International Journal of Clinical and Health Psychology (2018) **18**, 235–244

International Journal of Clinical and Health Psychology

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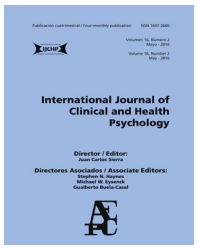

Polydrug use trajectories and differences in impulsivity among adolescents

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Received 18 May 2018; accepted 13 July 2018
Available online 22 August 2018

KEYWORDS
Impulsivity;
Sensation seeking;
Polydrug;
Delay discounting;
Ex post facto study

Abstract *Background/Objective*: Although alcohol, tobacco and cannabis are the most widely consumed drugs, sparse data exist regarding polydrug use in adolescents and its relationship with impulsivity. This study aims to identify trajectories of polydrug use and analyze differences in impulsivity between them. *Method*: A total of 1,565 adolescents (54.4% males; mean age = 13.02, *SD* = 0.57) were annually assessed over three years using the Barratt Impulsiveness Scale, the Zuckerman Impulsive Sensation Seeking Scale, a Stroop Test and a Delay Discounting Task. Frequency of alcohol, tobacco, and cannabis use, intoxication episodes and problem drinking were also assessed. Polydrug trajectories were identified using latent class mixed modelling. To examine differences in self-reported and behavioral impulsivity two mixed multivariate analyses of covariance were used. *Results*: Three trajectories of substance use were found. The 'Experimental use' and the 'Early use' trajectories presented the lowest and highest impulsivity, respectively. Substance use increases in the 'Telescoped used' trajectory were associated with parallel increases in impulsivity. *Conclusions*: individuals with divergent patterns of substance use during adolescence differ in their impulsiveness, primarily in general impulsivity and sensation seeking. Present findings suggest the relevance of these facets as possible targets for interventions preventing the onset and escalation of substance use.

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https://doi.org/10.1016/j.ijchp.2018.07.003

PALABRAS CLAVE
Impulsividad;
búsqueda de sensaciones;
policonsumo;
descuento por demora;
estudio ex post facto

Trayectorias de policonsumo y diferencias en impulsividad entre adolescentes

Resumen *Antecedentes/Objetivo*: A pesar de que el alcohol, tabaco y cánnabis son las drogas más utilizadas, existen pocos estudios sobre policonsumo y su relación con la impulsividad en adolescentes. Los objetivos de este estudio son identificar trayectorias de policonsumo y analizar diferencias en impulsividad. *Método*: Se evaluaron anualmente 1.565 adolescentes (54,4% hombres; edad media = 13,02, *DT* = 0,57) durante tres años usando la Escala de Impulsividad de Barratt, la Escala de Búsqueda de Sensaciones de Zuckerman y las Tareas de Stroop y Descuento por Demora. Se evaluó el uso de alcohol, tabaco, cannabis, uso problemático de alcohol y borracheras. Se usaron modelos mixtos de clases latentes y análisis mixtos multivariados de covarianza. *Resultados*: Se encontraron tres trayectorias de policonsumo. Las trayectorias de ''Uso experimental'' y ''Uso temprano'' presentaron los menores y mayores niveles de impulsividad, respectivamente. Los incrementos en el consumo de la trayectoria de ''Escalamiento'' se asociaron con incrementos paralelos en la impulsividad. *Conclusiones*: Las personas con distintos patrones de consumo de sustancias durante la adolescencia difieren en sus niveles de impulsividad, principalmente en impulsividad general y búsqueda de sensaciones. Los resultados sugieren la relevancia de estas facetas como dianas para prevenir el inicio y escalamiento del consumo.

Alcohol, tobacco and cannabis are the most widely consumed drugs among adolescents (Plan Nacional Sobre Drogas, 2016). Their concurrent use has been associated with several negative health consequences (European Monitoring Center for Drugs & Drug Addiction, 2009) and poses a specific risk for substance use disorders later in adulthood (Moss, Chen, & Yi, 2014).

Previous research has analyzed independent trajectories of alcohol (Ashenhurst, Harden, Corbin, & Fromme, 2015; Derefinko et al., 2016), tobacco (Dutra, Glantz, Lisha, & Song, 2017; Westling, Rusby, Crowley, & Light, 2017) and cannabis (Derefinko et al., 2016; Taylor et al., 2017) use through adolescence, but scarce longitudinal evidence exists regarding their concurrent use (Tomczyk, Isensee, & Hanewinkel, 2016). Further, most studies involved individuals in mid- to late-adolescence which limits the exploration of onset trajectories. In a recent longitudinal study with early adolescents, Khurana et al. (2015) detected two main classes: 'low/non-users' (minimal drug use over time) and 'progressors' (high probability of substance use over time). Despite the relevance of these findings, these trajectories present low specificity, which could be due to the low variability produced by using dichotomous items. Following this line of enquiry, a recent systematic review (Tomczyk et al., 2016) recommends the use of ordinal indicators of substance use instead of binary ones as they differentiate distinct patterns of use within each substance. A more accurate description of polydrug trajectories woud allow the identification of risk factors specifically linked to concrete patterns of substance use.

Impulsivity and sensation seeking (SS) have been reported as vulnerability markers for substance use trajectories of specific substances (Flory, Lynam, Milich, Leukefeld, & Clayton, 2004). In one of the few studies (Khurana et al., 2015) examining concurrent polydrug use, results indicated that increased impulsivity in early adolescence predicts progression in polydrug use. Nonetheless, the study by Khurana utilized latent class growth analysis (LCGA), which does not consider sample heterogeneity or individual variability, thus preventing the precise identification of subpopulations. Additionally, the cross-sectional assessment of impulsivity contrasts with its dynamic development (Argyriou, Um, Carron, & Cyders, 2017). A lower decline in impulsivity and a greater increase in SS were found among users of different drugs at the age of 15, compared to non-users (Charles et al., 2016). Although this study considered temporal changes in impulsivity, participants were classified using a cross-sectional measure, bypassing the dynamic evolution of the substance use over time. Therefore, specific analytic strategies that consider longitudinal changes in both variables are needed.

This study extends previous evidence by examining dynamic patterns of concurrent use of alcohol, tobacco and cannabis and exploring differences in impulsivity among early adolescents. The objectives were: (1) to identify trajectories of polysubstance use, (2) to analyze differences in impulsivity between trajectories, and (3) to examine changes in impulsivity across trajectories. The hypotheses were: (1) at least a low risk alcohol-use trajectory and a polydrug trajectory exist, (2) adolescents with a low risk trajectory present the lowest impulsivity, and (3) changes in impulsivity are related to substance use severity.

Method

Study design and Procedure

A total of 22 public and private schools, located in different cities from Asturias and Valencia, were selected following a random stratified and incidental procedure. Letters were mailed to the parents of students enrolled in the second course of secondary education in order to obtain their written informed consent. No parent refused permission.

Participants were assessed in their own classrooms at regular school times using digital devices (Samsung Galaxy Tab2 10.1), which permit individualized responding. Trained experimenters provided instructions regarding how to respond. Participants were given guarantees of total confidentiality and anonymity by assigning a numerical ID to each student and not retaining any personal data. Following the same procedure, students were requested to respond to substance use and impulsivity questions once a year over the course of three years. The first assessment was conducted from September 2013 to April 2014 (T1), the second from September 2014 to April 2015 (T2), and the last from September 2015 to April 2016 (T3). The Institutional Review Board of the University of Oviedo, the local educational authorities and the participating schools approved this study. Data were collected following the Declaration of Helsinki.

Participants

A flowchart of the participants is depicted in Fig. 1. At T1, 1,790 adolescents (55% male; mean age = 13.17, *SD* = 0.69) made up the sample. The inclusion criteria were to be currently enrolled in the second grade of high school and to be attending class the assessment day. The exclusion criteria were: (1) being $\geq$ 15 years old at the study entry; (2) having any sensory impairment; (3) being diagnosed with an intellectual disability, and (4) presenting random responses. Descriptive statistics of the variables used in the model are shown in Table 1.

Measures

Demographical data. Data were collected regarding participants' age, sex and course of study.

Control variables. For detecting random responses, the Oviedo Infrequency Scale (Fonseca-Pedrero, Paino-Piñeiro, Lemos-Giráldez, Villazón-García, & Muñiz, 2009) was used. It comprises 12 Likert-type items, interspersed throughout the assessment. Participants were required to respond to basic questions with obvious answers (from *totally disagree* to *totally agree*) such as 'I have sometimes watched films on TV'. As per the authors' guidelines, participants with more than three wrong answers were excluded.

Frequency of substance use. Previous year of alcohol, tobacco and cannabis use was assessed using items from the

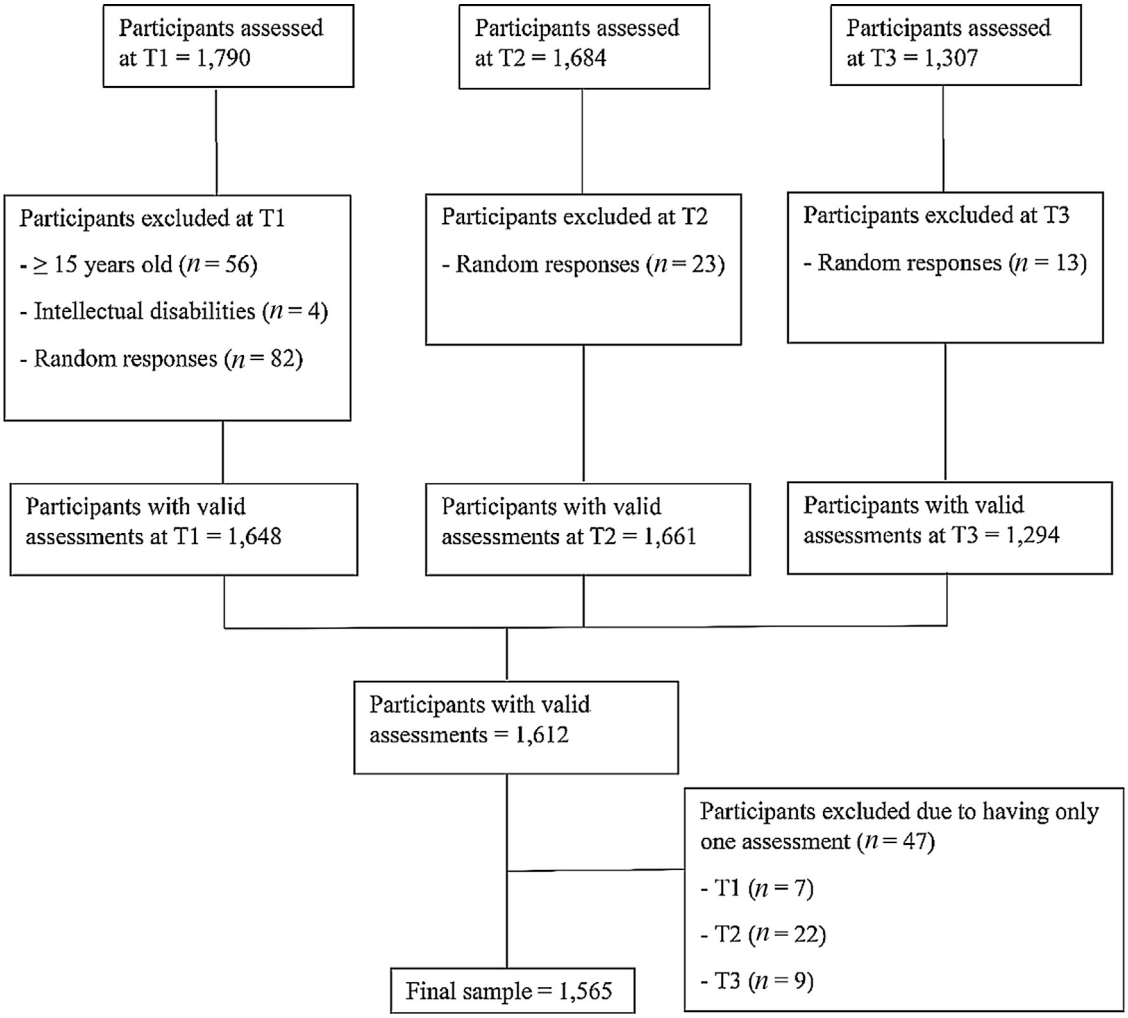

Fig. 1 Flowchart of sampling progression.

Table 1 Descriptive statistics of the variables used in the model.

	T1 *n* (%)	T2 *n* (%)	T3 *n* (%)
Age (years) [a]	13.03 (0.52)	14.16 (0.67)	15.13 (0.69)
Tobacco use			
None	1,297 (82.9)	1,284 (82.0)	1,117 (71.4)
1-2 times	50 (3.2)	82 (5.2)	124 (7.9)
3-5 times	39 (2.5)	42 (2.7)	61 (3.9)
6-9 times	123 (7.9)	33 (2.1)	36 (2.3)
10-19 times	19 (1.2)	36 (2.3)	47 (3.0)
20-39 times	14 (0.9)	25 (1.6)	59 (3.8)
40 times or more	23 (1.5)	63 (4.0)	121 (7.7)
Alcohol use			
None	857 (54.8)	732 (46.8)	439 (28.1)
1-2 times	317 (20.30)	328 (21.0)	303 (19.4)
3-5 times	121 (7.7)	167 (10.7)	214 (13.7)
6-9 times	99 (6.3)	115 (7.3)	123 (7.9)
10-19 times	98 (6.3)	91 (5.8)	186 (11.9)
20-39 times	24 (1.5)	69 (4.4)	147 (9.4)
40 times or more	49 (3.1)	63 (4.0)	153 (9.8)
Cannabis use			
None	1,467 (93.7)	1,386 (88.6)	1,248 (79.7)
1-2 times	39 (2.5)	75 (4.8)	110 (7.0)
3-5 times	18 (1.2)	29 (1.9)	46 (2.9)
6-9 times	8 (0.5)	12 (0.8)	24 (1.5)
10-19 times	9 (0.6)	19 (1.2)	34 (2.2)
20-39 times	13 (0.8)	17 (1.1)	25 (1.6)
40 times or more	11 (0.7)	27 (1.7)	78 (5.0)
Intoxication episodes			
None	1,500 (95.8)	1,452 (92.8)	1,327 (84.8)
1-2 times	43 (2.7)	84 (5.4)	170 (10.9)
3-5 times	17 (1.1)	19 (1.2)	34 (2.2)
6-9 times	1 (0.1)	7 (0.4)	9 (0.6)
10-19 times	3 (0.2)	0 (0.0)	23 (1.5)
20-39 times	1 (0.1)	3 (0.2)	2 (0.1)
RAPI[a]	0.66 (3.39)	1.13 (4.37)	2.19 (5.39)

Note. RAPI = Rutgers Alcohol Problem Index.
[a] Mean (Standard Deviation).

European School Survey Project on Alcohol and Other Drugs (2007). Participants had to respond on the occasions of use on a 7-point Likert-type scale (0 = *none*, 1 = *1-2 times*, 2 = 3-5 *times*, 3 = 6-9 *times*, 4 = 10-19 *times*, 5 = 20-39 *times*, 6 = 40 *times or more*).

Heavy drinking. Considering the high prevalence of alcohol use among adolescents shown by epidemiological data (Plan Nacional Sobre Drogas, 2016), two additional alcohol-related variables were included with the aim of identifying different patterns of drug use. Participants who reported alcohol use were asked about the frequency (0 = *none*, 1 = *1-2 times*, 2 = *3-5 times*, 3 = *6-9 times*, 4 = *10-19 times*, 5= *20-39 times*) of intoxication episodes ('getting drunk') within the past month and about the presence of problem drinking using the Spanish adaptation for adolescents of the Rutgers Alcohol Problem Index (RAPI; López-Nuñez, Fernández-Artamendi, Fernández-Hermida, Campillo-Álvarez, & Secades-Villa, 2012). This includes 23 Likert-type questions (answered from 0 to 3) on the frequency of alcohol-related events in the past year. In this study, the RAPI has shown excellent reliability over time (α = .88-.92).

Impulsivity. The Spanish adaptation (Martinez-Loredo, Fernandez-Hermida, Fernandez-Artamendi, Carballo, & Garcia-Rodriguez, 2015) of the Barratt Impulsiveness Scale-11-Adolescents (BIS-11-A) was used. It includes 30 Likert-type items (from *rarely or never* to *almost always or always*). It contains two subscales which showed good reliability in the present study: general (BIS-g, α = .79-.81 across assessments) and non-planning (BIS-np, α = .73-.74) impulsivity.

Impulsive Sensation Seeking. The Spanish adaptation for adolescents (Fernandez-Artamendi, Martinez-Loredo, Fernandez-Hermida, & Carballo, 2016) of the Impulsive Sensation Seeking scale was used. It has 19 true/false items providing two sub-scores: impulsivity (Imp) and sensation seeking (SS). In the present study, the internal consistency was good (α = .75-.76 and .74-.76 for Imp and SS, respectively).

Impulsive choice. A computerized version of the delay discounting task (DD) was used. DD is a behavioral measure that describes how a reinforcer loses value as the delay to its receipt increases. Participants have to choose between a virtual amount of €1,000 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. The DD rates were calculated using the log-transformed *k*-values (Mazur, 1987).

Inhibitory control. A computerized version of the original Stroop test was also used. The Stroop test has been widely used as a measure of inhibitory control (Stevens et al., 2014). Participants were instructed to press, as quickly as possible, one of four buttons displayed on the lower part of the screen corresponding to the four possible colors. An interference index (IRT) was calculated by subtracting the mean reaction time (RT) of the baseline from the mean RT of the incongruent block (Ludwig, Borella, Tettamanti, & de Ribaupierre, 2010).

Analytic strategy

Preliminary analyses

To deal with missing data, a multiple imputation approach based on the Markov Chain Monte Carlo method and linear regression was used. Missing values were estimated for individuals with data in two of the three assessments using the 10th iteration solution (Yu, Burton, & Rivero-Arias, 2007) under the assumption of missing at random. Then, a confirmatory factor analysis (CFA) was performed to support the inclusion of different substance use variables (i.e., frequency of alcohol, tobacco and cannabis use, intoxication episodes and problem drinking) in the same growth model. The diagonally weighted least squares method was used. Goodness of fit was assessed by the comparative fit index (CFI $\geq$ .95), the root mean square of error of approximation (RMSEA $\leq$ .05) and the standardized root mean square residual (SRMSR $\leq$ .05).

Identification of polydrug trajectories

To examine the number of polydrug trajectories, a latent class mixed modeling (LCMM) approach was used based on a maximum likelihood framework with a modified Marquardt iterative algorithm and a Newton-Raphson-like algorithm (Proust-Lima, Philipps, & Liquet, 2016). This is a relatively new person-centered method especially relevant in exploring non-Gaussian distributed longitudinal trajectories of multiple clinical outcomes (e.g., Bornas, de la Torre-Luque, Fiol-Veny, & Balle, 2017). LCMM extends LCGA by considering sample heterogeneity and individual variability. It allows us to handle latent continuous or ordinal processes and person-specific processes derived from multiple measurements over time. Growth solutions with increasing numbers of trajectories were compared against each other until two consecutive models without convergence were found. The sample-adjusted Bayesian information criterion (SABIC) and the Akaike information criterion (AIC) were used to determine the goodness of fit. The entropy-based measure classification likelihood criterion (CLC) was used to account for class enumeration accuracy (Biernacki & Govaert, 1997). The growth solution with the best fit was proved by (1) the smallest SABIC, AIC and CLC (Henson, Reise, & Kim, 2007; Proust-Lima, Amieva, & Jacqmin-Gadda, 2013), (2) means of posterior probabilities in each class higher than .80, and (3) covering at least 5% of participants in each class.

Differences in impulsivity between trajectories across assessments

Two mixed multivariate analyses of covariance (MANCOVA) were performed for self-reported and behavioral impulsivity. Classes of polydrug use (between-groups factor) and the three assessment points (within-groups factor) were used as independent variables. Due to the evidence regarding gender differences in some impulsivity facets (Cross, Copping, & Campbell, 2011), sex was entered as a covariate. Variables violating the normality assumption (skewness $\leq$ 2 and kurtosis $\leq$ 7; Kim, 2013) were recorded by replacing outliers as one unit higher than their next lowest non-outlying value (Tabachnick & Fidell, 2000). Welch and Greenhouse-Geisser corrections were used when homoscedasticity assumptions were violated. Games-Howell and Bonferroni post hoc tests were conducted to analyze pairwise differences between trajectories over time. A higher score in self-reports, DD and Stroop indicates greater impulsivity. Effect sizes were estimated using the $\eta^2_{partial}$ statistic. The R x64 3.0.1 (lcmm package; Proust-Lima et al., 2016) and the SPSS v.21 softwares were used to perform the mixed model and MANCOVA. G*Power 3.1.9.2 was used for calculating the required sample size for conducting the abovementioned analyses.

Table 2 Latent class mixed models for polydrug use.

	LL	AIC	SABIC	CLC
Class = 1	Model without convergence			
Class = 2	-39,110.87	78,273.74	78,330.29	80,390.37
Class = 3	**-38,206.95**	**76,473.91**	**76,539.27**	**76,494.90**
Class = 4	-39,109.29	78,286.58	78,360.66	82,507.37
Class = 5	Model without convergence			
Class = 6	Model without convergence			

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

Results

The overall model fit of the CFA was good (CFI = .99, RMSEA = .02, SRMR = .05) and the Spearman's rank correlation coefficients between alcohol-related variables ranged between .31 and .59. This result supports the inclusion of all the assessed substance use variables in the same growth model.

Identification and description of trajectories of substance use

After model comparison (see Table 2), a 3-class solution was retained based on AIC, SABIC, CLC and mean posterior probabilities (ranged between .96 and .99). The first trajectory comprised 136 participants (8.69%), the second 1,272 participants (81.28%) and the third 157 participants (10.03%). Figures 2 and 3 depict participants' substance use over the three assessments by trajectories.

As the first trajectory was characterized by using tobacco and cannabis at T1 and an increase in alcohol, tobacco and cannabis use from T1 to T3, it was labelled the 'Early use' trajectory. The second one showed a moderate alcohol involvement from T1 to T3, in the absence of frequent use of other substances; hence being called the 'Experimental use' trajectory. The last trajectory was characterized by a low substance use until T2, followed by an escalation in substance use between T2 and T3. At T3, participants showed a relatively high polydrug use, intoxication episodes and problem drinking; hence the name of 'Telescoped use' was adopted.

Differences in impulsivity across trajectories of substance use

A main effect of polydrug class was found for general impulsivity, $F(2, 1{,}561) = 67.42$, $p < .001$, $\eta^2_{partial} = .08$; non-planning, $F(2, 1{,}561) = 24.57$, $p < .001$, $\eta^2_{partial} = .03$; Imp,

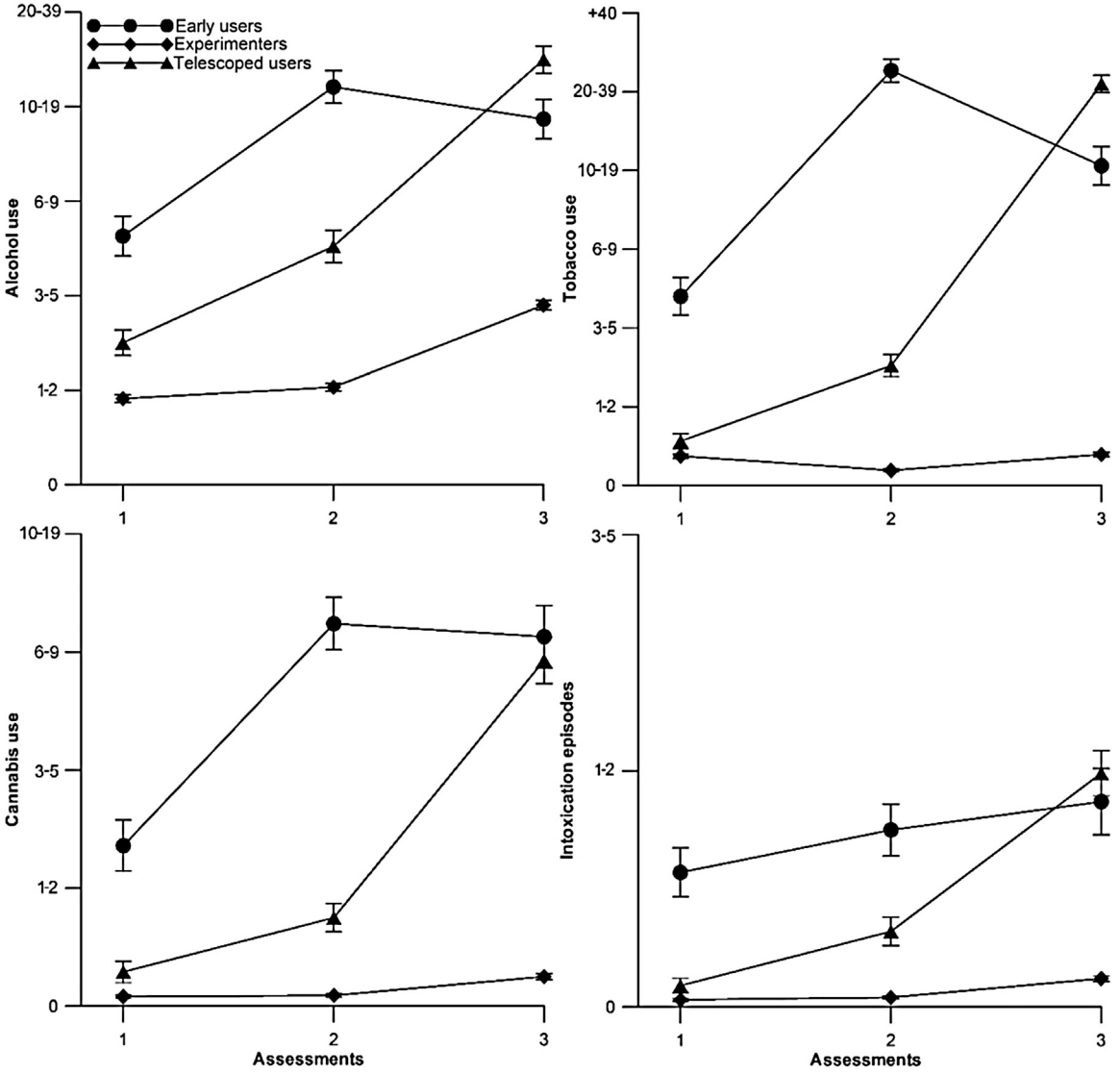

Fig. 2 Changes in alcohol use, tobacco use, cannabis use and intoxication episodes by polydrug trajectories. X-axis depicts the frequency of substance use. Y-axis depicts each assessment wave in years.

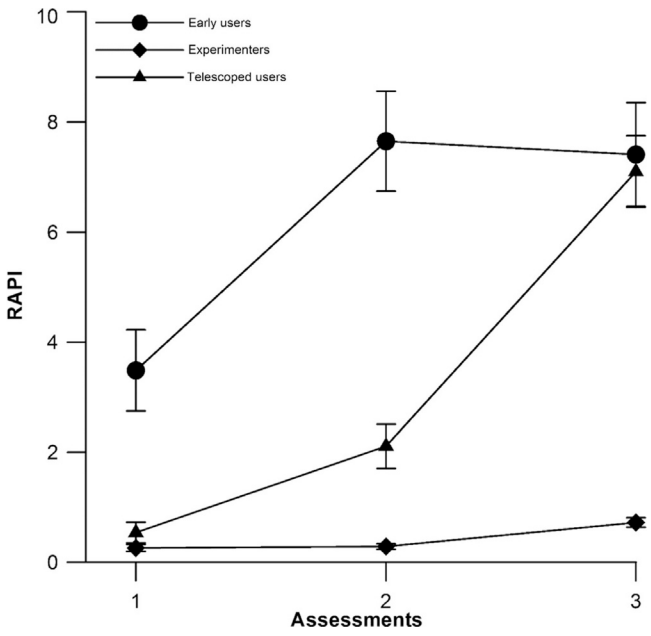

Fig. 3 Changes in the Rutgers Alcohol Problem Index (RAPI) by polydrug trajectories. X-axis depicts the total score. Y-axis depicts each assessment wave in years.

$F(2, 1{,}561) = 52.72$, $p < .001$, $\eta^2_{partial} = .06$; and sensation seeking, $F(2, 1{,}561) = 60.61$, $p < .001$, $\eta^2_{partial} = .07$. Furthermore, an interaction effect between time and polydrug class was found for general impulsivity ($F(3.74, 2{,}924.78) = 3.22$, $p = .014$, $\eta^2_{partial} = .004$) and sensation seeking ($F(3.88, 3{,}031.48) = 2.84$, $p = .024$, $\eta^2_{partial} = .04$). Also, a main effect of gender was observed for non-planning ($F(1, 1{,}561) = 14.87$, $p < .001$, $\eta^2_{partial} = .01$) and sensation seeking ($F(1, 1{,}561) = 4.48$, $p = .035$, $\eta^2_{partial} = .003$).

Longitudinal changes in impulsivity by trajectories are shown in Table 3. Regarding cross-sectional differences, at T1 experimenters reported lower impulsivity and sensation seeking than early and telescoped users ($p < .001$), with females reporting higher non-planning impulsivity and sensation seeking than males (see Table 3). At T2, the three trajectories differed in their level of general impulsivity ($p < .001$), while telescoped and early users did not differ in ImpSS scores ($p = .99$). At T3, telescoped and early users did not differ in any impulsivity measure ($p = .99$) or sensation seeking ($p = .084$).

Discussion

This study expands previous research and overcomes shortcomings by showing specific patterns of polydrug use over time and changes in impulsivity among adolescents. The main results were: (1) Three trajectories of polydrug use were identified: early users, experimenters and telescoped users; (2) experimenters presented the lowest impulsivity and SS; (3) impulsivity and SS increased parallel to substance use in telescoped users. These findings support the abovementioned hypothesis by (1) showing a low risk trajectory partially comprised by moderate alcohol users and two polydrug trajectories, (2) reporting lower impulsivity in experimenters than in early or telescoped users and (3) revealing changes in impulsivity parallel to changes in substance involvement.

Polydrug use trajectories

In the present study three trajectories were identified. The 'Early onset' trajectory was mainly comprised of tobacco and cannabis users, especially at T2. This dual use category has been reported previously (Tomczyk et al., 2016) and is consistent with epidemiological data showing tobacco as the first substance used, as well as with the increasing prevalence of tobacco and cannabis co-use (Plan Nacional Sobre Drogas, 2016). This increase seems mediated by the decreasing risk perception of cannabis use (Plan Nacional Sobre Drogas, 2016). Thus, interventions aimed at increasing the risk perception of cannabis may reverse this trend (Foster, Ye, Chung, Hipwell, & Sartor, 2018), as has been shown regarding tobacco use (Martino, Setodji, Dunbar, Gong, & Shadel, 2018).

The 'Experimental use' trajectory included adolescents reporting no substance use, together with those presenting a stable pattern of moderate use of alcohol in the absence of other drug use. This result is in line with epidemiological data showing moderate alcohol use as the most common pattern among adolescents (Plan Nacional Sobre Drogas, 2016). Additionally, previous research (Tomczyk et al., 2016) has already reported this low-risk class characterized by a low probability of high use of alcohol in the absence of other drug use. In line with previous studies (Khurana et al., 2015; Lamont, Woodlief, & Malone, 2014), non-users and low alcohol users fell within the same group due to the similarity of the response pattern (low variability over time, no or very low alcohol use and absence of other substance use) and the low risk of limited alcohol users of progressing in substance use involvement.

Participants displaying a 'Telescoped use' trajectory did not report frequent use of any substance until the last assessment. Previous studies have reported accelerated progressions from the onset of alcohol (Jackson, 2010), tobacco (Storr, 2008) or marijuana use (Derefinko et al., 2016) to their abuse or dependence. However, evidence regarding concurrent use of different substances is still scarce and only exists among adults (Lewis, Hoffman, & Nixon, 2014).

Differences in impulsivity between trajectories

At the T1 stage, experimental users were already reporting lower general impulsivity, lack of premeditation and SS than early users and telescoped users. This finding builds on previous research (Khurana et al., 2015) by showing that specific facets predict particular trajectories. However, participants did not differ in non-planning impulsivity. Sensation seeking and reward-driven impulsivity have been related to drug experimentation in adolescents (Dawe & Loxton, 2004; Malmberg et al., 2012), whereas non-planning seems to be more associated with regular and polydrug use in young adults (Moreno et al., 2012). Considering that the capacity for strategic planning develops later in adolescence (Albert & Steinberg, 2011a) and the long-term potential deleterious consequences of substance use, differences in future-related impulsivity (e.g. non-planning) may appear from

Table 3 Differences in impulsivity and sensation seeking between trajectories

	T1	T2	T3	
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*p*
General Impulsivity				.014
Early users	38.36 (9.32)$_a$	40.73 (9.84)$_b$	40.02 (8.67)$_b$	
Experimenters	33.63 (7.18)$_a$	34.24 (7.04)$_b$	34.86 (7.16)$_c$	
Telescoped users	37.02 (8.22)$_a$	37.53 (7.91)$_a$	39.31 (7.81)$_b$	
Non-planning in males				.593
Early users	28.97 (5.66)$_a$	29.91 (5.68)$_a$	29.72 (5.32)$_a$	
Experimenters	27.62 (5.91)$_a$	27.74 (5.79)$_a$	27.82 (5.45)$_a$	
Telescoped users	29.54 (5.83)$_a$	30.51 (6.06)$_a$	30.46 (6.33)$_a$	
Non-planning in females				.323
Early users	30.88 (5.50)$_{ab}$	31.43 (6.09)$_a$	29.82 (4.97)$_b$	
Experimenters	28.59 (5.70)$_a$	28.81 (5.66)$_a$	28.57 (5.41)$_a$	
Telescoped users	30.75 (5.67)$_a$	30.94 (5.26)$_a$	30.04 (5.58)$_a$	
Zuckerman's Impulsivity				.288
Early users	3.95 (2.50)$_a$	4.21 (2.41)$_a$	3.99 (2.38)$_a$	
Experimenters	2.81 (2.22)$_a$	2.80 (2.22)$_a$	2.88 (2.25)$_a$	
Telescoped users	3.79 (2.11)$_a$	4.14 (2.26)$_a$	3.91 (2.24)$_a$	
Sensation seeking in males				.034
Early users	6.96 (2.32)$_a$	7.44 (2.50)$_a$	6.81 (2.52)$_a$	
Experimenters	5.75 (2.65)$_a$	5.75 (2.63)$_a$	5.93 (2.80)$_a$	
Telescoped users	6.93 (2.85)$_a$	7.31 (2.45)$_{ab}$	7.81 (2.30)b	
Sensation seeking in females				.579
Early users	7.58 (2.69)$_a$	7.78 (2.44)$_a$	7.52 (2.22)$_a$	
Experimenters	5.83 (2.64)$_a$	5.97 (2.68)$_{ab}$	6.18 (2.81)$_b$	
Telescoped users	7.37 (2.49)$_a$	7.69 (3.42)$_a$	7.93 (2.63)$_a$	
Delay Discounting				.489
Early users	-2.05 (1.48)$_a$	-2.22 (1.42)$_a$	-2.25 (1.31)$_a$	
Experimenters	-2.33 (1.48)$_a$	-2.61 (1.41)$_b$	-2.68 (1.32)$_b$	
Telescoped users	-2.22 (1.41)$_a$	-2.32 (1.30)$_a$	-2.46 (1.45)$_a$	
Stroop test				.489
Early users	153.51 (143.01)$_a$	131.23 (126.46)$_a$	66.94 (76.68)$_b$	
Experimenters	156.11 (148.66)$_a$	123.40 (125.11)$_b$	78.88 (85.71)$_c$	
Telescoped users	178.41 (155.92)$_a$	129.21 (119.54)$_b$	87.38 (95.35)$_c$	

Note. Subscripts indicate within-group differences. Assessments with the same subscript did not differ significantly from each other. *M* = mean; *SD* = Standard Deviation; T1 = first assessment; T2 = second assessment; T3 = third assessment.
Regarding behavioral measures, a main effect of polydrug class for DD was found ($F(2, 1{,}561) = 8.23$, $p < .001$, $\eta^2_{partial} = .01$) with experimenters having lower impulsive choice than early and telescoped users. A main effect of time ($F(1.88, 2{,}926.38) = 21.22$, $p < .001$, $\eta^2_{partial} = .01$) was observed for inhibitory control. Results showed a lineal increase in inhibitory control from T1-T3 ($p < .001$), with females showing a higher level than males ($F(1, 1{,}561) = 20.01$, $p < .001$, $\eta^2_{partial} = .01$).

young adulthood onwards. Experimenters discounted less than early and telescoped users and decreased their impulsive choice between T2 and T3, reflecting the maturation process that has occurred in the rewarding areas of the brain (Dawe & Loxton, 2004). Consistent with previous studies using different designs and populations (Fernie et al., 2013; Khurana et al., 2015; Weidberg, Gonzalez-Roz, & Secades-Villa, 2017) this finding suggests that impulsive choice varies as a function of the degree of substance involvement. Despite the fact that poor inhibition has been reported to predict general alcohol involvement (Fernie et al., 2013), the analysis of specific patterns of use over time diminishes this relationship (Goudriaan, Grekin, & Sher, 2011).

Impulsivity changes by trajectories

In line with previous studies (Charles et al., 2016; Lynne-Landsman, Graber, Nichols, & Botvin, 2011 but see Derefinko et al., 2016) and in contrast with early users, impulsivity and sensation seeking increased significantly from T2 to T3 among telescoped users. Evidence suggests that adolescents involved in hazardous behaviors report lower risk perception than those not involved in such behaviors (Albert & Steinberg, 2011b). Thus, substance use experience may prompt a re-evaluation of adolescents' self-reported impulsiveness. As early users have an established pattern of substance use without already experiencing the long-term

negative consequences of chronic use, they may evaluate their behavior as less novel and dangerous; hence leading to stable levels of self-reported impulsivity (Liu et al., 2013). On the other hand, engaging in reward-driven activities such as the use of new substances (e.g. cannabis) or new patterns (e.g. heavy use) may increase reward-seeking behaviors, leading to parallel increases in self-reported impulsivity (Charles et al., 2016; Lynne-Landsman et al., 2011). Taken together, these findings may be of interest when designing more adequate personality-tailored interventions (Beutler, Someah, Kimpara, & Miller, 2016).

Limitations

This study has some limitations. Participants were followed up to mid-adolescence, which constrains the exploration of impulsivity changes among telescoped users. However, the focus of this study was on early substance use, and our results provide relevant information on this age. The impulsivity measures were tested separately to explore the unique contribution of each facet. However, specific developmental patterns of impulsivity (e.g., high-risk trajectories of impulsivity) were not evaluated and could be related to specific substance use behaviors. Rates of substance use at T1 were relatively low, which may preclude detection of significant relationships. Finally, although the present model may be useful for the general population, more research on vulnerable and clinical populations would be of great interest.

Conclusions

This study suggests the benefit of estimating multiple dynamic patterns of substance use. As individuals displaying divergent trajectories may use the same substances but with different patterns or levels of engagement, this ecologically valid assessment overcomes limitations associated with *a priori* classification of individuals based on isolated indexes (e.g., prevalence or frequency of use, diagnostic criteria). The study suggests the relevance of general impulsivity and sensation seeking as possible targets for interventions preventing the onset and escalation of substance use.

Funding

This work was supported by the Spanish Ministry of Health, Social Services and Equality [grant number MSSSI-12-2012/131] and by the Ministry of Economy and Competitiveness [grant number BES-2015-073327].

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