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Sensation Seeking, Impulsivity, and Aggression Moderate Sex Effects on Adolescent Laboratory Binging

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Abstract

Sex, comprising biological and gender-related distinctions, is a known risk factor for alcohol use disorders. Moreover, sensation seeking, impulsivity, and aggression have been found to predict binge drinking and to reflect behavioral disinhibition. We tested effects of these disinhibited traits on bingeing during intravenous Alcohol Self-Administration (ivASA), a method that eliminates sex differences in the pharmacokinetics of alcohol. Eighty-five German social drinkers (49 men), completed three questionnaires assessing sensation seeking, impulsivity, and aggression, as well as an ivASA session at age 18-19. Sixty-five of them were re-tested at age 21-22. Participants reported real-life drinking problems and the number of binge days in the 45 days preceding lab testing. Analyses employed continuous data and median splits to examine associations between disinhibited traits and the portion of women and men in the sample who achieved a breath alcohol concentration of 80mg% during ivASA ('binge fraction'). At age 18-19, and only if scoring low on sensation seeking, impulsivity, or aggression, women had significantly lower binge fractions during ivASA than men. Further, low compared to high impulsivity or aggression, predicted lower binge fractions in women, but not in men. Neither 1st, nor 2nd wave disinhibited traits significantly predicted binge fractions at age 21-22. We perceive that personality traits reflecting behavioral disinhibition might be a strong indicator of drinking problems, specifically among young women. Targeted brief interventions might therefore be used in educational or clinical settings to inform such women about their increased risk and the potential health and behavioral problems associated with binge drinking.

Keywords: Computer-assisted Alcohol Infusion System (CAIS); Computer-Assisted Self-infusion of Ethanol (CASE); real-life drinking; intravenous alcohol self-administration (ivASA); impulsivity

Sensation seeking, impulsivity, and aggression moderate sex effects on adolescent laboratory bingeing

Being male is a known risk factor for alcohol use disorders, attributable to biological as well as psychosocial, gender-related factors (Erol & Karpyak, 2015; Nolen-Hoeksema & Hilt, 2006). It was often reported that women drink less alcohol than men (Erol & Karpyak, 2015) by age 18-19 (Orth, 2017). These sex differences are commonly explained pharmacokinetically – women have a smaller alcohol volume of distribution than men, which leads to higher blood alcohol concentrations and presumably greater levels of intoxication when drinking the same amount of alcohol (Cederbaum, 2012; Erol & Karpyak, 2015). Adolescent girls have also been found to display an increased sensitivity towards negative alcohol effects (Jünger et al., 2016). In addition, certain personality traits, such as sensation seeking, impulsivity, or aggression, are commonly found to be higher in men than women (Archer, 2004; Cross, Cyrenne, & Brown, 2013; Nolen-Hoeksema & Hilt, 2006), and have been associated with alcohol use and alcohol use disorders (Dick et al., 2010; Hittner & Swickert, 2006; Lejuez et al., 2010). Hierarchical models suggested that sensation seeking, impulsivity, and aggression reflect different facets of behavioral disinhibition (Bogg & Finn, 2010), a superordinate risk factor for substance use disorders, that is highly heritable (Iacono, Malone, & McGue, 2008; Young, Stallings, Corley, Krauter, & Hewitt, 2000; Zucker, Heitzeg, & Nigg, 2011). According to this concept, greater levels of disinhibition will lead to more thrill-seeking, more impulsiveness, and neglect of long-term consequences of one's behavior (Vrieze, McGue, Miller, Hicks, & Iacono, 2013).

Self-reports of alcohol consumption are necessarily confounded by the variability in breath alcohol concentration (BAC) after oral intake (Ramchandani, Plawecki, Li, & O'Connor, 2009; Zimmermann, O'Connor, & Ramchandani, 2013). We therefore perceive intravenous

alcohol self-administration (ivASA) to be a more relevant dependent measure when examining relationships between alcohol intake and personality, as it tightly controls for sex differences in alcohol pharmacokinetics (Plawecki et al., 2012; Ramchandani et al., 2009; Zimmermann et al., 2013). Each drink request during ivASA provides the same increment of BAC by accommodating the aforementioned sex differences in the volume of distribution. Binging during ivASA was recently shown to be sensitive to biological risk factors, including sex and family history of alcoholism (Gowin, Sloan, Stangl, Vatsalya, & Ramchandani, 2017). Thus, we tested individual effects of three disinhibited personality traits on binging during ivASA in eighty-two 18-19-year-olds after receiving a priming exposure of 30mg% BAC (= German unit ‰*100). Longitudinal studies demonstrated acceleration of drinking during adolescence, reaching its peak during young adulthood (Tucker, Orlando, & Ellickson, 2003), whereas sensation seeking and impulsivity were found to decline (Harden & Tucker-Drob, 2011). To capture such changes in binging and personality, participants were re-tested at age 21-22. We hypothesized that the fraction of the sample achieving a BAC of 80mg% would be lower for women than men, as well as for those scoring low compared to high on sensation seeking, impulsivity or aggression.

Method

Comprehensive details of the Dresden Longitudinal study on Alcohol use in Young Adults (D-LAYA) have been published elsewhere (Jünger et al., 2016). Its procedures (Clinical Trials NCT01063166) were reviewed and approved by the ethics committee of the Technische Universität Dresden (EK 333122008) and fully complied with the Declaration of Helsinki.

Participants

Dresden residents, aged 18-19, were invited to a screening visit and provided written informed consent. Eligible participants had experienced at least one episode of drunkenness and

reported having two or more alcoholic drinks per week during the last two months. Exclusion criteria were: Previous alcohol-related treatments; DSM-IV (American Psychiatric Association, 2000) alcohol or substance dependence (except nicotine); medical disorders associated with adverse effects when consuming alcohol; elevated liver enzymes; severe current or past DSM-IV axis I disorders; positive urine drug screens (Nal von Minden Multi 12TF test, Moers, Germany) or urine pregnancy tests (Alere medical pregnancy test, Köln, Germany); breast-feeding; medication possibly interacting with alcohol; drinking alcohol on the test day or the day before. When re-tested at age 21-22, current real-life drinking levels, alcohol-related treatments, or substance dependence were no longer exclusion criteria.

The final sample consisted of 85 adolescents aged 18-19 (49 men), 65 of them (38 men) were re-tested at age 21-22.

General procedure

Participants underwent an ivASA session at age 18-19, and another 2.9-4.6 years later, ($Mdn=3.1$) at age 21-22. They reported to the lab at 1 p.m., were seated in a comfortable arm chair, and had an IV line placed in their non-dominant arm. During the next 45 minutes, they completed questionnaires. Personality traits were measured at the 1st assessment wave; in addition, sensation seeking and impulsivity were also measured at age 21-22. Baseline BAC was determined to be zero using an Alcotest 6810med breath analyzer (Draeger Sicherheitstechnik, Lübeck, Germany). The ivASA session lasted 2 hours and 25 minutes beginning with the priming exposure, with BAC readings obtained at 10 minutes, and then every 20 minutes. BAC readings were entered in real time to improve the individual pharmacokinetic model and adapt prescribed infusion rates accordingly. Participants could order additional alcohol infusions to increase their BAC, were free to watch sitcoms and to use the bathroom. They were released

when their BAC was below 40mg% by taxicab or below 20mg%, if unaccompanied. They received 200€ for all ivASA sessions and up to 60€ driving expense.

Questionnaires

Personality traits were assessed at baseline. The Substance Use Risk Profile Scale (SURPS; Woicik, Stewart, Pihl, & Conrod, 2009) measured sensation seeking and impulsivity during both assessment waves. The Barratt Impulsiveness Scale (BIS; Patton & Stanford, 1995; Preuss et al., 2008) and the Buss- Perry Aggression Scale (BPAS; Buss & Perry, 1992; Herzberg, 2003) measured impulsivity and aggression, but only at age 18-19.

At age 18-19, real-life drinking was determined at baseline, and at age 21-22, during the screening visit, using the 45 days TimeLine Follow-Back (TLFB; Sobell & Sobell, 1992) and the Alcohol Use Disorders Identification Test (AUDIT; Babor, Higgins-Biddle, Saunders, & Monteiro, 2001).

Intravenous alcohol self-administration

The experiment employed the Computer-assisted Alcohol Infusion System (CAIS), which tightly controls for environmental factors and differences in alcohol pharmacokinetics, achieving the same incremental change in BAC in all subjects (Plawecki et al., 2012; Ramchandani et al., 2009; Zimmermann et al., 2008). Infusion solutions had an ethanol concentration of 6.0% (v/v). Participants' age, sex, height, and weight were used as parameters for the physiologically-based pharmacokinetic model (Plawecki et al., 2012). Pushing a button (Power Mate, Griffin Technology, Nashville, Tennessee) released alcohol infusions that were expected to increase BAC by 7.5mg% over 2.5 minutes. Thereafter, BAC steadily declined by 1 mg%/min until alcohol was ordered again. Participants were precluded from receiving another reward until reaching the peak BAC from the prior reward, up to the safety limit of 120mg%.

The experiment started with a 10 minute priming phase, during which participants were asked to push the button four times, resulting in a BAC of 30mg% (priming exposure). For the next 15 minutes, BAC decreased to 15mg% at 25 minutes. Thereafter, participants were instructed that they may self-administer alcohol to produce pleasant alcohol effects.

Analyses

Analyses were conducted using R version 3.5.1 (<https://www.R-project.org/>). First wave BPAS data of one participant and 2nd wave TLFB data of another were missing. Self-reported binge drinking was defined as having more than 4 or 5 drinks on an occasion for women and men, respectively, via TLFB (Courtney & Polich, 2009). AUDIT scores below eight were analyzed as low-risk drinking; higher scores were labeled as elevated risk for drinking problems. Besides using continuous scores, personality traits were median split into high and low values, regardless of sex. For visualization and to test all contrasts of interest with a minimum number of models, we combined the bivariate sex and personality data resulting in four groups (female low, female high, male low, and male high) for each questionnaire. As proposed by Gowin et al. (2017), we determined for each session the experimental time when a BAC of 80mg% was achieved (<https://pubs.niaaa.nih.gov/publications/AlcoholFacts&Stats/AlcoholFacts&Stats.htm>). If participants stayed below 80mg% BAC, time to binge was set to the maximum (145min). Time to binge and the event indicator (binged or not) were then predicted in two separate models for each questionnaire using Cox proportional hazards models (coxph, package survival). One tested the interaction between sex (reference level = male) and continuous questionnaire scores, the other tested effects of the combined factor (reference level = male high). Effects were reported only if log-rank tests were significant. Further, we tested all pairwise contrasts (pairwise_survdif, package survminer) between groups. Group differences in AUDIT and

TLFB, sex differences between traits, and changes over time were tested using t.tests (t.test, package stats), chi-squared tests (chisq.test, package stats), or Pearson correlations (cor.test, package stats).

In all trait questionnaires, drop-outs from the first (N=85) to the 2nd assessment wave (N=65) were equally distributed across high and low groups as well as sexes, and they emerged across all levels of mean BAC during ivASA. Eliminating drop-outs at age 18-19 did not change cut-off values of median splits, but the maximum was higher in the full sample for SURPS impulsivity (16 vs. 15) and BPAS aggression (50 vs. 47).

Results

Predictors of bingeing during ivASA

In the full sample of 18-19 year-olds, 41 participants (29 men) achieved 80mg% BAC during ivASA (i.e., laboratory bingers), while 44 participants (20 men) refrained from bingeing (i.e., laboratory non-bingers). Interactions between sex and continuous SURPS impulsivity, BIS impulsivity, or BPAS aggression were significant (p -values < .029), while the interaction between sex and SURPS sensation seeking failed to reach significance (p =.059). Splitting the sample into four groups, we found that women with low disinhibited personality traits had significantly lower binge fractions during ivASA than men with high scores (p -values < .021). Pairwise comparisons showed that women with low disinhibited personality traits also had lower binge fractions than men with low scores (p -values < .021). Moreover, women with low SURPS impulsivity, BIS impulsivity, or BPAS aggression had lower binge fractions than women with high scores in these questionnaires (p - values < .018).

In the subsample completing both assessment waves, we counted 33 laboratory bingers (24 men) and 32 laboratory non-bingers (14 men) at age 18-19. Interactions between sex and

continuous BIS impulsivity, or BPAS aggression were significant (p -values < .05), while the interaction between sex and both SURPS scores failed to reach significance (p -values > .06). Again, women with low disinhibited personality traits had significantly lower binge fractions during ivASA than men with high scores (p -values < .02; see Table 1, Figure 1A-D). The same was true for real-life drinking measured with the AUDIT and TLFB binge days (p -values < .002; see Figure 1E, F). No other group significantly differed from men with high scores.

Pairwise comparisons showed that women with low SURPS impulsivity, BIS impulsivity, or BPAS aggression also had lower binge fractions than men with low scores in these questionnaires (p -values < .023). Moreover, women with low BIS impulsivity, BPAS aggression, or low risk for drinking problems had lower binge fractions than women with high scores in these questionnaires (p -values < .024).

At age 21-22, there were 25 laboratory bingers (15 men) and 40 non-bingers (23 men). While controlling for 1st wave ivASA bingeing, men reporting less than five TLFB binge days at age 18-19, had higher binge fractions three years later than men reporting more TLFB binge days ($hazard\ ratio = 4.3, 95\% CI = 1.5-12.8, p = .008$). However, neither 1st wave, nor 2nd wave personality significantly predicted laboratory bingeing at age 21-22 (see Table 1).

Additional analyses to explore changes over time

Real-life drinking, laboratory bingeing and traits. At age 18-19, laboratory non-bingers had significantly lower AUDIT and TLFB scores than bingers (p -values < .003). Further, adolescents with low compared to high scores in either BIS impulsivity or BPAS aggression had significantly lower AUDIT scores (p -values < .03). We therefore tested the mediating role of real-life drinking measures. When including the main effect of raw TLFB binge days to the above described models, effects remained unchanged. However, continuous AUDIT scores

mediated the effects of BIS impulsivity, and BPAS aggression on laboratory bingeing, as differences between women with low scores and men with high scores failed to reach significance (p -values > .055) when controlling for AUDIT scores.

At age 21-22, participants with high compared to low SURPS impulsivity reported fewer TLFB binge days ($p = .025$).

Sex differences in traits. Sex differences in median split or continuous trait scores measured at age 18-19 were not significant. Three years later, men showed significantly higher SURPS sensation seeking than women ($t(46.7) = 2.6, p = .011$).

Changes in bingeing over time. In men, mean time to binge significantly increased over time ($t(73.2) = -2.2, p = .03$), but the numerical reduction in male bingers ($N = 9$) failed to reach significance ($p = .066$). Time to binge in women did not change appreciably.

Changes in traits over time. First and 2nd wave measurements of SURPS were significantly correlated: sensation seeking ($r(63) = .64, p < .001$) and impulsivity ($r(63) = .54, p < .001$). Paired t-tests did not detect differences in the continuous scores (p -values > .06).

Discussion

This is the first study reporting the effects of three disinhibited personality traits on laboratory bingeing in young men and women, after receiving a priming exposure of 30mg% BAC. As opposed to self-report measures of bingeing, ivASA eliminates sex differences in alcohol pharmacokinetics and tightly controls for situational factors, such as social interactions. Our two hypotheses that male sex and high scores in disinhibited traits would promote laboratory bingeing, were partly confirmed. At age 18-19 and only if scoring low on sensation seeking, impulsivity, or aggression, women manifested significantly lower binge fractions than men. Further, binge fractions were significantly associated with impulsivity or aggression in women

only. Our findings therefore suggest moderating effects of disinhibited personality traits on sex differences in laboratory binging beyond prior findings. One previous study did reveal a direct link between sensation seeking and alcohol use in women only, while this link was mediated by enhancement motives in men (Magid, Maclean, & Colder, 2007). Investigations of interaction effects between impulsivity and sex on alcohol use have been inconsistent (Magid et al., 2007; Nolen-Hoeksema & Hilt, 2006), comparable studies on aggression are lacking.

In other reports, women generally scored lower on traits associated with heavy alcohol use (Nolen-Hoeksema, 2004). However, in the present subsample of the D-LAYA study, women's trait scores varied substantially and were not significantly lower than those of men. At age 18-19, women scoring high on sensation seeking, impulsivity, or aggression, resembled men in terms of laboratory binging. Since excessive drinking is considered to be a stereotypically masculine behavior (DeVisser & McDonnell, 2012; Erol & Karpyak, 2015), we speculate that those women might have had less traditional gender-role beliefs. In line with that concept, previous studies have shown that masculinity, or the degree to which a person identifies themselves as having stereotypically masculine traits, predicts alcohol use in high school seniors (Iwamoto & Smiler, 2013), binge drinking in college students (Peralta, Steele, Nofziger, & Rickles, 2010), and drinking problems in university athletes (O'Brien et al., 2018). Moreover, women scoring lower on femininity were more likely to engage in high risk drinking, while there was no such association in men (Ricciardelli, Connor, Williams, & Young, 2001).

All group differences vanished during the 2nd wave, which, interestingly, could not be explained by significant reductions in SURPS sensation seeking or impulsivity, as previously suggested (Harden & Tucker-Drob, 2011). Instead, after adolescence, men seemed to binge later during ivASA and women scoring low vs. high on disinhibited personality traits appeared to

differ less in bingeing. One explanation might be the maturation of neural connectivity, which is known to support behavioral control and to reduce substance use (Bava & Tapert, 2010).

Alternatively, social factors outside the laboratory, such as leaving home (White et al., 2006; Willoughby, Good, Adachi, Hamza, & Tavernier, 2013), may have changed attitudes towards real-life bingeing which in turn led to less laboratory bingeing. In fact, most 18-19-year-olds in our sample were tested in their last school year (Jünger et al., 2016), and German binge drinking rates have been found to peak in that age group (Orth, 2017).

The effects of sex, BIS impulsivity, and BPAS aggression on bingeing were mediated by AUDIT scores. These findings highlight the importance of our reported interactions between sex and disinhibited personality traits for real-life drinking problems. Nevertheless, there are some limitations of our study, including the young age, the relatively small size of our German convenience sample, and the lack of repeated measurements on the BIS and BPAS. Further, the impact of the priming exposure on subsequent ivASA is uncertain.

In conclusion, we found that sensation seeking, impulsivity or aggression were associated with female laboratory bingeing at age 18-19, while male binge fractions were high, irrespective of personality. As such, the three traits reflecting behavioral disinhibition might be a stronger indicator for drinking problems in adolescent women compared with men. Since girls with highly expressed disinhibited traits can be easily identified in educational or clinical settings, via observation or questionnaire, targeted brief interventions might be more effective against adolescent binge drinking than general prevention strategies. As such, teachers or medical professionals could inform such girls about their increased risk and the potential health and behavioral problems associated with binge drinking, including unintended injuries, and risky sexual behavior (World Health Organization, 2018).

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Table 1

Results of Cox proportional hazards models with four trait x sex groups N = 65

questionnaire	hazard ratio	95 % confidence interval	p-value
ivASA binging at age 18-19			
SURPS sensation seeking	0.21	0.07 - 0.64	.006
SURPS impulsivity	0.17	0.05 - 0.62	.007
BIS impulsivity	0.09	0.01 - 0.67	.019
BPAS aggression	0.08	0.01 - 0.62	.016
AUDIT	0.14	0.04 - 0.42	<.001
TLFB binge days	0.17	0.06 - 0.51	.002
ivASA binging at age 21-22 (controlling for binging at age 18-19)			
SURPS sensation seeking age 18-19	0.80	0.24 - 2.65	.72
SURPS sensation seeking age 21-22	0.62	0.23 - 1.69	.35
SURPS impulsivity age 18-19	1.22	0.35 - 4.25	.75
SURPS impulsivity age 21-22	0.39	0.12 - 1.21	.10
BIS impulsivity age 18-19	1.00	0.26 - 3.91	1.0
BPAS aggression age 18-19	0.41	0.10 - 1.66	.21
AUDIT age 18-19	0.58	0.18 - 1.87	.36
AUDIT age 21-22	0.61	0.18 - 2.05	.43
TLFB binge days age 18-19	2.59	0.79 - 8.51	.12
TLFB binge days age 21-22	0.82	0.29 - 2.31	.71

Note. Model results are displayed for the contrast between the reference group: men scoring high on the respective questionnaire vs. women scoring low on the questionnaire. First wave measurements are labeled 'age 18-19'; 2nd wave measurements are labeled 'age 21-22'. At age 18-19, women scoring low on any of the questionnaires had significantly lower binge fractions during ivASA than men with high scores. At age 21-22, men reporting more than four binge days at age 18-19, had lower binge fractions during ivASA three years later than men reporting fewer binge days ($p = .008$). No other group significantly differed from men with high scores in each questionnaire.

Figure 1 caption

Figure 1. Kaplan-Meyer curves predicting rate of bingeing during ivASA at age 18-19 out of sex and disinhibited traits (A-D) as well as sex and real-life drinking (E&F) with p-values of log-rank test. For all questionnaires, women with low scores had significantly lower binge fractions than men with high scores. Besides that, women with low BIS impulsivity ($p = .014$), BPAS aggression ($p = .024$), or low risk for drinking problems ($p = .001$) had lower binge fractions than women with high scores in these questionnaires.