Trajectories of impulsivity by sex predict substance use and heavy drinking

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Abstract

Although impulsivity and sensation seeking have been consistently associated with substance use, few studies have analyzed the relationship between changes in these variables and substance use in early adolescents. The aim of this study was to identify trajectories of impulsivity and sensation seeking and explore their relationship with substance use and heavy drinking. A total of 1,342 non-user adolescents (53.6% males; mean age = 12.98, *SD* = 0.50) annually completed the Barratt Impulsiveness Scale, the Zuckerman's Impulsive Sensation Seeking scale and a delay discounting task, over a total period of three years. Past alcohol, tobacco and cannabis use, drunkenness episodes (DE) and problem drinking were also assessed. Impulsivity trajectories were explored using latent class mixed modelling. To study their predictive power binary logistic regressions were used. Two trajectories of impulsivity were found in males and five were found in females. Males with an increasing impulsivity trajectory were more likely to report tobacco [odds ratio (OR) = 1.84] and cannabis (OR = 3.01) use, DE (OR = 2.44) and problem drinking (OR = 3.12). The early increasing trajectory in females predicted tobacco use (OR = 3.71), cannabis use (OR = 5.87) and DE (OR = 3.64). Lack of premeditation and delay discounting were the most relevant facets in high-risk trajectories. Selective intervention and more intense and tailored treatment might help these adolescents to reduce early increases in impulsivity and prevent escalation of substance use.

Keywords: impulsivity; sensation seeking; delay discounting; alcohol; tobacco; cannabis

1. Introduction

Impulsivity and sensation seeking (SS) have been widely associated with the early use of differences substances (Jentsch et al., 2014; Mitchell & Potenza, 2014), representing an important risk factor for developing substance-related problems and substance use disorders later in life (Moss, Chen, & Yi, 2014). While impulsivity can be defined as a predisposition toward rapid reactions to different classes of stimuli without regard to potential negative consequences (Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001), SS refers to the seeking of experiences regardless of their associated risk (Zuckerman, 1994).

Numerous studies have consistently reported developmental changes in these two personality traits (Collado, Felton, MacPherson, & Lejuez, 2014; Littlefield, Stevens, Ellingson, King, & Jackson, 2016; Steinberg et al., 2008). As suggested by the dual systems model (Shulman et al., 2016), SS tends to peak at mid-adolescence (i.e. ages 14-17) decreasing thereafter, while impulsivity shows a linear decrease from early (ages 10-13) to late (ages 18-21) adolescence. Notwithstanding this, deviations in the aforementioned general development have also been reported (Collado et al., 2014; Harden & Tucker-Drob, 2011; Pedersen, Molina, Belendiuk, & Donovan, 2012). The number of studies exploring these divergences and the consistent evidence of gender differences in some facets (Cross, Copping, & Campbell, 2011) contrast with the paucity of studies examining gender-related differences in developmental changes in impulsivity (Collado et al., 2014; Littlefield et al., 2016). Although most studies in drug research have focused on the association between different levels of impulsivity and substance use (Mitchell & Potenza, 2014), it is possible that clinically relevant substance use is only related to certain patterns of impulsivity development (Sher, Gotham, & Watson, 2004), and that these patterns may differ by sex. Consequently, identifying high-risk patterns may enhance personality-targeted preventive intervention for substance use and escalation (Conrod, Castellanos-Ryan, & Strang, 2010).

One valuable approach to explore longitudinal variations in impulsivity between individuals is latent class growth modelling. Using this analytic approach, subpopulations with different levels and patterns of change in impulsivity can be identified. Once these subgroups are delimited, it is possible to describe their characteristics in relation to changes in specific facets of impulsivity and to explore their relationship with clinically relevant outcomes. Previous studies have reported between two and four trajectories of impulsivity and SS (Liu et al., 2013; Lynne-Landsman, Graber, Nichols, & Botvin, 2011; White et al., 2011). Although these studies differ regarding participants' ages and sex, variables assessed and length of time between follow-ups, participants with higher impulsivity trajectories reported more substance use, heavy drinking and gambling problems than those in the lower trajectories (Liu et al., 2013; Lynne-Landsman et al., 2011). Moderate trajectories tended to vary along with changes in the patterns of substance use (Lynne-Landsman et al., 2011; White et al., 2011).

Several shortcomings regarding the background of the samples and the assessments of impulsivity and substance use limit the impact of the findings. These studies used convenience samples of adolescents from minority populations and two of them included only male participants (Liu et al., 2013; White et al., 2011). Impulsivity was assessed using either observational information (Liu et al., 2013; White et al., 2011) or isolated items rather than validated instruments (Lynne-Landsman et al., 2011). Finally, substance use was poorly evaluated using composite scores (Lynne-Landsman et al., 2011) or collecting data on the quantity but not frequency of alcohol use (White et al., 2011). The present study aims to overcome gaps in the literature by identifying trajectories of impulsivity among early adolescents of both sexes from the general population and analyzing their relationship with the use of different substances, and heavy drinking. Using a comprehensive assessment approach, several facets of impulsivity were assessed (four self-reported and one behavioral measure).The specific objectives were: 1) to identify developmental trajectories of impulsivity; and 2) to explore the predictive power of these trajectories on alcohol, tobacco and cannabis use, episodes of drunkenness and alcohol-related problems. Considering the abovementioned gender differences, we hypothesized the existence of different trajectories by sex. No *a priori* hypotheses were established regarding the nature of such trajectories or their association with the use of different substances.

2. Materials and Methods

2.1. Participants

A total of 1,790 adolescents from 22 randomly selected Spanish high schools were assessed. The exclusion criteria were: 1) being over 15 years old at T1; 2) having any sensory impairment; 3) having any intellectual disability; and 4) presenting random responses. Some studies have reported altered levels of impulsivity among participants who persistently use alcohol and other drugs (Acheson et al., 2016; Peeters, Vollebergh, Wiers, & Field, 2014). Indeed, one of the most important limitations of studies exploring the relationship between impulsivity and substance use is the influence of past substance use in the current and prospective levels of impulsivity (Mitchell & Potenza, 2014). To remove any influence of previous substance use in impulsivity and SS, participants that reported having used any drug three or more times within the last year at the baseline were removed. After excluding 448 participants (56 due to age, 4 for intellectual disability, 118 for random responses and 270 for substance use), the final sample included 1,342 participants (74.97 %). In order to obtain the parents' written consent, letters were mailed giving guarantees of confidentiality and anonymity. No parents refused permission. The Ethics Committee of the Secretary of State of Research and Innovation, the local educational authorities and the participating schools approved this study.

2.2. Measures

Demographical data regarding participants' age and sex were collected. In order to detect random responses, the Oviedo Infrequency Scale (INF-OV; Fonseca-Pedrero, Paino-Piñeiro, Lemos-Giraldez, Villazon-Garcia, & Muñiz, 2009) was used. Its 12 Likert-type items were interspersed throughout the assessment and participants with more than three wrong answers were excluded, following the authors' guidelines.

A Spanish adaptation of the *Barratt Impulsiveness Scale* for adolescents (BIS-11-A; Martinez-Loredo, Fernandez-Hermida, Fernandez-Artamendi, Carballo, & Garcia-Rodriguez, 2015) was used to assess impulsivity. The BIS-11-A includes 30 Likert-type items (from rarely or never to almost always or always). Consistently with previous studies among adolescents (Leshem & Glicksohn, 2007; Yao et al., 2007), the BIS-11-A comprises two subscales with good reliability: general (BIS-g, α = .79-.81) and non-planning (BIS-np, α = .73-.74) impulsivity.

An adaptation of the *Impulsive Sensation Seeking scale* (ImpSS; Fernandez-Artamendi, Martinez-Loredo, Fernandez-Hermida, & Carballo, 2016) was also used. The ImpSS has 19 true/false items and provides two scores: Impulsivity (Imp, α = .75-.76), primarily covering lack of premeditation (Zuckerman, Kuhlman, Joireman, Teta, & Kraft, 1993), and Sensation Seeking (SS, α = .74-.76).

A *delay discounting task* (DD) was used to assess impulsive choice. DD describes how a reinforcer loses value as the delay to its receipt increases. Using an adjusting-amounts procedure (Holt, Green, & Myerson, 2012), participants have to choose between a virtual amount of 1,000 euros available after seven different delays (one day, one week, one month, six months, one year, five years and twenty-five years) versus multiple amounts of money available immediately. This DD task has been extensively used in drug research (Amlung, Vedelago, Acker, Balodis, & MacKillop, 2017) and its psychometric properties when used among early adolescents were good (Martinez-Loredo, Fernandez-Hermida, Carballo, & Fernandez-Artamendi, 2017). Based on participants' responses, seven indifferent points were identified and fitted to the Mazur equation (Mazur, 1987):

$$V = \frac{A}{1 + kD}$$

This equation describes the discount in the subjective value (V) of the magnitude of a given reinforcer (A) as a function of the time in days (D) to its delivery. *K* represents the rate of discounting. Due to the skew in the distribution of *k*-values, analyses were performed using the log-transformed *k*-values (log*k*; Mazur, 1987).

Substance use was analyzed using items from the European School Survey on Alcohol and other Drugs (ESPAD; European School Survey Project on Alcohol and Other Drugs, 2007) regarding the frequency of past year alcohol, tobacco and cannabis use (none, 1-2 times, 3-5 times, 6-9 times, 10-19 times, 20-39 times), and past month drunkenness episodes (DE). Problem drinking was assessed by means of the Spanish adaptation (López-Nuñez, Fernandez-Artamendi, Fernandez-Hermida, Campillo-Alvarez, & Secades-Villa, 2012) of the Rutgers Alcohol Problem Index (RAPI; White & Labouvie, 1989). The proposed cut-off of seven points for problem drinking and possible dependence yielded adequate levels of sensitivity (81.2%) and specificity

(72.2%). Age at first drink (AFD) was also collected. For analysis purposes, we dichotomized self-reported frequency of substance use and DE (no = 0, yes = 1).

2.3. Procedure

After parents' written consent, participants were surveyed between September 2013 and April 2014 in a single session sitting in their own classrooms using digital devices (Samsung Galaxy Tab2 10.1). The survey was designed to present relevant questions based on participants' previous answers. Both follow-ups (T2 between September 2014 and April 2015; and T3 between September 2015 and April 2016) took place under the same conditions and using the same devices.

2.4. Analytic Strategy

2.4.1. Preliminary analyses.

Descriptive analyses were performed in relation to the sample characteristics. Due to the low prevalence of alcohol-related problems, RAPI scores were dichotomized (no alcohol problems = 0; alcohol problems = 1). A multiple imputation approach (see Brand, 1999) based on the Markov Chain Monte Carlo method and linear regression was used to deal with missing data. Following Bennett (2001), data from participants who completed the survey at two out of the three assessment waves were estimated (33% of data). After checking the missing at random assumption, estimated values from the 10th iteration solution were selected in order to ensure model convergence (Yu, Burton, & Rivero-Arias, 2007).

The moderating role of sex on the trajectories was explored by means of multigroup latent growth analysis under the measurement invariance assumption (see Meredith & Teresi, 2006). Increasingly restrictive growth models were compared: the unconstrained solution of the pooled data (configural invariance), a model with constrained intercepts (scalar or strong invariance) and models with constrained intercepts, error variances and covariances (fully constrained models). A sex moderating effect was proved when a constrained model showed a better fit than the unconstrained one by means of: 1) a root mean square error of approximation (RMSEA) value equal to or lower than .05; 2) a standardized root mean square residual (SRMR) lower than .08; 3) a comparative fit index (CFI) and a Tucker-Lewis index (TLI) higher than 0.95; and 4) a lower Akaike information criterion (AIC) and sample size-adjusted Bayesian information criterion (SABIC). Growth models were compared using the Satorra-Bentler scaled chi-squared difference test to examine whether the models were nested and showed similar model fit (Satorra & Bentler, 2001). Also, the incremental CFI (ΔCFI) for comparison of nested models was calculated. If $\Delta\text{CFI} \geq .002$ between two proximal models, a better fit of the nested model could not be upheld (Meade, Johnson, & Braddy, 2008).

2.4.2. Latent classes estimation.

To estimate the differential trajectories of impulsivity underlying the overall trend over time, the multivariate latent class mixed modelling (LCMM) approach was used (Proust-Lima, Philipps, & Liquet, 2016). Parameter estimation was based on maximum likelihood framework with a modified Marquardt iterative algorithm and a Newton-Raphson like algorithm. In order to determine the goodness of fit, the SABIC and AIC were used. Following Proust-Lima, Amieva, and Jacqmin-Gadda, (2013) goodness of fit for the growth solutions was proved by: the smallest SABIC and AIC, means of posterior probabilities in each class of at least .70, and class sample size of at least 5% of participants.

2.4.3. Relationship between trajectories of impulsivity and substance use.

Chi-squared tests were performed to explore the relationship between impulsivity, substance use and heavy drinking (DE and alcohol-related problems). Differences in the AFD between trajectories were examined using analysis of variance (ANOVA). To explore the incremental validity of impulsivity over past substance use or heavy drinking by sex, hierarchical binary logistic regressions were performed. Previous substance use or heavy drinking were entered into the first block and impulsivity trajectories were entered into the second block as dummy variables (the first trajectory was considered as reference for males and the fifth for females). Tolerance values were greater than .931 and variance inflation factors (VIF) were below 1.07. The incremental contribution of impulsivity over past substance use was assessed by significant changes in explained variance (ΔR^2). Effect sizes were assessed using Cramer's V, φ coefficient and $\eta^2_{partial}$. Analyses were performed using SPSS v.23 and R x64 3.0.1 (lavaan and lcmm packages).

3. Results

3.1. Preliminary Analyses

As information from at least two waves is necessary to impute data and to explore longitudinal trajectories, 45 participants with two missing assessments were excluded. Subsequent analyses were thus performed with 1,297 participants (54% males). Attrition rates across assessments were 8.4% (n = 109), 4.47% (n = 58) and 17.19% (n = 223), respectively. Data from 437 missing values (11.23% of the total) were imputed. Characteristics of the final sample are reported in Table 1.

Table 1. Sample characteristics

	T1 (n = 1,188)	T2 (n = 1,239)	T3 (n = 1,074)

Age[a]	12.99 (0.50)	14.15 (0.68)	15.16 (0.70)
Impulsivity[a]			
General Impulsivity (BIS-11)	33.35 (6.98)	34.71 (7.37)	34.99 (7.17)
Non-planning (BIS-11)	27.99 (5.77)	28.46 (5.72)	28.54 (5.59)
ZKPQ Impulsivity	2.71 (2.11)	2.90 (2.23)	2.94 (2.25)
ZKPQ Sensation seeking	5.72 (2.64)	5.99 (2.72)	6.14 (2.78)
Log*k*	-2.30 (1.49)	-2.53 (1.43)	-2.63 (1.31)
Substance use[b]			
Tobacco	27 (2.1)	149 (11.5)	225 (17.3)
Alcohol	305 (23.5)	561 (43.3)	699 (53.9)
Cannabis	6 (0.5)	89 (6.9)	150 (11.6)
Heavy drinking			
Drunkenness episodes[b]	1 (0.1)	55 (4.2)	128 (9.9)
Alcohol-related problems[b]		34 (2.6)	95 (7.3)
Total RAPI scores[a]	-	0.57 (3.21)	1.54 (4.53)

Note. [a] Mean (Standard Deviation); [b] n (% yes).
BIS-11: Barratt Impulsiveness Scale; ZKPQ: Zuckerman–Kuhlman Personality Questionnaire; log*k*: log-transformed *k* value; RAPI: Rutgers Alcohol Problem Index

Multigroup growth analyses revealed sex differences in all impulsivity facets except non-planning impulsivity, in either the intercepts or slopes. Thus, separate analyses for males and females were performed. Fit indices for all the tested models and sample characteristics by sex are shown in the supplementary material (Tables S1 and S2).

3.2 Trajectories of Impulsivity

Although fit indexes among males suggested a 4-class solution (see Table 2), the mean posterior probabilities were lower than .70 and some latent classes did not reach the 5% sample size criteria. Consequently, the second best fit model was selected (i.e., 2-class solution; means of posterior probabilities = .92 and .88). To facilitate comprehension and in considering the facets as a whole, the first trajectory (n = 434, 61.91%) was labelled the 'Low impulsivity' trajectory. The second trajectory was named an ‘Increasing’ trajectory (n = 267, 38.09%). Figures 1a-1b depict temporal changes in each impulsivity facet by trajectory in males.

Table 2. Latent class mixed models for males and females.

	LL	AIC	SABIC
Males			
Class = 1	-25,913.72	51,871.44	51,901.73
Class = 2	**-25,884.35**	**51,820.69**	**51,856.50**
Class = 3	-25,869.80	51,799.60	51,840.91
Class = 4	-25,850.30	51,768.61	51,815.44
Class = 5	-25,869.80	51,815.60	51,867.96
Class = 6	-25,854.62	51,793.24	51,851.09
Females			
Class = 1	-21,980.99	44,005.98	44,032.73
Class = 2	-21,962.65	43,977.29	44,008.89
Class = 3	-21,957.66	43,975.31	44,011.78
Class = 4	-21,954.15	43,976.30	44,017.63
Class = 5	**-21,946.24**	**43,968.47**	**44,014.67**
Class = 6	-21,958.47	44,000.94	44,051.99

Note. LL = Maximum log-likelihood estimator for model convergence; AIC = Akaike information criterion; SABIC = Sample-adjusted Bayesian information criterion.
Best fitting model shown in bold.

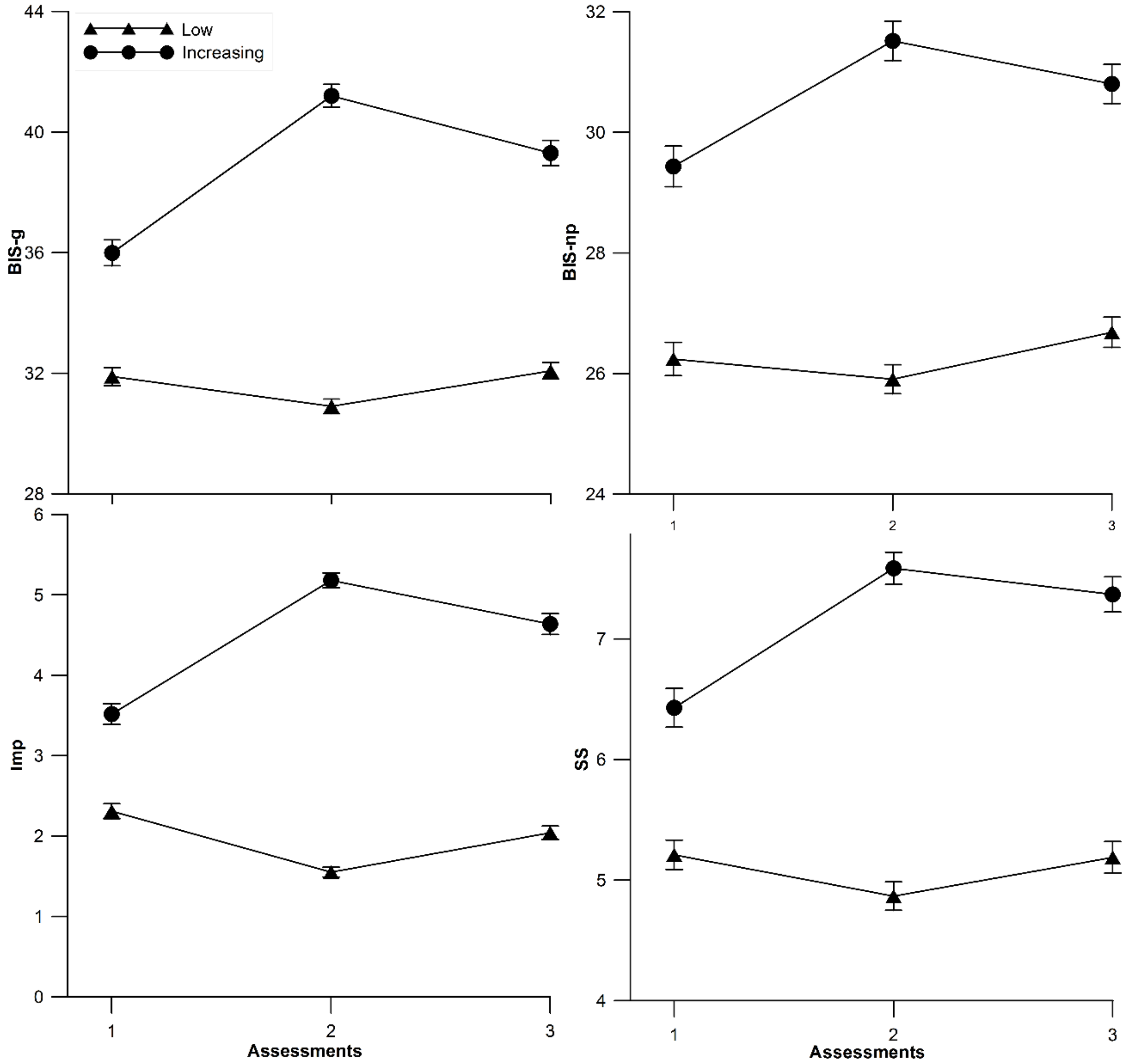

Figure 1a (2-COLUMN FITTING IMAGE)

Changes in the BIS-g, BIS-np, Imp and SS by impulsivity trajectory in males.

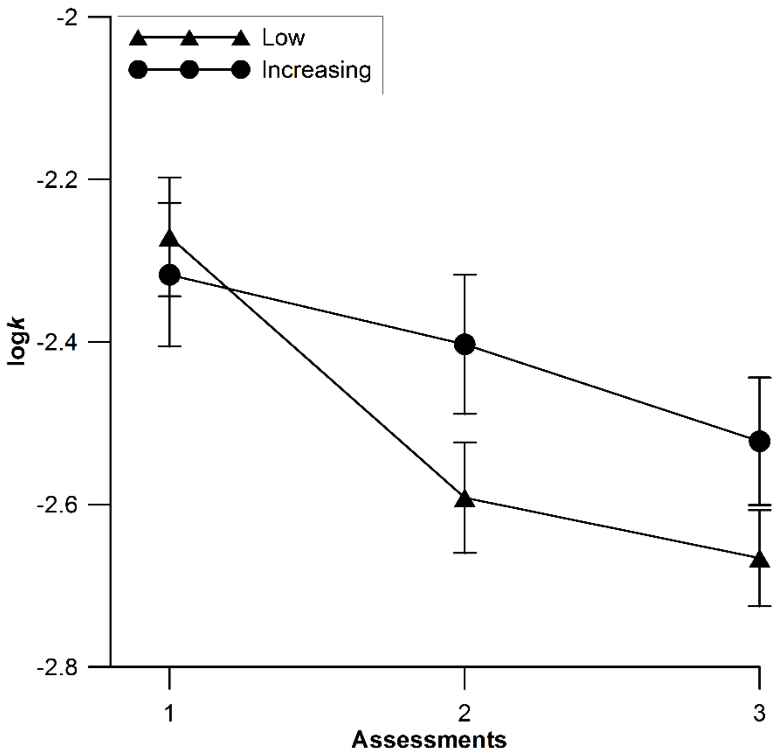

Figure 1b (1-COLUMN FITTING IMAGE)

Changes in the log*k* by impulsivity trajectory in males.

Regarding females, a 5-class model was the best fit (means of posterior probabilities between .69 and .85, see Table 2). As in males, the classes were named based on the overall pattern of most facets despite the potential differences, especially regarding DD. The five trajectories were labelled as follows: 1) ‘Inverted U-shaped’ (n = 39, 6.54%); 2) ‘Early increasing’ (n = 52, 8.72%); 3) ‘Moderate increasing’ (n = 141, 23.66%); 4) ‘Moderate stable’ (n = 190, 31.88%); and 5) ‘Decreasing’ (n = 174, 29.19%) trajectories. Figures 2a-2b depict temporal changes in each impulsivity facet by trajectory in females. Factor loadings for each criterion by sex are shown in the supplementary material (Table S3).

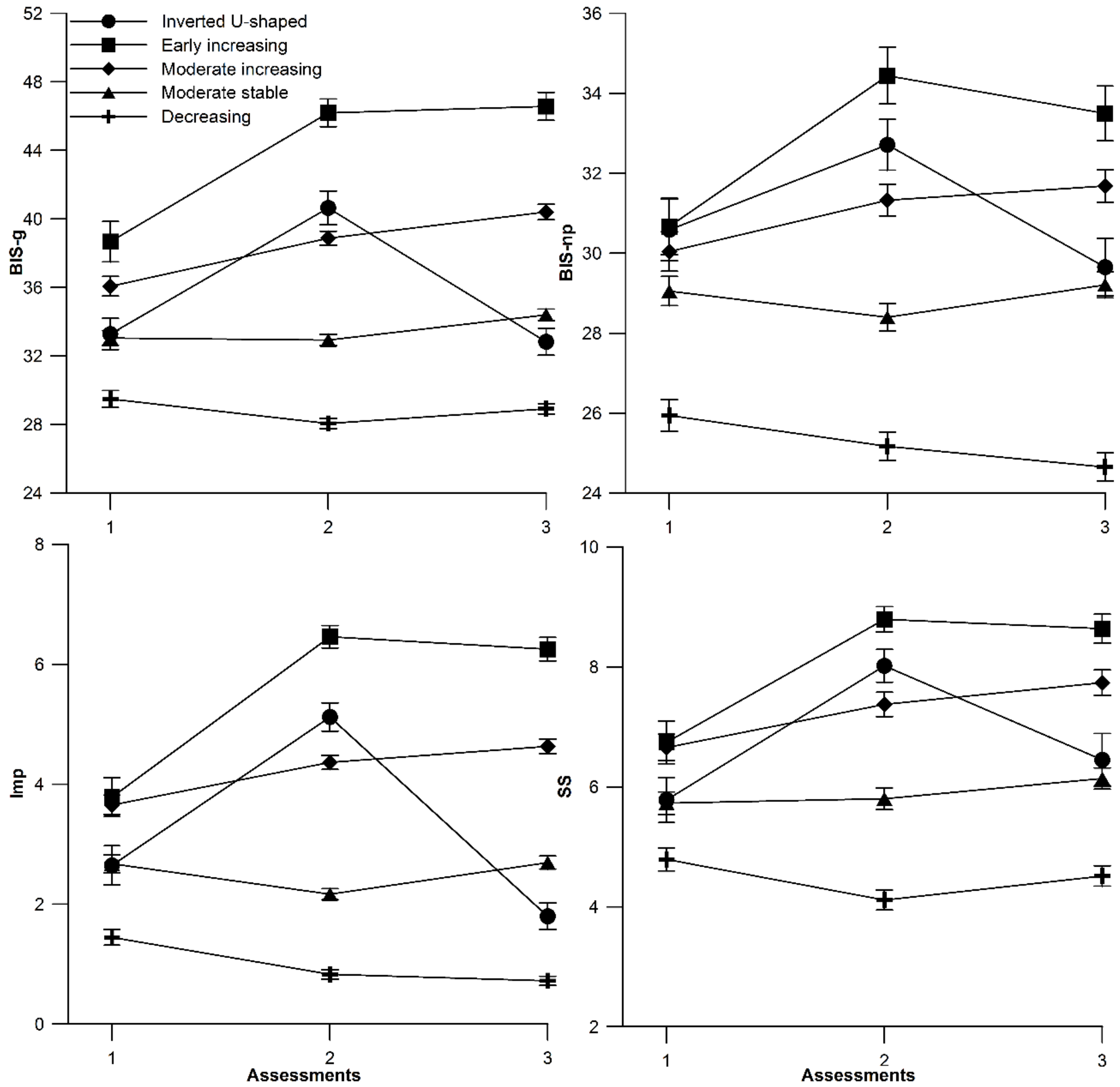

Figure 2a (2-COLUMN FITTING IMAGE)

Changes in the BIS-g, BIS-np, Imp and SS by impulsivity trajectory in females.

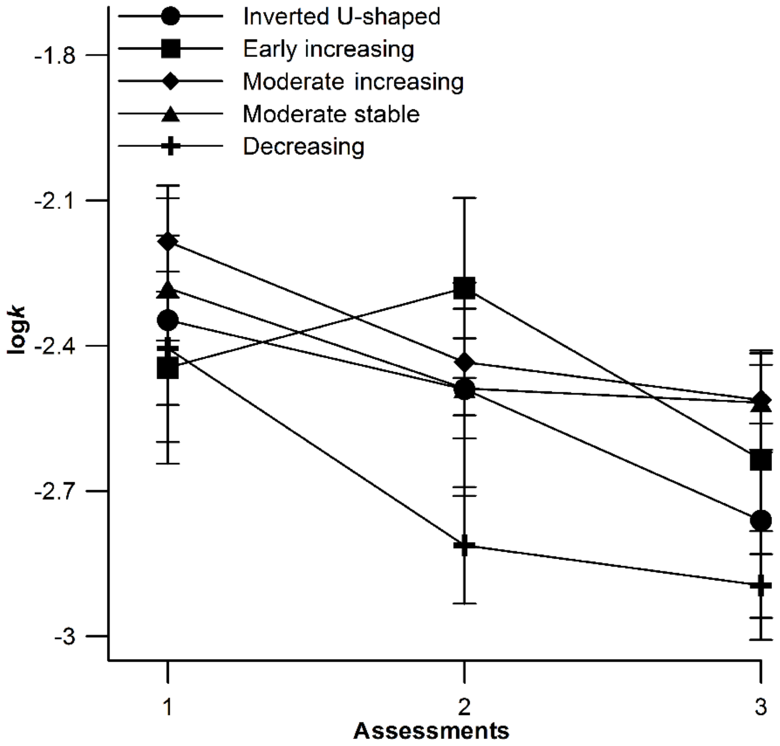

Figure 2b (1-COLUMN FITTING IMAGE)

Changes in the log*k* by impulsivity trajectory in females.

3.3. Predictors of Substance Use and Heavy Drinking

Bivariate analyses showed significant differences between substance use, heavy drinking and impulsivity trajectories (see Table 3). Males with an 'Increasing' trajectory were more likely to report any substance use, DE and alcohol-related problems. Females with an 'Early increasing' trajectory were more likely to report any substance use and alcohol-related problems. Females that showed a 'Moderate increasing' trajectory were more likely to report drunkenness episodes. AFD did not differ in either males [$t(331)$ = .899, p =.369] or females [$F(4, 289) = 1.318$, p = 263] between any trajectories.

Table 3. Impulsivity scores by trajectory over time

	Males				Females						
	Low (n = 434)	Increasing (n = 267)	χ^2	*Φ*	Inverted U-shaped (n = 39)	Early increasing (n = 52)	Moderate increasing (n = 141)	Moderate stable (n = 190)	Decreasing (n = 174)	χ^2	*V*
Alcohol use[a]	263 (56.9)$_a$	199 (43.1)$_b$	14.67**	.14	31 (7.2)$_{ab}$	44 (10.2)$_b$	114 (26.4)$_b$	144 (33.3)$_b$	99 (22.9)$_a$	31.98**	.23
Tobacco use[a]	65 (45.5)$_a$	78 (54.5)$_b$	19.77**	.17	9 (5.6)$_{abc}$	26 (16)$_c$	55 (34)$_{bc}$	50 (30.9)$_b$	22 (13.6)$_a$	42.63**	.27
Cannabis use[a]	42 (38.9)$_a$	66 (61.1)$_b$	27.55**	.20	10 (10.6)$_{ab}$	19 (20.2)$_b$	22 (23.4)$_{ac}$	31 (33)$_{ac}$	12 (12.8)$_c$	30.10**	.23
DE[a]	26 (40)$_a$	39 (60)$_b$	13.58**	.14	6 (6.1)$_{ab}$	13 (13.3)$_b$	37 (37.8)$_b$	31 (31.6)$_b$	11 (11.2)$_a$	25.63**	.21
RAPI[a]	21 (40.4)$_a$	31 (59.6)$_b$	10.07**	.13	5 (8.9)$_{ab}$	9 (16.1)$_b$	20 (35.7)$_b$	14 (25)$_{ab}$	8 (14.3)$_a$	13.78*	.15

Note. Subscripts indicate within-group differences. Groups with the same subscript did not differ significantly from each other.

DE: Drunkenness episodes; RAPI: Rutger's Alcohol Problem Index; χ^2: chi-squared statistic; *Φ*: Phi coefficient; *V*: Cramer's *V*.

[a] n (%) of "yes"

* $p < .05$ ** $p \leq .001$

The ‘Increasing’ trajectory among males significantly predicted tobacco use ($\chi^2(2) = 82.28$, $p < .001$, $\Delta R^2 = 1.4\%$) cannabis use ($\chi^2(2) = 78.79$, $p < .001$, $\Delta R^2 = 4.5\%$), DE ($\chi^2(2) = 21.06$, $p < .001$, $\Delta R^2 = 3\%$) and alcohol-related problems ($\chi^2(2) = 26.67$, $p < .001$, $\Delta R^2 = 4.8\%$), even after controlling for past substance use (see Table 4). In females, after controlling for past use, the ‘Moderate stable’ trajectory predicted alcohol use ($\chi^2(5) = 121.96$, $p < .001$, $\Delta R^2 = 2.2\%$) and the ‘Moderate increasing’ trajectory predicted both alcohol use and alcohol-related problems ($\chi^2(5) = 47.08$, $p < .001$, $\Delta R^2 = 2.5\%$). All the increasing trajectories significantly predicted tobacco use ($\chi^2(5) = 144.42$, $p < .001$, $\Delta R^2 = 4.6\%$) and DE ($\chi^2(5) = 55.43$, $p < .001$, $\Delta R^2 = 5.2\%$). Finally, cannabis use was predicted by the ‘Inverted U-shaped’, ‘Early increasing’ and ‘Moderate stable’ trajectories ($\chi^2(5) = 67.99$, $p < .001$, $\Delta R^2 = 4.8\%$) (see Table 4).

Table 4. Predictors of substance use and heavy drinking by sex

	Alcohol use	Tobacco use	Cannabis use	Drunkenness	Alcohol problems
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Past alcohol use					
Males	12.70 (7.84-20.56)**	-	-	-	-
Females	8.71 (5.52-13.76)**	-	-	-	-
Past tobacco use					
Males	-	16.86 (8.68-32.75)**	-	-	-
Females	-	14.01 (8.37-23.45)**	-	-	-
Past cannabis use					
Males	-	-	19.64 (9.27-41.62)**	-	-
Females	-	-	10.91 (5.63-21.15) **	-	-
Past drunkenness					
Males	-	-	-	8.62 (3.15-23.62)**	-
Females	-	-	-	9.57 (4.57-20.01) **	-
Past alcohol problems					
Males	-	-	-	-	13.31 (4.08-43.35)**
Females	-	-	-	-	23.02 (8.73-60.72)**
Male trajectories[a]					
Increasing	1.31 (0.84-2.05)	1.84 (1.10-3.08)*	3.01 (1.71-5.29)**	2.44 (1.26-4.75)*	3.12 (1.59-6.13)**
Female trajectories[b]					
Inverted U-shaped	2.02 (0.82-4.99)	0.97 (0.35-2.66)	3.11 (1.14-8.45)*	2.02 (0.66-6.15)	1.16 (0.28-4.75)
Early increasing	1.83 (0.75-4.55)	3.71 (1.66-8.29)**	5.87 (2.49-13.84)**	3.64 (1.45-9.11)*	2.39 (0.78-7.34)
Moderate increasing	2.28 (1.30-3.98)*	3.49 (1.90-6.41)**	1.90 (0.87-4.13)	4.48 (2.16-9.31)**	2.82 (1.18-6.75)*
Moderate stable	1.83 (1.12-2.98)*	2.06 (1.13-3.74)*	2.55 (1.25-5.23)*	2.66 (1.28-5.53)*	1.45 (0.59-3.59)

Note. [a] 'Low' trajectory as reference [b] 'Decreasing' trajectory as reference; OR: odds ratio, 95% CI: 95 % confidence interval.

* $p < .05$ ** $p \leq .001$

4. Discussion

This study builds on previous research and extends knowledge regarding the association between impulsivity development and substance use. We highlight three major findings: 1) the impulsivity changes among males displayed two different patterns whereas in females they displayed five; 2) the increasing impulsivity trajectory in males predicted being a smoker and a heavy drinker; 3) different trajectories among females predicted different profiles of substance use.

Two trajectories were found in males and five were found in females. These findings are consistent with studies exploring divergent courses of impulsivity (Littlefield, Sher, & Steinley, 2010; Lynne-Landsman et al., 2011; Martins et al., 2015) and extend dual systems models. Present results show that impulsivity is not equivalent in every adolescent at the same age. Indeed, incentive-based and control behaviors are not homogeneous but depend on sex and on different biological (Smith, Chein, & Steinberg, 2013) and contextual (Padmanabhan, Geier, ordaz, Teslovich, & Luna, 2011; Smith, Chein, & Steinberg, 2014) factors. The implementation of person-centered approaches provides an opportunity to improve these models by exploring the interaction between different facets and their role in the shaping of divergent patterns.

The contrasting number of trajectories between males and females may be explained by the divergent degree of sex differences in the facets comprising each trajectory (from no sex difference in the delay discounting to large differences in sensation seeking; see Cross et al., 2011 for a meta-analysis) and by differences in maturational changes (Weinstein & Dannon, 2015). Our study expands the findings of the only two studies that assess sex-specific trajectories (Liu et al., 2013; White et al., 2011) by showing changes in specific facets such as general impulsivity (BIS-g), lack of premeditation (Imp) or delay discounting (DD). No study to date has focused separately on females. However, the high number of trajectories found is consistent with the complex relationship between impulsivity and addictions in females, characterized by mixed results (Mitchell & Potenza, 2015).

Males showing an 'Increasing' trajectory were more likely to use tobacco and cannabis and to report heavy drinking. These participants presented early increases in general impulsivity (BIS-g) and lack of premeditation (Imp) while these facets, together with DD, decreased among those in the 'Low' trajectory. This finding suggests the role of early increases in lack of premeditation and general impulsivity as developmental lag markers of substance use (see Sher et al., 2004). The normative decreasing of impulsivity is not only inhibited but inverted among these individuals, which may promote the engagement in risk behaviors such as substance use (Dougherty et al., 2015). Although some impulsivity facets increased in the 'Low' trajectory, the maintained reductions in DD may curb their impact by broadening adolescents' time perspective and increasing the value of future consequences (Stein et al., 2016). The potential protective effect of reduced DD is consistent with a recent study that associates low levels of DD with less severe substance use (Amlung et al., 2017).

Regarding females, the 'Early increasing' trajectory predicted tobacco and cannabis use, and drunkenness episodes. The significant increase in lack of premeditation suggests the relevance of this facet in females regarding the use of different substances. Fostered by their limited history of drug use, females with low premeditation may be less sensitive to the long-term consequences of substance use (Lee, Peters, Adams, Milich, & Lynam, 2015; Patouris, Scaife, & Nobes, 2016; Shin, Chung, & Jeon, 2013). The early reduction in this facet in the 'Moderate stable' trajectory may explain the lower odds ratios than the ‘Early increasing’ trajectory for predicting the same outcomes. This fact reinforces the relevance of lack of premeditation and is consistent with a recent study linking this facet to treatment outcomes for substance use dependence (Hershberger, Um, & Cyders, 2017). The ‘Moderate increasing’ group was the only one that predicted alcohol-related problems. Despite their moderate self-reported impulsivity, these participants showed the highest DD at T1 and the smallest decrease over time. This fact suggests the importance of DD in early alcohol dependence (Dom, Hulstijn, & Sabbe, 2006).

In sum, the present study suggests that not only a high baseline impulsivity (e.g., as shown when comparing the ‘Early increasing’ and the ‘Inverted U-shaped’ trajectory) is an important variable regarding risk patterns of substance use. Also the increase (e.g., ‘Early increasing’ compared to ‘Moderate increasing’) and maintenance of moderate-high levels (e.g., ‘Early increasing’ compared to ‘Moderate stable’) of impulsivity throughout adolescence are relevant features of this variable. Despite having assessed individuals during early adolescence, we discovered that some were already using drugs at the baseline. As the present study focused on adolescence, it was not possible to explore the development of impulsivity during childhood. This fact may hypothetically enable the finding of any other trajectory in which these early users would fit. Further research using samples with an even lower age should examine this hypothesis. Time constraints during the assessments also prevented us from assessing other facets or variables associated with substance use, such as urgency (Smith & Cyders, 2016) or emotional regulation (Rogers et al., 2018).

This study has theoretical and clinical implications. Changes in impulsivity may not only be an effect of extended drug use (Verdejo-Garcia, Lawrence, & Clark, 2008) but they may also reflect a deviation from the normative trend leading to an increase in substance use. Present findings suggests the relevance of lack of premeditation and DD as transdiagnostic markers for substance use disorders (Brooks, Lochner, Shoptaw, & Stein, 2017). Additionally, we explored divergent sex-specific trajectories for the first time, shedding some light on the complex relationship between impulsivity and drug use among females. The screening of impulsivity courses linked to high-risk substance use would allow healthcare providers to implement tailored selective preventive strategies (Lammers et al., 2017). Previous evidence suggests that intra-treatment changes may also predict treatment outcomes (Blonigen, Timko, Finney, Moos, & Moos, 2011). Thus, some individuals with limited early changes during treatment may require tailored treatments with specific techniques that target lack of premeditation and DD, such as training in problem solving, cognitive remediation (Hershberger et al., 2017) or episodic future thinking (Snider, LaConte, & Bickel, 2016; Stein et al., 2016).

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