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What Predicts What? Self-Reported and Behavioral Impulsivity and High-Risk Patterns of Alcohol Use in Spanish Early Adolescents: A 2-Year Longitudinal Study

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Background: The directionality of the relationship between impulsivity and heavy drinking patterns remains unclear. Recent research suggests it could be reciprocal and depends on different facets of impulsivity and different patterns of drinking. The aim of this study was to analyze this potential reciprocal relationship between self-reported and behavioral measures of impulsivity and sensation seeking with specific patterns of heavy drinking in a sample of Spanish adolescents across 2 years.

Methods: The study has a cross-lagged prospective design in which participants were evaluated 3 times over 2 years (once a year). Participants were 1,430 adolescents (53.9% male; mean age at study commencement = 13.02, SD = 0.51) from 22 secondary schools in Spain. Computerized versions of the following instruments were used: 2 subscales of Impulsive Sensation Seeking, 2 behavioral measures (Stroop Test and Delay Discounting [DD] task), frequency of intoxication episodes (IE), and the Rutgers Alcohol Problem Index to evaluate alcohol-related problems (ARP). Random intercepts cross-lagged panel models of reciprocal relationships between impulsivity measures and alcohol use outcomes were used.

Results: Individual levels of self-reported impulsivity and sensation seeking significantly predicted prospective involvement in IE and ARP. Performance in behavioral measures (Stroop Test and DD) did not predict subsequent heavy drinking or alcohol problems. No measure of drinking was found to be a significant predictor of prospective changes in impulsivity.

Conclusions: Within-person levels of self-reported impulsivity and sensation seeking significantly predicted further heavy drinking from as early as 13 years old, whereas behavioral measures were not predictive. In our study, neither IE nor ARP predicted prospective changes in impulsivity. Further studies should address additional specific relationships between facets of impulsivity and specific outcomes of heavy drinking.

Key Words: Impulsivity, Alcohol, Adolescent, Longitudinal, Sensation Seeking.

EARLY USE OF alcohol during adolescence is an important risk factor for alcohol-related problems (ARP) including blackouts (Marino and Fromme, 2016) as well as several internalizing and externalizing problems (Chao et al., 2017). Although several studies have explored different facets of impulsivity and its relationship with adolescent drinking, many questions about this relationship remain unanswered (Peeters et al., 2014b).

Cross-sectional studies have confirmed significant associations between measures of impulsivity and the initiation of drinking and heavy drinking (Caswell et al., 2016; Field et al., 2007; Leeman et al., 2014; Richardson and Edalati, 2016). Nevertheless, some studies have found weak relationships (Balodis et al., 2009) or no relationship at all (Malmberg et al., 2010) between self-reported measures of impulsivity/sensation seeking and alcohol use, and no relationship with behavioral measures (Caswell et al., 2016; MacKillop et al., 2007). One factor that could be confounding this relationship is the possibility that the association between alcohol and impulsivity is reciprocal (Mitchell and Potenza, 2014; Riley et al., 2016; Stautz and Cooper, 2013). Therefore, only longitudinal studies combining different components of impulsivity with different patterns of drinking would be able to shed light on this interrelation. However, even the results of longitudinal studies are mixed.

On one hand, longitudinal studies have found evidence that self-reported impulsivity and sensation seeking may influence subsequent alcohol use (Crawford et al., 2003; Donohew et al., 1999; Farley and Kim-Spoon, 2015; Krank et al., 2011; MacPherson et al., 2010; Malmberg et al., 2012; Peeters et al., 2014a; see also the review by Dick et al., 2010), alcohol use initiation (Riley et al., 2016), and blackouts (Marino and Fromme, 2016). Likewise, some studies have

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shown that behavioral measures such as DD and risk-taking behaviors are associated with subsequent alcohol use and heavy drinking (Fernie et al., 2013; Wang et al., 2016). Nevertheless, other research has failed to detect consistent associations between DD and later alcohol use in teenagers (Isen et al., 2014). Previous studies have suggested that these inconsistencies are a consequence of different measures of impulsivity being differently related to the use of different drugs (Castellanos-Ryan et al., 2013; Dick et al., 2010; Martínez-Loredo et al., 2015; Riley et al., 2016). Previous studies have not yet determined whether this association is specific to particular patterns of alcohol use and related problems, as previously suggested (Curcio and George, 2011; Henges and Marczinski, 2012). Research has usually focused on variables such as frequency of drinking (Riley et al., 2016), alcohol use (Farley and Kim-Spoon, 2015), or alcohol involvement (Fernie et al., 2013). It has not been until recently that specific studies have focused on outcomes like alcohol-related blackouts (Marino and Fromme, 2016). Therefore, reciprocal associations between impulsivity measures and specific patterns of drinking, including intoxication episodes (IE) or problem drinking, need to be evaluated.

On the other hand, alcohol use might influence impulsivity as some studies have shown that alcohol has a neurotoxic effect on the brain with negative consequences on cognitive functioning (Peeters et al., 2014b; Squeglia et al., 2009), behavioral control (Oscar-Berman and Marinkovic, 2007), and ultimately increasing the risk of alcohol use disorders (Linden-Carmichael et al., 2017). Other studies indicate that cognitive control is not significantly impaired in young adults as a consequence of heavy drinking trajectories (Franken et al., 2017). As regards impulsivity, some studies have reported that alcohol use (regardless of amount) predicts increases in impulsivity and sensation seeking (Quinn et al., 2011; White et al., 2011), whereas others have failed to confirm this (Farley and Kim-Spoon, 2015; Rose and Grunsell, 2008). In this context, specific attention has been placed on the effects of heavy drinking (Peeters et al., 2014a), as cross-sectional data have shown that this drinking pattern is particularly associated with brain alterations (McQueeny et al., 2009) and episodes of intense intoxication could have specific brain effects (Shokri-Kojori et al., 2017; Tapia-Rojas et al., 2017) not present in low-dose alcohol use. Such brain alterations and effects could contribute to alter impulsivity. A few studies have already reported that heavy drinking predicts increases in both impulsivity and sensation seeking in college students (Quinn et al., 2011; White et al., 2011). Nevertheless, other studies have failed to detect prospective changes in impulsivity associated with alcohol involvement (Fernie et al., 2013) and binge drinking (Rose and Grunsell, 2008). Additionally, involvement in alcohol problems in early adolescence could in turn reinforce impulsivity and enhance additional impulsive behaviors across adolescence (Sher et al., 2017), although evidence is still scarce. According to Farley and Kim-Spoon (2015), the significant bidirectional association between impulsivity and drinking could be rather specific to heavy drinking. Fernie and colleagues (2013) have also suggested that focusing on at-risk users may be more likely to uncover significant effects of alcohol use on impulsivity.

Thus, given these mixed results, longitudinal studies are still needed to help clarify the associations between measures of impulsivity and drinking patterns. In particular, specific research is needed to address the association of self-reported and behavioral measures of impulsivity with different heavy drinking patterns (Mitchell and Potenza, 2014). Focusing on early adolescents is of particular interest in helping us clarify this interrelation, as they are in a developmental stage regarding impulsivity and substance use. To this end, the use of crossed-lagged models would be particularly helpful (Peeters et al., 2014b), as they allow for the study of longitudinal interrelationships between constructs.

Accordingly, the goal of the present research was to explore the relationships between impulsivity measures (impulsivity, sensation seeking, inhibitory control, and delay discounting) and heavy drinking (IE and problem drinking) in a sample of early adolescents from the general population. This was achieved by undertaking a 2-year longitudinal study in which these behaviors were assessed on 3 occasions. To clarify the hypothetical bidirectional relationship, early adolescents with no or little alcohol use were evaluated to avoid the possible confounding effect of accumulated effects of alcohol use. Using random intercepts cross-lagged panel models (RI-CLPMs), we were able to determine and compare the specific roles of different measures of impulsivity on drinking patterns accounting for the within-person effects. The use of the RI cross-lagged model also allowed us to evaluate the possible reciprocity of this relationship.

MATERIALS AND METHODS

Participants

The initial sample at the first wave (T1) was comprised of 1,792 adolescents (53.9% male; mean age = 13.02; SD = 5.07) enrolled in the second grade of secondary education (equivalent to U.S. 7th grade) recruited from 22 secondary schools in Spain (Table 1). This grade was selected because, based on official national data (Plan Nacional sobre Drogas, 2016), this is the specific period when most adolescents start drinking in Spain. The schools were selected using a random stratified and incidental procedure. The inclusion criteria for the study were as follows: (i) being 14 years old or younger at T1; (ii) having participated in at least 2 consecutive waves; (iii) having no sensory impairment; (iv) not presenting difficulties in understanding the Spanish language; (v) not being diagnosed with an intellectual disability; and (vi) not presenting random responses in any of the assessments, according to scores in the infrequency questionnaire (see Methods). Given that the study was conducted in classrooms at regular school times and that school attendance is mandatory by law in Spain, missing cases are expected to be random (due to causes such as medical issues, switching schools, or families moving outside of the study areas). Another 171 participants were excluded for not meeting the inclusion criteria. Thus, the final sample included for the analyses was 1,430 individuals (attrition rate: 79.79%).

Table 1. Descriptive Results of the Sample, Per Wave

	Wave 1	Wave 2	Wave 3
Sex (% male)	54.2	54.5	54.5
Age (*M*, SD)	13.02 (0.51)	14.16 (0.66)	15.13 (0.69)
Alcohol use last month (%)	16.9	25.5	55.8
Intoxication episodes last month (%)	2.6	6.9	14.2
Rutgers Alcohol Problem Index (*M*, SD)	0.55 (3.42)	1.07 (4.39)	2.04 (5.34)
Impulsivity (Imp) (*M*, SD)	2.95 (2.25)	3.05 (2.31)	2.98 (2.31)
Sensation seeking (SS) (*M*, SD)	6.01 (2.68)	6.13 (2.72)	6.24 (2.76)
Stroop interference response time (*M*, SD)	175.14 (162.81)	124.25 (133.49)	98.08 (95.37)
Area under the curve for DD (*M*, SD)	0.3085	0.3417	0.3429

The Ethics Committee of the Spanish Ministry of Health, Social Services and Equality approved this study. Participation was voluntary and approved by the educational centers and authorities. Anonymity was guaranteed to participants. The students gave informed consent and none of them refused to participate.

Procedure

After the schools and students agreed to participate, individuals were surveyed in their own classrooms using digital devices (Samsung Galaxy Tab 2 10.1 tablet; Samsung Electronics, Suwon, South Korea) containing a computerized version of all instruments. Participants completed the battery, which took a maximum of 50 minutes, sitting at individual desks, in their own classrooms and during class hours, under the supervision of trained experimenters. To maximize time and minimize fatigue, the computerized survey was designed to present only questions relevant for the participant based on their previous answers (i.e., "frequency of drinking" was only presented to those reporting "any drinking"). Before the assessment, trained experimenters provided detailed instructions on how to perform the behavioral tasks. Both follow-up sessions took place under the same conditions and with the same devices.

Measures

Demographic Data. Data were collected regarding participants' age and sex.

Control Variables. To detect participants responding in a random manner, the Oviedo Infrequency Questionnaire (Fonseca-Pedrero et al., 2009) was used. This instrument is made up of 12 items, interspersed throughout the assessment. These questions require participants to respond to Likert-type items (from totally disagree to totally agree) about obvious facts such as "I know people who wear glasses." According to the guidelines established by the authors, participants with more than 3 wrong answers were excluded.

DD Task. A computerized version of the DD Task was used. DD is a behavioral measure of impulsivity that describes how a reinforcer loses value as the delay to its receipt increases (Garcia-Rodriguez et al., 2013). Participants were presented with 7 independent tasks where they had to choose between a virtual amount of €1,000 available after different time periods (1 day, 1 week, 1 month, 6 months, 1 year, 5 years, and 25 years) versus multiple amounts of money available immediately. The value of the immediate option ranged from €5 to €1,000 in intervals of €10. Previous studies have shown that discounting rates in computerized versions and with hypothetical money are comparable with those from other formats (Johnson and Bickel, 2002; Smith and Hantula, 2008). The pattern of the indifference points can be described mathematically using a hyperbolic discounting function (Eq. 1) described by Mazur (1987):

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

This equation shows how the value (V) of a reinforcer of a specific amount (A) is discounted as a function of the delay (D) in receiving it (Mazur, 1987). The free parameter k describes the rate of discounting, with higher values indicating greater discounting and impulsivity. DD rates were calculated using the area under the curve (AUC) (Myerson et al., 2001).

Stroop Test. A computerized nonverbal version of the original Stroop Test was designed, based on models used in a previous study (Cox et al., 1999). Three blocks with 30 stimuli displayed in 4 colors (blue, green, red, and yellow) were included in the task: a first block of neutral stimuli (XXXX) appearing randomly; a second block of congruent stimuli (word and ink color-matched); and a third block of incongruent stimuli (word and ink color-unmatched). Participants were instructed to press 1 of 4 buttons displayed on the lower part of the screen corresponding to the 4 possible colors, as quickly as possible. The 3 blocks were presented sequentially. Reaction times (RT) in milliseconds were recorded to calculate the Stroop interference response time (IRT; mean RT in incongruent block minus mean RT at baseline), following Kindt and colleagues (1996) but using the mean values per block instead of the total RT (Ludwig et al., 2010). Stroop interference is used as a measure of response inhibition, and consequently behavioral impulsivity. Psychometric properties of the computerized nonverbal version of the Stroop are very similar to the original test (Gualteri and Johnson, 2006) but caution is advised before generalization (Peener et al., 2012).

Impulsive Sensation Seeking. The Spanish adaptation of the Impulsive Sensation Seeking (ImpSS) subscale (Fernández-Artamendi et al., 2016) from the Zuckerman–Kuhlman Personality Questionnaire (Zuckerman et al., 1993) was used. This brief subscale has 19 true/false (false 0, true 1) items which provide a general score and 2 subscores: Imp and SS. Cronbach's alpha indicates that the internal consistency of the ImpSS is good ($\alpha = 0.83$), and those of Imp ($\alpha = 0.75$) and SS ($\alpha = 0.74$) are acceptable.

Intoxication Episodes. Frequency of alcohol use and IE ("getting drunk") in the last month was evaluated using items from the ESPAD (European School Survey Project on Alcohol and Other Drugs, 2007). The 7-point Likert-type items included the following responses: none, once or twice, 3 to 5 times, 6 to 9 times, 10 to 19 times, 20 to 39 times, and more than 40 times.

Alcohol-Related Problems. To detect a continuous pattern of ARP and avoid scores resulting from incidental problems derived from occasional alcohol use, only participants who reported 10 or more drinking occasions within the last year were asked about the presence of ARP. The Spanish version (López-Nuñez et al., 2012) of the Rutgers Alcohol Problem Index (RAPI; White and Labouvie, 1989) was used for this purpose. This version has shown excellent reliability (Cronbach's $\alpha = 0.91$) with adolescents. The self-report includes 23 questions with Likert-type responses (where 0 = never; 1 = 1 to 2 times; 2 = 3 to 5 times; 3 = more than 5 times) on the frequency of alcohol-related events that occurred in the previous year.

Data Reduction and Analysis

In the Stroop Test, values >3.29 SD from the mean scores and disconnected from the distribution in each measure were recoded to a unit greater than the next most extreme value (Tabachnick and Fidell, 2007).

A descriptive analysis of the sociodemographic characteristics of the sample across waves was conducted including age, prevalence of alcohol use and IE, average IRT, scores on Imp, SS, and RAPI (Table 1).

Traditional CLPMs have recently been criticized for implicitly assuming that all participants vary over time around the same means, and therefore, these models do not capture trait-like individual differences. To overcome this shortcoming, we have followed recommendations from Hamaker and colleagues (2015), who proposed an extension to CLPMs in which RI for the constructs are included.[1] This extension allows for the separation of the within-person process from stable between-person differences. Consequently, the cross-lagged paths can be interpreted in a straightforward manner as the within-person effect of one variable on the subsequent measurement of a second variable (Flournoy, 2017). Accordingly, data in this study were analyzed using separate RI-CLPMs which were implemented using the lavaan package (Rosseel, 2012) within the R programming environment (R Core Team, 2013). First, models were examined for the relationship between each self-reported measure (Imp, SS) and IE and RAPI scores. Second, models were examined for each behavioral measure of impulsivity (DD, IRT) and IE and RAPI scores. The analyses conducted were unadjusted for confounders. All path weights are reported as standardized values. For clarity, only the autoregressive paths, cross-lagged paths, and covariances are included in the figures presented in the results section. For a complete pictorial representation of the RI-CLPMs which include all latent and observed variables along with how they differ from traditional CLPMs, refer to Fig. 1 of Hamaker and colleagues (2015).

Given that rates of IE and ARP at T1 and subsequent waves were relatively low, this could prevent the detection of significant cross-lagged relationships between T1 and T2. Consequently, additional RI-CLPMs with frequency of alcohol use in the last month (which has considerably higher rates at T1 compared to IE and ARP) were also carried out[1] for all impulsivity variables. Although the results from these additional models will be referred to across the discussion when necessary, due to space limitations, full details of these additional models are only included as Figs S1–S4.

Due to skewness of the data, and some missing values, maximum likelihood estimation with robust (Huber-White) standard errors was used for all analyses (option MLR in lavaan).

RESULTS

Rates of any alcohol use in the last month rose from 16.9% at T1 to 55.8% in T3, with increases in prevalence of IE (2.6% at T1, 14.2% at T3). Parallel to this increase, average RAPI scores rose from 0.55 (SD = 3.42) at T1 to 2.04 (SD = 5.34) at T3. These increases contrast with relatively stable scores in self-reported impulsivity and sensation seeking. The average IRT in the Stroop Test appeared to diminish across waves, which could be a result of the maturational processes expected at theses ages (Prencipe et al., 2011). DD scores remained stable, with only a minimum increase from T1 to T2.

Self-Reported Measures: Impulsivity and Sensation Seeking

The first 2 models explored the relationship between impulsivity and both IE and RAPI scores (see Figs 1 and 2). Both models have very good fit according to the indices (Imp–IE: χ^2[1, N = 1,430] = 1.02, p = 0.313; comparative fit index [CFI] = 1.000, standardized root mean square residual [SRMR] = 0.006; Imp–RAPI: χ^2[1, N = 1,430] = 0.49, p = 0.486; CFI = 1.000, SRMR = 0.004). Stability paths for impulsivity were found to be significant ($p \leq 0.01$) across all waves, whereas for IE and RAPI, they were significant only from T2 to T3 ($p \leq 0.001$). Cross-lagged paths were significant from impulsivity at T1 to IE at T2 ($p \leq 0.05$), and from Imp at T2 to IE at T3 ($p \leq 0.01$; and from Imp at T2 to RAPI at T3 ($p < 0.01$). In the other direction, cross-lagged relationships from IE/RAPI to impulsivity were not significant in any instance ($p > 0.05$). Overall, these results indicate that impulsivity predicted IE and problem drinking, but the reciprocal relationship was not significant.

A similar pattern is observed in the next 2 models for SS (see Figs 3 and 4). Model fit is very good for SS–IE (χ^2[1, N = 1,430] = 0.350, p = 0.554; CFI = 1.000; SRMR = 0.004). In this model, both stability paths for SS were significant ($p < 0.05$) and for IE between T2 and T3 ($p < 0.01$). Cross-lagged paths were significant from SS at T1 to IE at T2 ($p < 0.01$), and from SS at T2 to IE at T3 ($p < 0.001$), but not from IE to SS at either time ($p > 0.05$). With regard to RAPI, stability paths were significant between T2 and T3 ($p \leq 0.001$), in line with results with IE. Although the stability path for SS between T1 and T2 just failed to reach significance in the RAPI model (p = 0.059), its magnitude is nevertheless similar to that found in the IE model (β_{IE} = 0.144, β_{SS} = 0.142). The model also has very good fit (χ^2[1, N = 1,430] = 0,82, p = 0.364; CFI = 1.000, SRMR = 0.006). Overall, results indicate that there is a significant prospective association between SS and subsequent IE/RAPI that is not present in the other direction.

Behavioral Measures: Stroop Test and Delay Discounting

Models exploring relationships between Stroop and IE/RAPI indicate a very good fit for all indexes, both in the Stroop–IE model (χ^2[1, N = 1,430] = 0.023, p = 0.880; CFI = 1.000; SRMR = 0.001) and Stroop–RAPI (χ^2[1, N = 1,430] = 0.071, p = 0.790; CFI = 1.000; SRMR = 0.001) (see Figs 5 and 6). Stability paths were only significant between IRT at T1 and T2 ($p < 0.05$), and for IE and RAPI between T2 and T3 ($p < 0.01$). No cross-lagged paths were found to be significant. Overall, results indicate impulsivity does not predict IE or ARP, and neither do IE nor ARP predict changes in these impulsivity measures.

[1]We thank an anonymous reviewer for this suggestion.

Models with DD showed very good fit, both for AUC–IE (χ^2[1, N = 1,430] = 0.001 p = 0.975; CFI = 1.000; SRMR = 0.000) and for AUC–RAPI (χ^2[1, N = 1,430] = 0.070, p = 0.792; CFI = 1.000; SRMR = 0.001) (see Figs 7 and 8). Models indicated significant stability paths for AUC, IE, and RAPI between T2 and T3 ($p < 0.001$). No cross-lagged paths were significant ($p > 0.05$).

DISCUSSION

The present study explored the reciprocal relationship between a set of self-reported and behavioral measures of impulsivity and sensation seeking, and IE and problem drinking, in a community sample of Spanish early adolescents. Our study is the first to utilize a combination of behavioral tasks and self-reported instruments with 2 specific outcomes of heavy drinking: IE and ARP. Moreover, this is the first study to analyze the relationship between these variables in a Spanish-speaking culture and with a methodology that allows the separation of within-person effects from stable between-person differences (Hamaker et al., 2015). Overall, our results indicate that self-reported measures of impulsivity and sensation seeking significantly predicted prospective involvement in IE and ARP from as early as 13 years old. However, inhibitory control and DD did not predict prospective IE and ARP, and no measure of drinking predicted changes in impulsivity measures.

Impulsivity as a Predictor of IE and ARP

Our study confirms previous results (Castellanos-Ryan et al., 2013; Peeters et al., 2014b), indicating that individual self-reported impulsivity and SS predict IE from as early as 13 years old. Additionally, our results add to previous data on binge drinking and extend the results from previous studies (Castellanos-Ryan et al., 2013; White et al., 2011), indicating that SS predicts not only frequency of drinking (Dick et al., 2010) and blackouts (Marino and

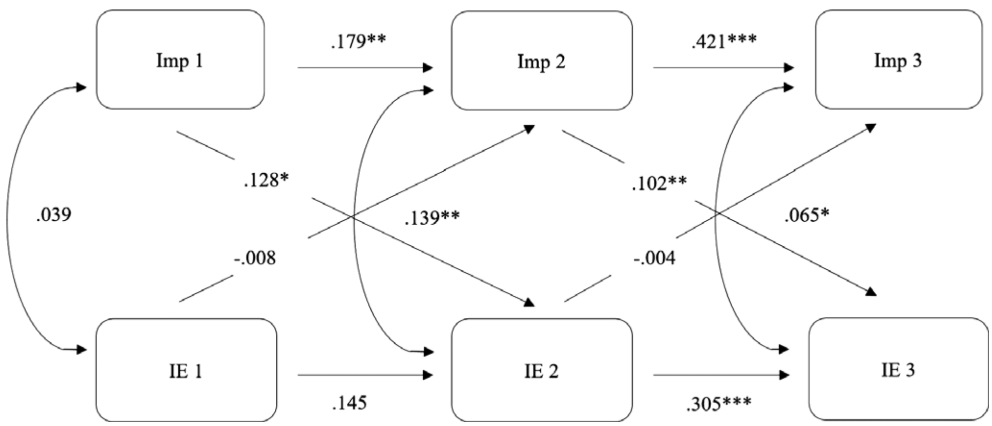

Fig. 1. Simplified representation of the random intercepts cross-lagged panel models showing only autoregressive paths and covariances of the reciprocal relationship between Imp scores and intoxication episodes (IE). Values refer to standardized cross-loadings: *$p < 0.05$, **$p < 0.01$, *** $p < 0.001$.

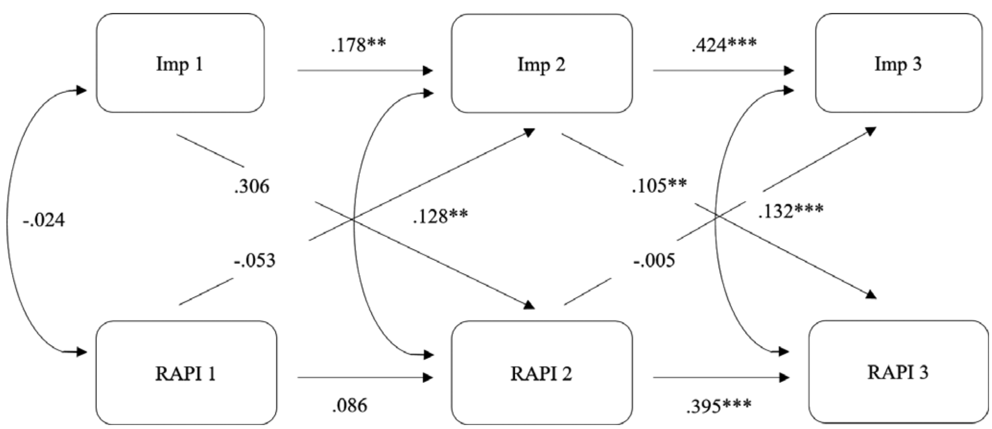

Fig. 2. Simplified representation of the random intercepts cross-lagged panel models showing only autoregressive paths and covariances of the reciprocal relationship between Imp scores and Rutgers Alcohol Problem Index (RAPI) scores. Values refer to standardized cross-loadings: **$p < 0.01$, *** $p < 0.001$.

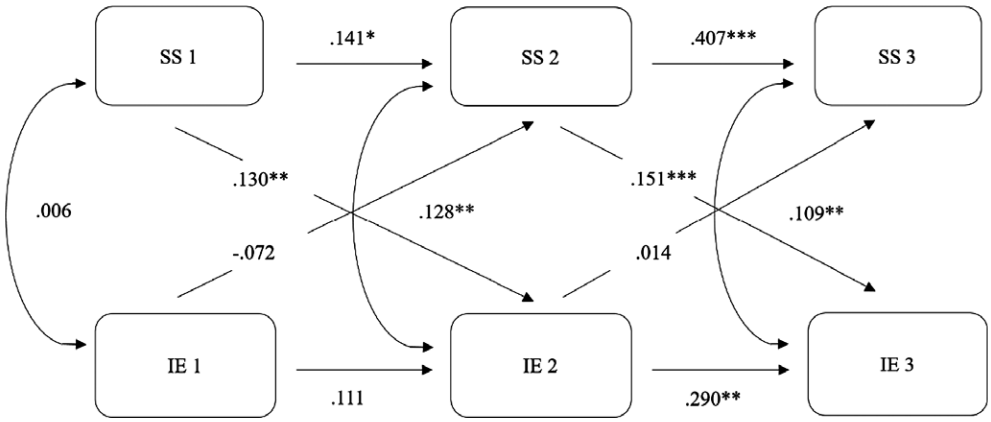

Fig. 3. Simplified representation of the random intercepts cross-lagged panel models showing only autoregressive paths and covariances of the reciprocal relationship between SS scores and intoxication episodes (IE). Values refer to standardized cross-loadings: *$p < 0.05$, **$p < 0.01$, *** $p < 0.001$.

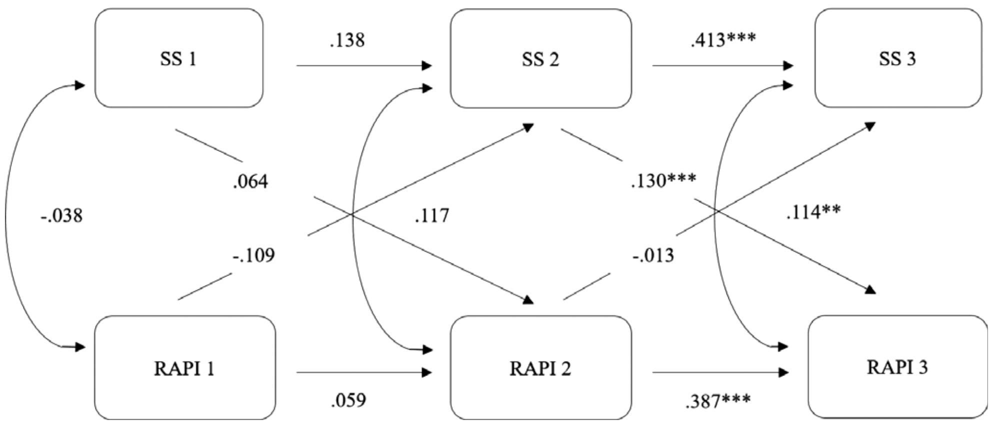

Fig. 4. Simplified representation of the random intercepts cross-lagged panel models showing only autoregressive paths and covariances of the reciprocal relationship between SS scores and Rutgers Alcohol Problem Index (RAPI) scores. Values refer to standardized cross-loadings: **$p < 0.01$, *** $p < 0.001$.

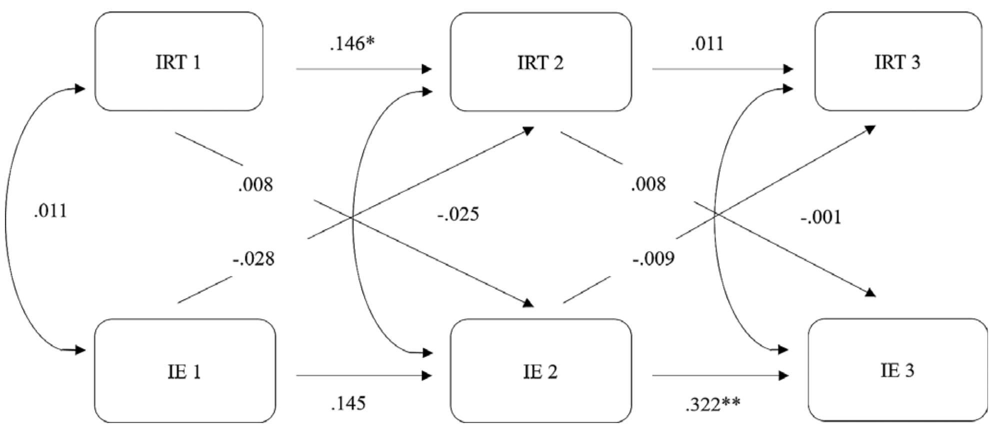

Fig. 5. Simplified representation of the random intercepts cross-lagged panel models showing only autoregressive paths and covariances of the reciprocal relationship between Stroop score (IRT) and intoxication episodes (IE). Values refer to standardized cross-loadings: *$p < 0.05$, **$p < 0.01$.

Fromme, 2016), but also IE and a more general concept of ARP in adolescents. More recently, and after the start of this longitudinal study, Riley and colleagues (2016) have suggested that a particular subcomponent of impulsivity, namely urgency, could be driving the relationship between impulsivity and drinking frequency. It would be interesting

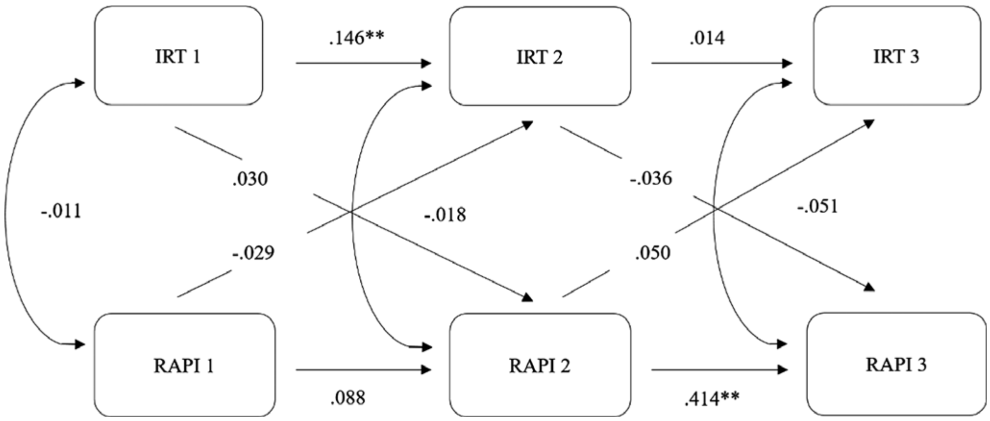

Fig. 6. Simplified representation of the random intercepts cross-lagged panel models showing only autoregressive paths and covariances of the reciprocal relationship between Stroop score (IRT) and Rutgers Alcohol Problem Index (RAPI) scores. Values refer to standardized cross-loadings: $^{**}p < 0.01$.

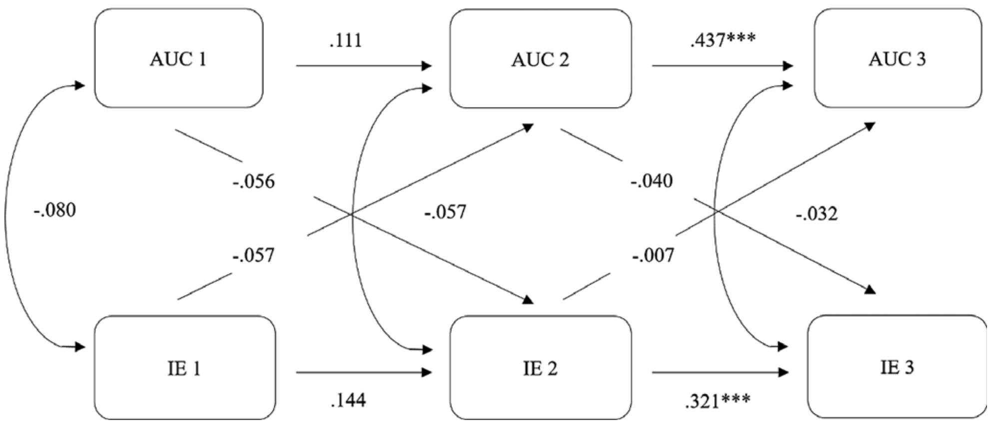

Fig. 7. Simplified representation of the random intercepts cross-lagged panel models showing only autoregressive paths and covariances of the reciprocal relationship between DD scores (area under the curve [AUC]) and intoxication episodes (IE). Values refer to standardized cross-loadings: *** $p < 0.001$.

to confirm whether this subcomponent is also associated with IE and problem drinking.

Regarding behavioral measures, results from previous studies on the predictive value of DD with alcohol use or heavy drinking have been inconclusive. Contrary to Wang and colleagues (2016), the results of the present study add to recent evidence (Isen et al., 2014; Janssen et al., 2015) on heavy drinking and alcohol use disorders. Our results indicate that DD was not a significant predictor of IE or ARP. We can also extend these results to ARP, as DD was not found to be a predictor of this measure. It could be that relatively low rates of IE and ARP at T1 prevented the detection of significant predictive paths from alcohol uses at T1 to the impulsivity measures at T2. For this reason, additional analyses with "frequency of alcohol use in the last month" (with considerable higher rates at T1 and subsequent waves) were carried out (see Figs S1–S4). However, results confirmed this lack of significant paths in the AUC model. Only 1 exception was detected in these additional models, with a weak cross-lagged path found between AUC at T2 and frequency of alcohol use at T3 ($p = 0.047$). These results contrast with those of Fernie and colleagues (2013), where DD was found to be a significant predictor of a latent factor of "alcohol involvement." However, as in our work, in the study by Fernie and colleagues (2013), predictive value was not replicated across all 5 waves and correlation values were weak ($r \leq 0.10$). As the Fernie and colleagues (2013) study's construct of alcohol involvement included frequency of alcohol use, intoxication, and ARP, it could be that DD is not a significant predictor of heavy or problem drinking, but instead is only a predictor of a more latent factor of alcohol involvement. Whatever the case, more research is definitely needed. Nevertheless, comparing studies which have used different formats of the DD task may be problematic, and this is discussed further in the limitations section.

Previous studies (Fernie et al., 2013; Nigg et al., 2006) have reported that disinhibition or poor inhibition control significantly predicted alcohol involvement. Nonetheless, in

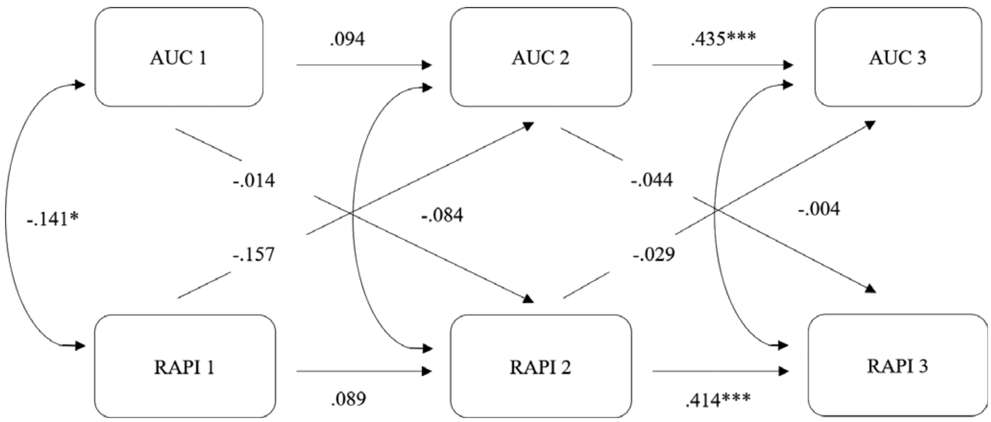

Fig. 8. Simplified representation of the random intercepts cross-lagged panel models showing only autoregressive paths and covariances of the reciprocal relationship between DD scores (area under the curve [AUC]) and Rutgers Alcohol Problem Index (RAPI) scores. Values refer to standardized cross-loadings: *$p < 0.05$, *** $p < 0.001$.

our study inhibitory control was not a significant predictor of IE or ARP (nor of frequency of alcohol use in the last month). In line with previous evidence with DD tasks, results suggest that behavioral measures may predict a latent factor of alcohol involvement or broad outcomes of high-risk drinking (Fernie et al., 2013; Nigg et al., 2006) but would lose predictive value with specific patterns of use such as those utilized in this study. This hypothesis still requires further research. Differences in predictive value between self-reported and behavioral measures of impulsivity are not surprising, given previous studies which suggest that they measure different domains (Dick et al., 2010; Reynolds et al., 2006). With regard to the Stroop Test, it could also be the case that the use of a computerized nonverbal version has limited the magnitude of the Stroop interference effect (Peener et al., 2012). In addition, the time between waves in our study was 1 year, twice that of the study by Fernie and colleagues (2013), and this could be concealing significant short-term effects. Additionally, we did not observe any significant relationships in the concurrent or longitudinal associations between behavioral measures and heavy drinking, and only a weak cross-lagged relationship was found between AUC at T2 and drinking frequency at T3. Clearly, further research is needed that focuses on different drinking outcomes and time frames.

IE and ARP as Predictors of Impulsivity Measures

Quinn and colleagues (2011) found that a latent factor of heavy drinking prospectively predicted higher scores on impulsivity and sensation seeking among college students. Riley and colleagues (2016) confirmed the relationship between alcohol drinking and the trait of urgency, and White and colleagues (2011) reported increases in impulsive behavior as a consequence of heavy drinking. However, in line with other studies (Fernie et al., 2013), our results indicate that neither IE, ARP, nor drinking frequency predict prospective changes in self-reported or behavioral impulsivity. Regarding this apparent inconsistency, White and colleagues (2011) have suggested that it could be adolescents with moderate impulsivity levels who are at particular risk of subsequent increases as a consequence of heavy drinking. Therefore, it is plausible that in community samples, alterations in impulsivity remain under detectable thresholds (Peeters et al., 2014b). Additionally, the present study deliberately evaluated early adolescents at the very start of their alcohol use, and these alterations might only appear after extended chronic use (Fernie et al., 2013; MacKillop et al., 2007; Malmberg et al., 2012). Relatively short-term longitudinal studies with early adolescents such as the present one might not be able to detect significant changes present in longer ones (Quinn et al., 2011).

Limitations

This study has some limitations. First, the adolescents were followed for 2 years only, thus limiting the long-term effects which could not be explored. Second, previous studies (Peeters et al., 2014b; Wang et al., 2016) have suggested additional factors that could have a significant mediator role, which, given the extension of the evaluation and time limitations, could not be included in the present study. This is also the case with other well-known predictors of adolescent drinking such as alcohol expectancies or drinking motives. Time restrictions also limited the possibility of conducting a more in-depth evaluation of additional impulsivity constructs like those proposed by Whiteside and Lynam (2001). However, our goal was to focus on the comparison between self-reported and behavioral measures, and their relationship with heavy drinking patterns. Accordingly, the instruments selected allowed us to meet this goal. Further research is needed to undertake specific analyses with additional subcomponents and mediator variables that could influence this interrelation. Third, although computerized versions of DD and Stroop Test have been shown to be reliable (Gualteri and Johnson, 2006; Smith and Hantula, 2008), there is a question about their generalizability, particularly for Stroop Test (Peener et al., 2012). Nevertheless, their use facilitates recruitment of relatively large samples as it was the case for the present study. Fourth, due to the lack of studies evaluating the relationship between these variables outside Anglo-Saxon cultures, there is insufficient evidence to enable us to compare and discuss whether cultural differences are behind some of the discrepancies between our results and previous research.

CONCLUSIONS

There were 2 main findings in the present study. First, according to our results, individual levels of self-reported impulsivity and sensation seeking early in adolescence significantly predict IE and ARP in adolescents. Second, and in contrast to previous studies with alcohol involvement (e.g., Fernie et al., 2013), behavioral measures were not found to be significant predictors. Furthermore, although impulsivity and sensation seeking were significant predictors of later alcohol use, the effect size is small, and predictive value must therefore be interpreted with caution. We did not detect significant effects on any impulsivity measure as a consequence of IE and ARP. Additionally, recent research has suggested that particular subcomponents of impulsivity, specifically urgency (Riley et al., 2016), could be especially related to adolescent drinking. Further research should address the explicit role of each of these subcomponents to clarify its relationship with problem and heavy drinking. In addition, it seems necessary to evaluate whether using longer periods of follow-up or special populations would help in detecting significant alterations in impulsivity measures. Furthermore, conducting specific analyses of different profiles of drinkers, particularly early problem drinkers, as well as including mediator variables could provide additional information on the mechanisms underlying this complex interrelation. To our knowledge, ours is the first study that evaluates this relationship in a Spanish-speaking sample, replicating and extending previous results from Anglo-Saxon countries, and contributing to the generalizability of some results. Moreover, our study was conducted with early adolescents in schools, and as Spain has a school enrollment rate of 97.4% (Instituto Nacional de Estadística, 2017), and school attendance is obligatory under national law, our sample is highly representative of the Spanish adolescent general population.

In our study, the relationship between impulsivity and drinking in a community sample was fundamentally unidirectional, with impulsivity predicting subsequent heavy drinking and ARP. Our results indicate that early evaluation of impulsivity and sensation seeking through self-report instruments screening for impulsive behaviors could help detect high-risk profiles for subsequent heavy drinking and related problems. Moreover, early intervention aimed at improving coping strategies and curbing early impulsive behaviors might ultimately be of use in preventing progression to heavy drinking patterns. This hypothesis, however, goes beyond our results and needs additional research. According to our study, interventions aimed at executive functions such as inhibitory control or decision making would not have a significant effect on high-risk patterns of alcohol use.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Fig. S1. Simplified representation of the RI-CLPMs showing only autoregressive paths and covariances of the reciprocal relationship between Imp scores and frequency of alcohol use in the last month (Freq Alcohol).

Fig. S2. Simplified representation of the RI-CLPMs showing only autoregressive paths and covariances of the reciprocal relationship between SS scores and frequency of alcohol use in the last month (Freq Alcohol).

Fig. S3. Simplified representation of the RI-CLPMs showing only autoregressive paths and covariances of the reciprocal relationship between Stroop scores (IRT) and frequency of alcohol use in the last month (Freq Alcohol).

Fig. S4. Simplified representation of the RI-CLPMs showing only autoregressive paths and covariances of the reciprocal relationship between DD scores (AUC) and frequency of alcohol use in the last month (Freq Alcohol).