria excluded participants with a current medical condition or medication use contraindicated with alcohol, with adverse reactions or allergies to alcohol, who reported smoking 15+ cigarettes per day, or who met criteria for current/past alcohol use disorder. Participants with an initial blood alcohol content (BAC) above 0.00%, weighing 15% below their ideal body weight, with current psychiatric concerns (e.g., anxiety, depression, thoughts of suicide), or with a positive pregnancy test result (for females) were also excluded at the experimental session.

Procedures

All study procedures were approved by the university's Institutional Review Board (IRB). Interested participants completed a phone screen for eligibility, and eligible participants were scheduled for an experimental session. Each session consisted of one laboratory visit that lasted approximately 4 hours. Upon session initiation, research assistants collected a government issued photo identification and secondary identification (e.g., credit card, student identification) to verify participant age. Participants provided written, informed consent and agreed not to drive for two hours after their session concluded (as part of the alcohol administration component).

Research assistants collected height, weight, and initial blood alcohol content (BAC) measurements from all participants and administered a pregnancy test to all female participants. Participants completed an eligibility questionnaire (to assess further study eligibility criteria), provided a saliva sample for genotyping, and completed a questionnaire assessing peer norms, impulsivity, and past-90-day alcohol use.

Measures

***DRD4* VNTR genotype.** A saliva sample was collected from each participant for *DRD4* VNTR genotyping. Participants were asked to rinse their mouth with water and were given sugarless gum to increase saliva production. The saliva sample was collected in a plastic tube and immediately frozen until it was shipped to a private facility for genotyping. Of the 120 participants who completed the experimental session, seven (6%) samples could not be genotyped. Participants who had complete genetic data did not differ significantly from those who did not have complete genetic data, except that participants with undetermined genetic data reported greater maximum alcohol use (M = 13.14, SD = 2.61) and frequency of heavy-drinking (M = 24.57, SD = 13.09) than those with complete genetic data (M = 8.93, SD = 4.51 and M = 11.99, SD = 11.88, respectively). Our final sample consisted of 113 young adults with complete genetic data.

Novelty-seeking. The Temperament and Character Inventory (TCI) is a self-report measure that assesses several domains of personality, including novelty-seeking, harm avoidance, reward dependence, persistence, self-directedness, cooperativeness, and self-transcendence (Cloninger, Przybeck, Svrakic, &Wetzel, 1994). The current study administered the novelty-seeking subscale only, as novelty-seeking has been correlated with both *DRD4* VNTR genotype and young adult alcohol use (Benjamin et al., 1996; Magid & Colder, 2007;

Park et al., 2014). This subscale consists of 40 items (e.g., "I like to explore new things," "I prefer to spend money rather than saving it") answered by selecting true or false. A sum score was used for analyses (Cronbach's $\alpha = .83$).

Sensation seeking. The UPPS-P Impulsive Behavior Scale (UPPS-P) is a self-report measure assessing several facets of impulsivity including Urgency (positive and negative), Premeditation (lack of), Perseverance (lack of), and Sensation Seeking (Whiteside & Lynam, 2001; Cyders & Smith, 2007). The current study administered the sensation seeking subscale, as sensation seeking has been associated with young adult alcohol use (Cyders et al., 2009; Magid & Colder, 2007; Park et al., 2014). This subscale contains 12 items (e.g., "I quite enjoy taking risks," "I would enjoy parachute jumping") that are answered on a 1 (*agree strongly*) to 4 (*disagree strongly*) Likert Scale. A sum score was used for analyses (Cronbach's $\alpha = .83$).

Peer descriptive norms. Participants responded to 5 items regarding how many of their close friends drank (e.g., "How many of your close friends would you estimate get drunk at least once a week?") using a 0 (*none*) to 4 (*all*) Likert scale. A sum score was used for analyses (Cronbach's $\alpha = .65$).

Peer injunctive norms. Participants responded to 5 items regarding how their close friends feel about their drinking habits (e.g., "How do you think your close friends feel [or would feel] about you getting drunk at least once a week?") using 0 (*strongly approve*) to 4 (*strongly disapprove*) Likert scale. A sum score was used for analyses (Cronbach's $\alpha = .71$).

Alcohol use. Participants reported the number of standard drinks they consumed on each of the past 90 days using a Timeline Follow-Back calendar (Sobell & Sobell, 1992). Holidays as well as several local, sport, and television events were included on the calendars to aid participants in their recall (e.g., concerts at a local venue, sporting events on campus, popular TV

series premiers or finales). Participant responses were recoded into three alcohol use outcomes: frequency of alcohol use (number of drinking days over the past 90 days), maximum alcohol use (maximum number of alcoholic drinks on a single drinking day over the past 90 days), and number of heavy-drinking days (number of days consuming 4+ [for females] or 5+ [for males] drinks).

Potential confounding variables. An item was administered to assess gender (0 = *female* and 1 = *male*), which was included as a covariate in all analyses. To control for potential confounding effects (Keller, 2014), all models included a two-way interaction between all model covariates (i.e., male gender, sensation seeking, novelty-seeking) and *DRD4* and peer norms (e.g., male gender***DRD4*).

Results

Descriptive Statistics

As shown in Table 1, participants were on average 22 years old (*SD* = 2.18) and 50% female. Participants reported consuming alcohol on over 32 of the past 90 days, drinking about four standard drinks on a typical drinking day. Participants consumed about nine standard drinks on their heaviest-drinking day and engaged in heavy-drinking on 12 of the past 90 days.

Descriptive norms were moderately correlated with injunctive norms ($r = .47$, $p < .001$; Table 1). Descriptive norms were also positively correlated with frequency of any alcohol use and frequency of heavy-drinking ($r = .18 – .21$, ps $< .05$), while injunctive norms were positively correlated with all alcohol outcomes ($r = .19 – .31$, ps $< .05$). Sensation seeking and novelty seeking were moderately correlated with each other ($r = .38$, $p < .001$). Novelty-seeking was positively correlated with frequency of heavy-drinking ($r = .18 – .28$, ps $< .05$), while sensation seeking was positively correlated with all alcohol outcomes ($r = .18 – .28$, ps $< .05$) aside from

frequency of heavy-drinking. *DRD4* VNTR genotype was not correlated with any study variables.

Descriptive Norms

Generalized negative binomial models revealed that presence of a *DRD4* VNTR 7-repeat allele moderated the relationship between descriptive norms and frequency of heavy drinking over the past 90 days (incidence rate ratio [IRR] = 1.16, p = .21; Table 2). As shown in Figure 1, there was a stronger, positive relationship between descriptive norms and number of heavy-drinking days among carriers of a 7-repeat allele than among noncarriers. There were no significant interaction effects between *DRD4* VNTR genotype and descriptive peer norms on frequency of alcohol use, or maximum alcohol use. Instead, greater descriptive norms were associated with more frequent alcohol use (IRR = 1.04, p = .18) and greater maximum alcohol use (IRR = 1.04, p = .17), regardless of *DRD4* VNTR genotype.

When either sensation seeking or novelty-seeking were added to the model, the interaction between *DRD4* VNTR genotype and descriptive norms on number of heavy-drinking days remained significant. That is, impulsivity did not affect the significant interaction between descriptive peer norms and *DRD4* VNTR genotype on frequency of heavy drinking. This suggests that neither the sensation seeking nor novelty-seeking facets of impulsivity were responsible for any *DRD4* VNTR-related susceptibility to descriptive norms; impulsivity did not explain why carriers were more susceptible to descriptive norms than noncarriers. Further, neither sensation seeking nor novelty-seeking were associated with any alcohol outcomes, regardless of *DRD4* VNTR genotype or descriptive norms.

Injunctive Norms

In contrast to models with descriptive peer norms, there were no significant moderating effects of *DRD4* VNTR presence on the relationship between injunctive peer norms and any alcohol outcomes (Table 2). Greater injunctive norms were associated with more frequent alcohol use (IRR = 1.06, p = .22) and heavy-drinking (IRR = 1.09, p = .31) over the past 90 days, regardless of *DRD4* VNTR genotype. Similar to models for descriptive norms, neither sensation seeking nor novelty-seeking were associated with any alcohol outcomes, regardless of *DRD4* VNTR genotype or injunctive norms.

Discussion

The present study extended the literature by examining the relationships between perceived peer drinking, *DRD4* VNTR genotype and impulsivity on young adult alcohol use. Specifically, it examined whether differences in susceptibility to descriptive and injunctive peer norms as a function of *DRD4* VNTR genotype could be accounted for by sensation seeking and novelty-seeking. Findings suggested that *DRD4* VNTR 7-repeat carriers engaged in more frequent heavy-drinking as their perceptions of peer drinking (but not peer approval of drinking) increased, as compared to noncarriers. Impulsivity (either sensation seeking nor novelty-seeking) did not account for this heightened susceptibility of *DRD4* VNTR carriers to perceived peer drinking, although replication is needed.

Our findings suggest that *DRD4* VNTR genotype and descriptive norms interplay to influence alcohol use, which is consistent with the literature. Young adult carriers of a *DRD4* VNTR 7-repeat allele who reported high perceived peer drinking engaged in more frequent heavy-drinking than noncarriers; that is, when young adult 7-repeat allele carriers perceived their peers to be more heavy-drinking (i.e., high descriptive peer norms), they tended to engage in more heavy-drinking themselves. This result is in line the findings of van der Zwaluw, Larsen,

and Engels (2012), Mrug and Windle (2014), and Park and colleagues (2016) in which carriers of a risky *DRD4* VNTR allele engaged in greater alcohol consumption than noncarriers as perceived peer drinking increased. Additional research suggests that young adult 7-repeat allele carriers may also be more vulnerable to actual (as compared to perceived) peer drinking. Specifically, Larsen and colleagues (2010) found that *DRD4* VNTR risky allele carriers may be more influenced by their peers' heavy-drinking behavior than noncarriers in an experimental alcohol administration study. Thus, current findings are consistent with literature demonstrating greater susceptibility of risky *DRD4* VNTR carriers to perceived and actual peer drinking.

In contrast to previous research, young adult *DRD4* VNTR 7-repeat allele carriers were not more susceptible to perceived peer approval of drinking (i.e., injunctive peer norms) than noncarriers. Existing research suggests that injunctive norms are strongly and positively correlated with heavy alcohol use (Lee et al., 2007; Neighbors, O'Connor, Lewis, Chawla, Lee, & Fossos, 2008), but research regarding the influence of injunctive norms on *DRD4* VNTR carriers' alcohol use is more limited. Specifically, Park and colleagues (2016) found that carriers of a *DRD4* VNTR 7-repeat allele were more susceptible to a combined variable of descriptive and injunctive peer drinking norms than noncarriers in a high school sample, but not in a college sample. Additionally, emerging research suggests that descriptive peer norms may be more strongly associated with maximum alcohol use and drinking quantity than injunctive peer norms (DeTore, 2014). Our findings suggest that genetic influences on drinking are not affected when high perceptions of peer approval of drinking are present. Further research is needed to clarify these findings.

While findings demonstrated differences in susceptibility to descriptive norms as a function of *DRD4* VNTR genotype, findings also suggested that impulsivity may not explain this

interplay. This was the first study to explore whether personality may account for differences in susceptibility to peer drinking as a function of the *DRD4* VNTR, and such findings represent a novel demonstration that impulsivity may not be the mechanism through which variation in *DRD4* VNTR genes influence alcohol consumption as a function of perceived peer drinking. While these findings require replication, they suggest that alternative mechanisms may explain the increased alcohol consumption of carriers when in the presence of high perceived peer drinking. For example, other aspects of personality (e.g., extraversion) may account for this relationship; carriers of a risky *DRD4* VNTR variant may display more extraverted personality, and such extraverted qualities (i.e., gregariousness, tendency for social stimulation) may promote increased drinking when carriers perceive their peers to be heavy-drinking. Further, alcohol-related cognitions (e.g., social drinking motives) or mood (e.g., anxiety) may account for such differences in *DRD4* VNTR-related susceptibility to perceived peer drinking and require examination in future research.

Several limitations should be considered when interpreting these results. First, the current study was based on a small sample of mostly college students from a private Northeastern university who were mainly White and between 21 and 22 years of age. This limits the generalizability of study findings to additional populations. Second, peer descriptive and injunctive norms were measured using two, five-item self-report measures, and all alcohol outcomes were based upon participants' self-report over the past 90 days. These are certainly subject to self-report biases (e.g., difficulty in accurately recalling every drink consumed over the past 90 days and/or those with higher impulsivity may over-report on questionnaires). Third, as this research was conducted as part of a larger study that had strict eligibility criteria, we excluded heavy cigarette smokers (15+ cigarettes per day), those who meet criteria for

current/past alcohol use disorder, and those with any psychiatric conditions. These exclusion criteria may have excluded more impulsive individuals who engaged in heavy/problematic alcohol and cigarette use, and the relationship between peer norms and alcohol use may differ in populations with alcohol use disorder, depression and/or anxiety.

Despite these limitations, the current findings expanded the literature on peer norms, *DRD4* VNTR genotype, and impulsivity by demonstrating that *DRD4* VNTR 7-repeat carriers engaged in more frequent heavy-drinking as their perceptions of peer drinking (but not peer approval of drinking) increased, and that impulsivity does not explain carriers' increased susceptibility to perceived peer norms. Future, prospective studies are needed to explore alternative mechanisms for *DRD4* VNTR-related susceptibility to descriptive peer norms as well as the extent to which *DRD4* VNTR genotype influences the relationship between injunctive norms and alcohol consumption among young adults.

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Table 1
Means (with standard variations) and Pearson correlation coefficients of study variables

Variable	*M* (*SD*)	*r*								
		1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Male gender	50%	1								
2. *DRD4* VNTR genotype	30%	.01	1							
3. Descriptive peer norms	11.56 (3.78)	-.11	-.03	1						
4. Injunctive peer norms	13.09 (3.51)	-.01	-.08	**.47*** **	1					
5. Sensation seeking	25.48 (6.13)	**.18***	.03	.17	.11	1				
6. Novelty-seeking	20.89 (6.45)	-.09	-.02	.17	.06	**.38*** **	1			
7. Frequency of alcohol use	32.28 (16.12)	.15	.14	**.18***	**.22***	**.18***	.70	1		
8. Maximum alcohol use	9.18 (4.52)	**.44*** **	.08	.17	**.20***	**.28****	.18	**.25*** **	1	
9. Frequency of heavy-drinking	12.73 (12.26)	.16	-.02	**.21***	**.31*** **	.17	**.28*** **	**.46*** **	**.62*** **	1

Note. $N = 113$. Significant correlation coefficients at $p < .05$ are shown in bold font.
* $p < .05$. ** $p < .01$. *** $p < .001$

Table 2

Incidence rate ratios (IRRs) from negative binomial analyses examining the influence of the DRD4 VNTR 7-repeat allele, descriptive and injunctive peer drinking norms, and novelty-seeking/sensation seeking on self-reported alcohol use

Descriptive peer norms			
	Frequency	Maximum	Heavy-drinking
DRD4 VNTR 7-repeat allele	1.46	1.51	0.22
Descriptive peer norms	**1.04****	**1.04***	1.06
DRD4 VNTR × peer norms	0.99	0.98	**1.16***
Male	1.45	1.68	2.18
Male × DRD4 VNTR	0.92	0.85	0.64
Male × peer norms	0.99	1.00	0.98
DRD4 VNTR 7-repeat allele	1.27	0.75	**0.03****
Descriptive peer norms	1.01	0.95	0.96
DRD4 VNTR × peer norms	0.99	0.99	**1.18***
Sensation seeking	1.00	0.97	0.95
Male	1.46	1.87	3.01
Male × *DRD4* VNTR	0.95	0.85	0.56
Male × peer norms	0.98	0.99	0.96
Sensation seeking × *DRD4* VNTR	1.00	1.03	1.08
Sensation seeking × peer norms	1.00	1.00	1.01
DRD4 VNTR 7-repeat allele	2.55	1.50	0.16
Descriptive peer norms	0.98	1.04	1.12
DRD4 VNTR × peer norms	1.00	0.98	**1.17***
Novelty-seeking	1.00	1.02	1.08
Male	1.43	1.68	2.22
Male × *DRD4* VNTR	0.85	0.85	0.64
Male × peer norms	0.99	1.00	0.98
Novelty-seeking × *DRD4* VNTR	**0.97†**	1.00	1.01
Novelty-seeking × peer norms	1.00	1.00	1.00
Injunctive peer norms			
	Frequency	Maximum	Heavy-drinking
DRD4 VNTR 7-repeat allele	1.37	1.93	1.50
Injunctive peer norms	**1.06****	1.03	**1.09***
DRD4 VNTR*peer norms	0.99	0.97	0.99
Male	1.66	1.39	1.34
Male × *DRD4* VNTR	0.95	0.88	0.65
Male × peer norms	0.98	1.01	1.01
DRD4 VNTR 7-repeat allele	1.38	1.27	0.34
Injunctive peer norms	1.07	1.03	1.11
DRD4 VNTR*peer norms	1.00	0.97	1.00
Sensation seeking	1.02	1.02	1.02
Male	1.65	1.37	1.23
Male × *DRD4* VNTR	1.00	0.93	0.66
Male × peer norms	0.97	1.01	1.01
Sensation seeking × *DRD4* VNTR	1.00	1.01	1.05
Sensation seeking × peer norms	1.00	1.00	1.00
DRD4 VNTR 7-repeat allele	2.57	1.92	1.37
Injunctive peer norms	1.04	1.05	1.11
DRD4 VNTR*peer norms	0.99	0.97	0.98
Novelty-seeking	1.02	1.03	1.05
Male	1.78	1.58	2.24
Male × *DRD4* VNTR	0.89	0.87	0.56
Male × peer norms	0.97	1.00	0.98
Novelty-seeking × *DRD4* VNTR	0.97	1.00	1.01
Novelty-seeking × peer norms	1.00	1.00	1.00

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

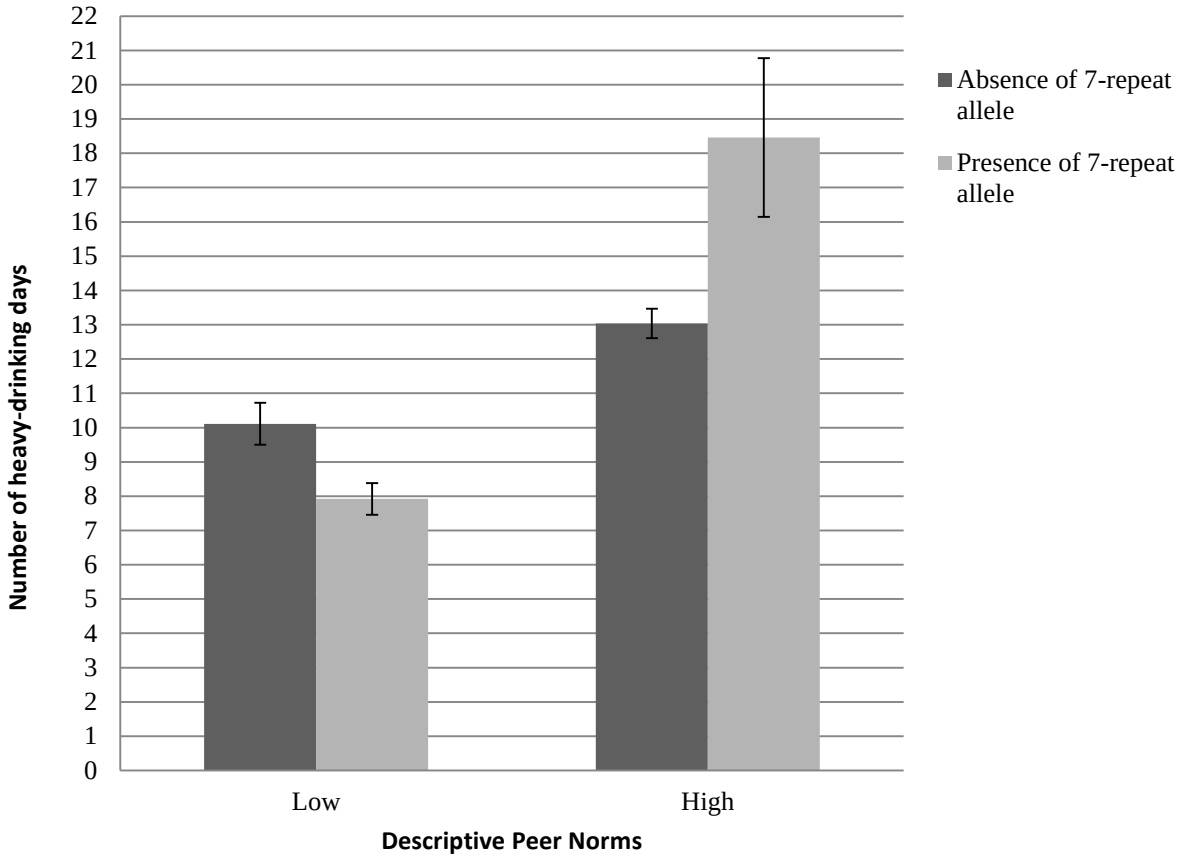

Figure 1. Mean (with standard errors) frequency of heavy-drinking over the past-90-days as a function of descriptive peer norms and *DRD4* VNTR 7-repeat allele presence.