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Properties of the Cannabis Abuse Screening Test (CAST) in the general population

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Abstract

This paper explores the DSM-IV latent structure of cannabis users (especially its invariance towards gender and age) and assesses the psychometric properties of the Cannabis Abuse Screening Test (CAST) by confrontation with the theoretical diagnoses [dependence and cannabis use disorders (CUD)] and the latent class structure of the DSM-IV. The random sample comprised 550 French cannabis smokers aged 15–62 years interviewed by telephone. DSM-IV diagnoses were assessed with the Munich Composite International Diagnostic Interview. Internal structures of both instruments were assessed using factor analysis and latent class analysis. Optimal CAST cutoffs were determined by sensitivity, specificity and area under the receiver operating curve (AUC). CAST and DSM-IV were unidimensional (Cronbach's $\alpha = 0.742$ and 0.752, respectively), although a two-factor solution showed a better fit for the CAST. CAST cutoffs for screening CUD and dependence were three (AUC = 0.851) and five (AUC = 0.868), respectively. DSM-IV latent class structure varied only marginally in age and gender. Three classes of cannabis smokers were determined, ordered along a continuum of symptoms: *non-symptomatic* (61.1%), *moderate* (32.9%) and *severe* (6.0%). CAST cutoff scores for screening *moderate/severe* and *severe* were, respectively, three (AUC = 0.869) and eight (AUC = 0.952). Results are compared to those obtained in previous CAST studies and discussed in line with the DSM-5. *Copyright © 2015 John Wiley & Sons, Ltd.*

Introduction

Many screening scales assessing cannabis-related problems have been developed and tested in recent years (Beck and Legleye, 2008), although very few have been validated in Europe (Piontek *et al.*, 2008; Annaheim, 2013). One of the most-used is the Cannabis Abuse Screening Test (CAST) (Legleye *et al.*, 2007). Originally designed for adolescents, it was adopted in the European School Survey Project on Alcohol and other Drugs (ESPAD) (Hibell *et al.*, 2009; Piontek *et al.*, 2009). Its psychometric properties have been assessed in representative samples of adolescents in France (Legleye *et al.*, 2011; Legleye *et al.*, 2013) and Italy (Bastiani *et al.*, 2013). Good internal, psychometric and screening properties were also found in small samples of young adults in Spain (Cuenca-Royo *et al.*, 2012; Fernandez-Artamendi *et al.*, 2012) as well as in Hungary (Gyepesi *et al.*, 2014). The internal structure was found unidimensional in studies from France, Italy and Hungary or bifactorial in a study from Spain, the two factors being correlated (Cuenca-Royo *et al.*, 2012; Fernandez-Artamendi *et al.*, 2012).

In Europe, patterns of cannabis use differ between adolescents and adults: last-year and last-month use is concentrated among 15–24 and 15–34 year-olds (EMCDDA, 2011). However, in some countries (Czech Republic, Italy, United Kingdom), older smokers are quite numerous. In France, while cannabis use is concentrated among people aged less than 25 years old, 8% of men aged 35–44 and 3% of those aged 45–54 reported last-year cannabis use in 2010, while the corresponding proportion in these age groups among women was 2% (Beck *et al.*, 2011). Previous studies showed that smoking before midday and intensity of smoking were more frequent among young than older adults (Legleye *et al.*, 2008; Beck *et al.*, 2013). Screening instruments therefore need to be validated in a wider age range of the general population.

Most validation studies of screening instruments used the DSM-IV as gold standard (Martin *et al.*, 2006; Piontek *et al.*, 2008; Steiner *et al.*, 2008; Bashford *et al.*, 2010; Legleye *et al.*, 2011; Cuenca-Royo *et al.*, 2012; Bastiani *et al.*, 2013). However, its validity has been challenged. First, there is evidence that a unidimensional solution describes cannabis use disorders (CUD) better than the two concepts of abuse and dependence (Teesson *et al.*, 2002; Martin *et al.*, 2006; Gillespie *et al.*, 2007; Baillie and Teesson, 2010; Piontek *et al.*, 2011), whose clinical relevance has been questioned (Babor and Caetano, 2006; Hesselbrock and Hesselbrock, 2006). There was also discussion as to whether these diagnoses should be categorical or dimensional (Muthen, 2006). These problems contributed to the revision of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM), involving a unidimensional structure of substance use disorders with the number of endorsed criteria defining a continuum of severity (Regier *et al.*, 2013).

Second, the DSM-IV has been criticized for not taking account of gender differences. Among adolescents, Piontek *et al.* (2011) found that the criteria relating to tolerance and withdrawal showed differential item functioning between genders, while Martin *et al.* (2006) found similar results for hazardous use, legal problems, and physical-psychological problems. Also among adolescents, the latent structure of the DSM-IV was found to vary with gender (Piontek *et al.*, 2011; Legleye *et al.*, 2013) and similar results were found in adults (Grant *et al.*, 2006). By comparison, research on age differences is scarce: only one study has assessed the potential age sensitivity of the DSM-IV criteria for CUD in the general population, pointing that despite a global invariance towards age, the "Hazard use" criteria discriminated differently in 18–24 years old and older users (Mewton *et al.*, 2010). One reason for this may be the small numbers of studies screening cannabis problematic use in the general population. Recently, a study on age differences in DSM-IV alcohol use disorders revealed substantial differences in the endorsement of several diagnostic criteria that are attributable to, for instance, the different interpretation of the criteria by different age groups, independent of their patterns of use (Pabst *et al.*, 2012). It is not unlikely, that such differences also exist with regard to CUD.

As previous validations of the CAST were done in adolescent populations or in young adults (namely students), results may not be valid in the adult population. This study uses the methodology of two previous publications on adolescents (Legleye *et al.*, 2011; Legleye *et al.*, 2013) using a large representative sample of past-year cannabis users from the general population. The aims were (1) to examine the internal structure of the DSM-IV and the CAST; (2) to examine the latent class structure of the DSM-IV criteria, especially its variability by age and gender; (3) to assess the screening properties of the CAST against both the classic theoretical diagnoses of the DSM-IV and the latent class structure considered as an empirical gold-standard, following previous studies (Hawkins *et al.*, 2001; Garrett *et al.*, 2002). Furthermore, criterion and convergent validity were investigated.

Methods

Design and sample

Data was derived from the 2010 National Health Barometer, the latest survey of a series regularly carried out by the French Institute for Health Promotion and Health

Education (INPES) since 1992. The study protocol included: (a) a formal request to participate that was delivered by post before the first telephone call (or after for individuals with confidential numbers whose addresses were unknown beforehand); (b) a computer-assisted telephone interview (CATI). Unsuccessful calls were repeated 30 and 90 minutes later; up to 40 attempts were made, on different days and at different times (Beck and Richard, 2013).

The survey used a two-stage random sample of French speaking people aged 15 to 85 years and living in metropolitan France (overseas territories excluded), using random-digit-dialling to landline and mobile phones. Only private households (whether in telephone registry or not) were included (the final proportion of households/individuals with only a mobile phone was 12%). First, households were randomly selected (by telephone number), then one individual was selected using the Kish method (Kish, 1949). The mean duration of interviews was 32 minutes. In all, 60.5% of all selected households completed the interview ($n = 27{,}653$). Details of the methodology can be found in (Beck and Richard, 2013). The survey was approved by the National Data Protection Authority [Commission Nationale Informatique et Liberté (CNIL)].

For budget reason, we were forced to restrict the data collection to a third ($n = 560$) of the past-year cannabis users aged 15–64 years [$n = 1753$, who represent 8% of the 22,774 individuals aged 15–64 years: (Beck *et al.*, 2011)]. These individuals were randomly chosen during the CATI interview. In all, 10 individuals with missing responses to the CAST or the DSM items were excluded. The final sample analysed comprised 550 individuals. No weighting was used in the analyses.

Instruments

The CAST is a six-item scale that assesses the frequency of the following events within the past 12 months: non-recreational use ("Have you smoked cannabis before midday?"; "Have you smoked cannabis when you were alone?"), memory disorders ("Have you had memory problems when you smoked cannabis?"), being encouraged to reduce or stop using cannabis ("Have friends or family members told you that you should reduce or stop your cannabis use?"), unsuccessful attempts to quit ("Have you tried to reduce or stop your cannabis use without succeeding?"), and problems linked to cannabis use ("Have you had problems because of your cannabis use (argument, fight, accident, poor results at school, etc.)?"). All items are answered on a five-point scale (0 "never", 1 "rarely", 2 "from time to time", 3 "quite often", 4 "very often"). A total score ranging from zero to 24 is obtained.

Questions on DSM-IV abuse and dependence of the telephone interview were drawn from the Munich Composite International Diagnostic Interview (M-CIDI) substance use sections (Wittchen *et al.*, 1995). The M-CIDI is an updated version of the World Health Organization's CIDI version 1.2 (WHO, 1990), a standardized interview administered during a personal face-to-face interview for the assessment of the symptoms and diagnoses of substance use and mental disorders. It comprises 19 items to form the 11 DSM-IV criteria. Abuse is defined by at least one out of the four abuse criteria, without meeting a dependence diagnosis, dependence is defined by at least three out of the seven dependence criteria, CUD is defined as either abuse or dependence diagnosis. The M-CIDI has been reported reliable and valid in community samples (Lachner *et al.*, 1998). It was translated into French following the recommendation by Tafforeau *et al.* (2005).

External validators and covariates

The number of cannabis-smoking days in the past month, the number of DSM-IV criteria met and two items dealing with cannabis-related problems during the past 12 months were used as external validators to check the convergent validity of the CAST: *having thought about seeking help* for the cannabis use (yes/no), *having experienced work or family problems* due to cannabis use (yes/no). Age is a strong predictor of cannabis use patterns, but the main differences are found between young users (15–24) and the others (EMCDDA, 2011). The covariates in the latent class analysis (LCA) were thus gender, age (15–24, 25–64), gender × age, daily cannabis use and the last two external validators.

Statistical analyses

The internal structures of the CAST and the DSM-IV were investigated by exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) to explore the underlying dimensional structure. Because CAST responses are categorical and DSM-IV criteria are dichotomous, traditional linear models were inappropriate. Instead, non-linear factor analyses were performed using robust estimation of weighted least squares means and variance. CFA model fit was examined using the comparative fit index (CFI) and the root mean square error of approximation (RMSEA). A cutoff of 0.95 on the CFI with a RMSEA below 0.06 was considered an adequate model fit (Hu and Bentler, 1999).

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Opposite to EFA and CFA, LCA assumes a categorical underlying structure. LCA was run on all DSM-IV criteria derived from the M-CIDI using SAS PROC LCA (Lanza *et al.*, 2014). A multiple-group LCA testing measurement invariance across age and gender (and gender × age-group) was performed, following a three-step procedure (Hagenaars and McCutcheon, 2002; Collins and Lanza, 2010). In the first step, an optimal baseline model was retained from a series of models fitted to the total sample with no additional parameters (two to five classes). The model with the optimal number of classes was the one with the lowest BIC (Bayesian information criterion) and the highest entropy (Celeux and Soromenho, 1996). We also computed the bootstrapped likelihood ratio test using the SAS Macro LcaBootstrap (Dziak *et al.*, 2011) to test whether the k-class model is adequate relative to the k + 1-class alternative (100 replications were used): a *p*-value above 0.05 means that we could not reject k classes. Then, age, gender and gender × age were separately included as group variables in the baseline model. For each of these variables, measurement invariance across groups was tested by comparing two models: one model with all parameters freely estimated (unconstrained model, Step 2); one model with item response probabilities constrained to be equal across groups (Step 3). As the model in Step 3 is nested in the model in Step 2, the difference between the corresponding G^2 (deviance) can be compared to a Chi-square distribution. A significant G^2 test suggests rejection of the hypothesis of measurement invariance (or structural equivalence): the meaning of the latent classes may differ across groups, and separate analyses by groups may be preferable.

Each model was run with 100 random starts to avoid local minimum and to assess the stability of the results. The final model included covariates to improve class membership predictions. Each individual was assigned on the basis of the maximum posterior class membership probability. The classes were described by proportions and mean numbers of endorsed DSM-IV criteria. The robustness of the classification process was assessed using Kappa indexes (Landis and Koch, 1977) comparing the classes to those obtained by different choices for invariance and covariates.

Internal consistency was assessed with Cronbach's α coefficient and item-total correlation. For criterion validity, the Youden index Y (Y = sensitivity + specificity − 1) was used to identify the optimal scores of the CAST against the theoretical DSM-IV diagnoses and the latent classes. The AUC (area under the receiver operating characteristic curve) was also used as an indicator of the discrimination power (Murphy *et al.*, 1987). An area of 0.8 means that the CAST score of a randomly selected individual that is DSM-IV positive is larger than the one of a randomly selected individual that is DSM-IV negative in 80% of the cases. Usually, an area of 0.8 to 0.89 is considered good, an area of 0.9 to 0.99 is considered excellent. The positive predictive value (PPV) reflects the probability of a clinical diagnosis obtaining a positive screening result, whereas the negative predictive value (NPV) is the probability of not having a diagnosis when the screening result is negative. All analyses used SAS V9.3, except for non-linear EFA and CFA where MPlus V7 was used (Muthen and Muthen, 2010).

Results

Description of the sample

The sample comprised 550 individuals (67.1% were men) aged 15–62 years [mean = 29.0, standard deviation (SD) = 10.4, the group of 15 to 24 year-olds amounting to 42.2% of the total] who had smoked cannabis in the past 12 months (Table 1). The prevalences of dependence, abuse and CUD were 12.6%, 16.4% and 28.9%, respectively. Men and women did not differ in respect of their prevalences of dependence, but men were more likely to meet abuse criteria or CUD. Men were also more likely to smoke cannabis daily (17.3% versus 8.3%), to drink alcohol at least four times per week (22.0% versus 8.8%) or to drink at least six glasses in one occasion per week (27.1% versus 9.9%), while daily tobacco smoking and the use of any other illicit drug in life were similar in the two genders (69.6% and 51.3%, respectively). The proportion of DSM-IV diagnoses is also higher in the younger age group: dependent individuals amounted to 16.4% in the 15–24 age group against 9.8% in 25–64 group ($p < 0.05$) while the mean difference in DMS-IV criteria (0.3) and dependence criteria (0.4) were also significant ($p < 0.05$).

Regarding the CAST, Items 1 (*cannabis before midday*) and 2 (*cannabis when alone*) were the most commonly endorsed (35.5% and 44.7%), while Item 6 (*problems*) was only reported by 7.1%. Overall, 41.1% reached a score of three or more, 28.6% five or more and 16.0% eight or more (the optimal thresholds defined later). Differences between genders were significant for all items except Item 6 (*problems*), while difference between age groups was significant only for Item 1 ($p < 0.05$). Gender differences in mean number of DSM-IV abuse or dependence criteria were all relatively large and significant (Table 1). Globally, there were thus fewer differences between age groups than between genders.

Table 1. Distribution of substance use, CAST and DSM-IV criteria (column %, mean and standard deviation, SD)

	Men $N=369$	Women $N=181$	*D*	*P*	15–24 $N=232$	25–62 $N=318$	*D*	*P*	Total $N=550$
Age, mean (SD)	29.4 (10.2)	28.3 (10.7)	1.0 (0.9)	ns	—	—		—	29.0 (10.4)
15–24 years old	38.8	49.2		*	—	—		—	42.2
25–62 years old	61.2	50.8			—	—		—	57.8
At least four alcohol use per week	22.0	8.8		***	13.4	20.8		*	17.6
At least 6+ glass per occasion, weekly	27.1	9.9		***	25.0	18.9		ns	21.5
Daily tobacco smoking	71.0	66.9		ns	64.2	73.6		*	69.6
Daily cannabis use last month	17.3	8.3		**	12.9	15.4		*	14.4
Thought about seeking help for cannabis use	8.7	2.2		**	6.5	6.6		ns	6.6
Family or work problems due to cannabis use	9.8	8.8		ns	11.6	7.9		ns	9.5
Any other lifetime illicit drug use	53.4	47.0		ns	49.1	52.8		ns	51.3
CAST (*at least once*)									
Cannabis before midday	41.7	22.7		***	41.8	30.8		**	35.4
Cannabis when alone	52.0	29.8		***	43.1	45.9		ns	44.7
Memory problems	29.5	19.2		**	29.3	23.9		ns	26.2
Friends or family	24.7	9.4		***	22.8	17.3		ns	19.6
Tried to reduce or stop	20.1	9.4		***	15.5	17.3		ns	16.5
Problems	7.3	6.6		ns	7.3	6.9		ns	7.1
DSM-IV abuse criteria									
Role impairment	1.1	1.7		ns	3.0	0.0		**	1.3
Hazardous use	17.3	5.5		***	12.5	14.2		ns	13.5
Legal problems	6.2	1.1		**	5.6	3.8		ns	4.6
Social problems	14.4	7.2		*	15.1	9.8		*	12.0
DSM-IV dependence criteria									
Tolerance	18.2	9.9		*	21.1	11.2		**	15.5
Withdrawal	5.7	4.4		ns	5.2	5.4		ns	5.3
Larger, longer use than intended	20.1	14.9		ns	19.4	17.6		ns	18.4
Impaired control	30.6	24.9		ns	27.2	30.0		ns	28.7
Much time spent	11.4	7.2		ns	13.4	7.2		**	10.0
Reduced activities	4.6	3.9		ns	5.2	3.8		ns	4.4
Use despite problems	17.9	16.6		ns	24.6	12.3		***	17.5
CUD diagnosis (abuse or dependence)	34.7	17.1		***	32.3	26.4		ns	28.9
Abuse diagnosis only	20.9	7.2		***	16.0	16.7		ns	16.4

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Dependence diagnosis only	13.8	9.9		ns	16.4	9.8		*	12.6
DSM-IV abuse criteria, mean (SD)	0.4 (0.7)	0.2 (0.5)	0.2 (0.05)	***	0.4 (0.7)	0.3 (0.6)	0.1 (0.05)	ns	0.3 (0.6)
DSM-IV dependence criteria, mean (SD)	1.1 (1.4)	0.8 (1.4)	0.3 (0.1)	*	1.2 (0.1)	0.9 (0.1)	0.3 (0.1)	*	1.0 (1.4)
DSM-IV criteria, mean (SD)	1.5 (1.8)	1.0 (1.8)	0.5 (0.2)	**	1.5 (1.3)	1.1 (1.6)	0.4 (0.2)	*	1.3 (1.8)
CAST score, mean (SD)	3.7 (4.1)	2.0 (3.6)	1.6 (0.4)	***	3.3 (0.3)	3.0 (3.9)	0.2 (0.3)	ns	3.1 (3.9)
CAST optimal cutoffs for:									
CUD (cutoff = 3)	48.8	25.4		***	41.4	40.9		ns	41.1
Dependence (cutoff = 5)	33.9	17.7		***	29.7	27.7		ns	28.6
Moderate/severe (cutoff = 3)	48.8	25.4		***	41.4	40.9		ns	41.1
Severe (cutoff = 8)	18.7	10.5		***	16.8	15.4		ns	16.0

Note: *D*, mean of differences (SD); *P*, *p*-value for Chi-square test (%) or for *t*-test (mean) when comparing men and women or 15–24 years old and 25–62 years old: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$, ns, not significant.

Internal structure and reliability

The results of the EFA on the CAST (Table 2) suggested a two-factor solution (Items 1 and 2 loaded on the first factor, the other items on the second) confirmed by the CFA [CFI = 1.000, TLI = 1.000, RMSEA = 0.009, 90% confidence interval (CI) = (0.000–0.051)]. The first factor comprises patterns of use (non-recreational use described as smoking before midday and smoking alone), while the second one is more related to associated problems. However, as the two factors were highly correlated ($r = 0.834$, SD = 0.046), a one-factor solution with a lower fit could also be retained [CFI = 0.989, TLI = 0.982, RMSEA = 0.061, 90% CI = (0.036; 0.088)], with a Cronbach's $\alpha = 0.742$. Correlations between items ranged from 0.170 (*problems* × *cannabis before midday*) to 0.620 (*cannabis when alone* × *cannabis before midday*), with a majority of values between 0.20 and 0.35. Table 3 shows that item-total correlations on the CAST range from 0.651 (*cannabis when alone*) to 0.327 (*problems*).

The EFA on the DSM-IV criteria resulted in all four abuse criteria and the dependence criteria *tolerance*, *reduced activities* and *use despite problems* loading on factor one and the other four dependence criteria loading on factor two. The CFA confirmed this structure [CFI = 0.996, TLI = 0.996, RMSEA = 0.011, 90% CI = (0.000–0.031)]. Again, as the factors were highly correlated ($r = 0.877$, SD = 0.050), we retained a one-factor solution [CFI = 0.989, TLI = 0.986, RMSEA = 0.021, 90% CI = (0.000; 0.037)], with Cronbach's $\alpha = 0.752$.

Convergent validity

Mean CAST scores differed significantly according to DSM-IV diagnoses (all bivariate *t*-tests *p*-values < 0.01): 1.6 (SD = 2.5) for the absence of CUD, 6.9 (SD = 4.4) for CUD, 5.6 (SD = 4.0) for abuse and 8.5 (SD = 4.4) for dependence. The convergent validity of the CAST was assessed from the number of cannabis-smoking days in the past month, and the numbers of DSM-IV abuse and dependence criteria: Pearson's correlation coefficients were 0.52 ($p < 0.0001$), 0.65 ($p < 0.0001$) and 0.72 ($p < 0.0001$), respectively. Mean CAST scores were also significantly higher among respondents who reported that they had thought about seeking help for their cannabis use (9.2 versus 2.7, $p < 0.0001$) and among those who reported problems at work or with their families because of their cannabis use (8.1 versus 2.6, $p < 0.0001$).

Table 2. Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) of the CAST and the DSM-IV criteria

	EFA				CFA			
	F1 Loading[a]	SE	F2 Loading[a]	SE	F1 Loading[a]	SE	F2 Loading[a]	SE
CAST								
Cannabis before midday	*0.724*	0.116	0.250	0.118	0.781	0.029		
Cannabis when alone	*0.929*	0.138	0.256	0.091	0.942	0.029		
Memory problems	0.494	0.056	*0.533*	0.081			0.744	0.040
Friends or family	0.519	0.063	*0.528*	0.097			0.768	0.039
Tried to reduce or stop	0.357	0.049	*0.587*	0.089			0.639	0.046
Problems	0.312	0.084	*0.612*	0.134			0.624	0.058
DSM-IV								
Abuse criteria								
Role impairment	*0.783*	0.140	0.191	0.154	0.701	0.151		
Hazardous use	*0.439*	0.103	0.256	0.103	0.494	0.074		
Legal problems	*0.706*	0.106	0.219	0.122	0.652	0.087		
Social problems	*0.552*	0.097	0.545	0.098	0.795	0.046		
Dependence criteria								
Tolerance	*0.600*	0.102	0.502	0.102	0.793	0.046		
Withdrawal	0.172	0.091	*0.975*	0.121			0.863	0.063
Larger, longer use than intended	0.278	0.116	*0.588*	0.092			0.654	0.057
Impaired control	0.277	0.112	*0.596*	0.093			0.658	0.054
Much time spent	0.462	0.115	*0.677*	0.100			0.857	0.046
Reduced activities	*0.668*	0.098	0.411	0.122	0.770	0.077		
Use despite problems	*0.578*	0.089	0.423	0.102	0.715	0.049		

[a]Standardized loading with Varimax rotation (orthogonal on EFA).
Note: In italic type the items chosen for each factor. In each CFA, the two factors are highly correlated: $r = 0.834$ (SD = 0.046) for the CAST, 0.877 (SD = 0.050) for the DSM-IV.

Table 3. Psychometric properties of the CAST

	Mean score (SD)	Correlation with total score	Cronbach's alpha when item deleted	Item-total correlation
Total				
1: Cannabis before midday	1.7 (1.1)	0.705	0.685	0.545
2: Cannabis when alone	2.1 (1.4)	0.800	0.651	0.651
3: Memory problems	1.5 (0.9)	0.683	0.700	0.501
4: Friends or family	1.5 (1.0)	0.704	0.691	0.525
5: Tried to reduce or stop	1.4 (1.0)	0.568	0.730	0.386
6: Problems	1.1 (0.4)	0.491	0.747	0.327

Latent class analysis of the DSM-IV

The optimal number of classes (Table 4) according to BIC, entropy and bootstrap likelihood ratio test was three (step 1: BIC = 617.8, log-likelihood = −1756.8, entropy = 0.76). Following (Magidson and Vermunt, 2001), bivariate residuals (BVR) larger than 3.84 indicate correlations that have not been captured adequately in the model and one solution may be to consider more classes. Among the 66 BVR between the 11 abuse and dependence items of the DSM, only one was above this threshold, namely between *Hazardous use* and *Impaired control* (BVR = 4.04). In the four-class model, the highest BVR (between *Role impairement* and *Reduced activities*) was 2.73. However,

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Table 4. Latent class analysis (LCA) of the DSM-IV criteria

Model	AIC	LogL	G^2	BIC	Degrees of freedom	Entropy	Reduction in LogL (%)	Percentage of starts with best model[a]
Baseline model								
1 class	970.9	−2032.8	948.9	1018.3	2036	1.00	0[c,**]	100.0
2 classes	528.9	−1799.8	482.9	628.0	2024	0.82	−11.5[c,**]	100.0
3 classes	*466.9*	*−1756.8*	*396.9*	*617.8*	*2012*	*0.76*	*−15.3*[c, ns]	*100.0*
4 classes	461.8	−1742.2	367.8	664.3	2000	0.76	−16.5[c]	60.0
5 classes	463.5	−1731.0	345.5	717.8	1988	0.68	−17.3[c]	51.0
Models with group variables								
Baseline + gender								
Unconstrained	621.9	−1720.9	481.9	923.6	4025	0.78	0	98.0
Constrained	605.3	−1745.6	531.3[b]	764.8	4058	0.77	1.4	100.0
Baseline + age								
Unconstrained	647.7	−1726.4	507.7	949.4	4025	0.78	0	95.0
Constrained	636.0	−1753.5	562.0[b]	795.5	4058	0.76	1.6	99.0
Baseline + gender × age								
Unconstrained	887.3	−1683.8	607.3	1490.7	8051	0.80	0	5.0
Constrained	803.7	−1741.0	721.8	980.5	8150	0.77	3.4	100.0
Model: baseline with covariates[d]		−1653.4					−5.8[e]	39.0
Final model: baseline with covariates[d] *and direct effects*		−1630.1					−7.2[e]	100.0

Note: In italic type, the baseline model chosen.
[a]Estimated among 100 random starts. The higher the percentage, the more stable the results.
[b]*p*-Value of the Chi-squared test of the G^2 comparing constrained and unconstrained models < 0.05.
[c]Bootstrapped likelihood ratio test, testing the null hypothesis that k classes (instead of k + 1 classes) is sufficient (100 replications): $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$, not significant.
[d]Covariates are (*p*-value): gender × age ($p = 0.001$), daily cannabis use in the last month ($p = 0.000$), thought about seeking help ($p = 0.000$), family or work problems due to cannabis ($p = 0.000$).
[e]Compared to the baseline model with three classes.

the fit indexes were markedly degraded (BIC = 664.3) such that the three-class solution was finally chosen. Next, age (15–24, 25–64), gender and gender × age were considered separately as group variables, and a test for the structural invariance of each was performed (steps 2 and 3). For both age and gender, the G^2 test was significant, suggesting a rejection of the invariance hypothesis ($p < 0.05$) and the need to consider separate analyses (the structure of the classes differ slightly between genders and age groups). For gender × age, invariance was not rejected (*p*-value = 0.15): the structures of the three classes may be considered identical across the four groups. However, in our sample of 550 individuals split in four gender × age groups and three classes by group, this test may have limited power, and the invariance assumption may be considered very strong. Nevertheless, if invariance holds, according to Collins and Lanza (2010, pp. 169–170), this model has to be equivalent to the one obtained with gender × age-group as a covariate. This was confirmed by the almost perfect agreement between the two (Kappa = 0.986, 95% CI = (0.972–0.997)). This model with invariance is more parsimonious, has a better fit (lower AIC (Akaike information criterion) and BIC) and a better stability than the one without equivalence. As gender and age are strong determinants of cannabis use, as *daily use of cannabis*, *having thought about seeking help* and *family or work problems* are also determinants of cannabis problematic use, we chose to add these variables as covariates in the baseline model to build our final model. In this latter, three BVR were above 3.84: *daily use of cannabis* and *Hazardous use* (BVR = 9.06), *having thought about seeking help* and *Impaired control* (BVR = 7.73) and *Hazardous use* and

Impaired control (BVR = 5.39). In order to account for these excessive residual associations that were not explained by the models, the local independence assumption between the corresponding items was relaxed by adding a direct effect between these variables that led to a slightly better likelihood and a better stability.

We checked that the final classification was close to: (1) the one resulting from the baseline model, which does not consider any covariates: Kappa = 0.841, 95% CI = (0.800; 0.884); (2) the one considering gender × age-group (and the other covariates) as a covariate without the direct effect (Kappa = 0.907, 95% CI = (0.875; 0.942)).

It was possible to order the three classes finally obtained on a continuum according to the number of DSM-IV-related symptoms (Figure 1). The largest class ($n = 336$, 61.1% of the sample), hereafter termed *non-symptomatic*, consists of respondents meeting rarely an abuse diagnosis and showing very low scores in the number of abuse and dependence criteria (Table 5). In the second ($n = 181$, 32.9%), the *moderate* class, 40.9% of respondents meet an abuse diagnosis and 21.0% a dependence diagnosis. The mean number of criteria in this class is moderate (0.57 for abuse, 1.70 for dependence, 2.27 in total). In the smallest *severe* class ($n = 33$, 6.0%), 93.6% are diagnosed dependent, with high mean numbers of abuse and dependence criteria (1.63 and 4.88, respectively). The CAST scores are 1.08 in the *non-symptomatic* class, 5.46 in the *moderate* class and 11.15 in the *severe* class. The proportions of respondents that had thought about asking for help for their cannabis use, or had reported family or work problems due to their cannabis use, are coherent with the three ordered classes. Almost all the Chi-square and mean tests comparing *non-symptomatic* and *moderate* on the one hand, *moderate* and *severe* on the other hand, were significant (with the exception of alcohol use, tobacco and daily cannabis use indicators between *moderate* and *severe*). The proportion of men is larger in the *moderate* and *severe* classes compared to the *non-symptomatic* class and the mean age is lower in the *moderate* and *severe* classes.

Criterion validity

Table 6 shows that on the basis of the Youden Index, the optimal cutoff was three for CUD and five for dependence. The AUC were good for both CUD (AUC = 0.851, 95% CI = (0.814–0.887)) and dependence (AUC = 0.868, 95% CI = (0.823–0.913)) and so were sensitivity (Se) and specificity (Sp) (Se = 80.5, Sp = 74.9 for CUD; Se = 81.2, Sp = 79.0 for dependence). False positive and false negative rates are fairly high for CUD (25.1% and 19.5%) and dependence (21.0% and 18.8%). Among the false positives for dependence ($n = 101$), 45.5% were daily cannabis smokers, 64.4% experienced another illicit drug, 17.8% experienced family or work problems because of their cannabis use, 18.8% thought about seeking help, and 59.3% endorsed two or more DSM-IV criteria (additionally, 78.2% were classified as having *moderate/severe* symptoms). Among the false negatives for dependence ($n = 13$), 84.6% ($n = 11$) had three dependence criteria and 61.5% ($n = 8$) had three DSM-IV criteria (and all were classified as *moderate*).

When compared to the empirical latent classes the thresholds are three for *moderate/severe* and eight for severe (seven being also acceptable). The AUC was good for *moderate/severe* (AUC = 0.869, 95% CI = (0.837–0.900)) and excellent for *severe* (AUC = 0.952, 95% CI = (0.933–0.971)). Sensitivity and specificity for these thresholds were also well balanced: 77.6 and 82.1, respectively, for *moderate/severe* and 93.9 and 89.0, respectively, for *severe*. The proportions of false positives and false negatives were fairly high for *moderate/severe* (17.9% and 22.4%, respectively) but fairly low for *severe* (11.0% and 6.1%, respectively). Among the false positive for severe ($n = 57$), 57.9% were daily cannabis smokers, 70.2% experienced another illicit drug 15.8% experienced family or work problems because of their cannabis use, 21.0% thought about seeking help, 53.3% endorsed two or more dependence criteria and 75.4% endorsed two or more DSM-IV criteria.

As a sensitivity analysis, we checked that: (1) the description of the latent classes were almost unchanged when considering either the three-classes basic model or the three classes model with covariates but no direct effect, and (2) that the thresholds for the CAST were unchanged in these situations (i.e. three and seven or eight).

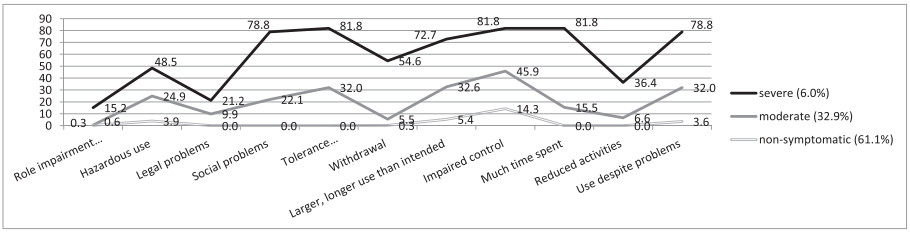

Figure 1. Items endorsement in latent classes (%).

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Table 5. Description of the latent classes (column %, means and standard deviation, SD)

	Non-symptomatic $N=336$ (61.1%)	Moderate $N=181$ (32.9%)	Severe[a] $N=33$ (6.0%)	Diff[b] moderate/non-symptomatic	Diff[c] moderate/severe
External variables					
DSM-IV diagnoses (%)					
CUD	4.2	61.9	100.0***	***	***
Abuse	4.2	40.9	6.1***	***	***
Dependence	0.0	21.0	93.9***	***	***
Number of abuse criteria					
Mean	0.04	0.57	1.63***	0.53***	1.06***
(SD)	(0.20)	(0.66)	(1.02)	(0.42)	(0.73)
Number of dependence criteria					
Mean	0.23	1.70	4.88***	1.47***	3.17***
(SD)	(0.43)	(1.05)	(1.38)	(0.71)	(1.10)
Total number of DSM-IV criteria					
Mean	0.28	2.27	6.51***	2.00***	4.24***
(SD)	(0.47)	(1.13)	(1.82)	(0.77)	(1.26)
CAST score					
Mean	1.08	5.46	11.15***	4.38***	5.69***
(SD)	(1.89)	(3.90)	(2.98)	(2.76)	(3.78)
At least four episodes of alcohol use per week (%)	13.4	23.8	27.3**	***	ns
Weekly binge drinking (6+ standard glasses) (%)	17.6	26.5	33.3*	*	ns
Daily tobacco smoking (%)	61.9	80.1	90.9***	***	ns
Daily cannabis use last month (%)	0.0	34.8	48.5***	***	ns
Thought about seeking help (%)	0.0	12.9	42.4***	***	***
Family or work problems due to cannabis (%)	0.3	14.9	72.7***	***	***
Any other illicit drug use in life	43.8	61.3	72.7***	***	ns
Males (%)	58.3	81.8	75.8***	***	ns
Age					
Mean	30.12	27.45	24.07***	2.67**	3.37*
(SD)	(11.11)	(8.52)	(5.83)	(10.42)	(8.20)
15–24 years old	40.2	42.0	63.6 *	ns	*
25+ years old	59.8	58.0	36.4		

[a]Chi-square *p*-value for percentages and *F*-test *p*-values for means respectively:
*$p<0.001$, **$p<0.01$, ***$p>0.05$ when comparing the three latent classes.
[b]Diff: *p*-value for Chi-square or mean (SD) differences between *moderate* and *non-symptomatic*: *$p<0.05$, **$p<0.01$, ***$p<0.001$, ns, not significant.
[c]Diff: *p*-value for Chi-square or mean (SD) differences between *moderate* and *severe*: *$p<0.05$, **$p<0.01$, ***$p<0.001$, ns, not significant.

Discussion

Summary of the findings

This study is the first assessing the structure of the DSM-IV and validating the CAST in the general population. The internal structures of the CAST and the DSM-IV were found unidimensional (although a solution with two correlated factors had higher fit for the CAST) and the LCA structure of the DSM-IV was not invariant for age and gender (invariance for gender × age is not certain because of the sample size). Taking this latter finding into account, a three-class typology of cannabis users based on the DSM-IV criteria ordered individuals along a continuum of problems: *non-symptomatic* (61.1% of the

Table 6. Screening properties of the CAST against theoretical and empirical standards (%)

	Se	Sp	PPV	NPV	FPR	FNR	Correct	$Y = Se + Sp - 1$
DSM_IV CUD								
1	90.6	56.8	46.0	93.7	43.2	9.4	66.5	47.3
2	88.1	67.3	52.2	93.3	32.7	11.9	73.3	55.3
3	*80.5*	*74.9*	*56.6*	*90.4*	*25.1*	*19.5*	*76.5*	*55.4*
4	74.8	80.3	60.7	88.7	19.7	25.2	78.7	55.1
5	66.7	87.0	67.5	86.5	13.0	33.3	81.1	53.6
6	59.1	91.0	72.9	84.6	9.0	40.9	81.8	50.2
DSM_IV dependence								
1	95.7	48.6	21.1	98.7	51.4	4.3	54.5	44.3
2	92.8	57.6	23.9	98.2	42.4	7.2	62.0	50.3
3	87.0	65.5	26.5	97.2	34.5	13.0	68.2	52.4
4	87.0	71.7	30.6	97.5	28.3	13.0	73.6	58.7
5	*81.2*	*79.0*	*35.7*	*96.7*	*21.0*	*18.8*	*79.3*	*60.2*
6	75.4	84.0	40.3	96.0	16.0	24.6	82.9	59.4
7	68.1	87.7	44.3	95.0	12.3	31.9	85.3	55.8
8	62.3	90.6	48.9	94.4	9.4	37.7	87.1	53.0
Latent class Moderate/severe								
1	88.8	63.4	60.7	89.9	36.6	11.2	73.3	52.2
2	72.8	74.7	49.4	89.0	25.3	27.2	74.2	47.5
3	*77.6*	*82.1*	*73.5*	*85.2*	*17.9*	*22.4*	*80.4*	*59.7*
4	71.5	87.2	78.1	82.8	12.8	28.5	81.1	58.7
5	63.1	93.5	86.0	79.9	6.5	36.9	81.6	56.5
6	54.7	96.4	90.7	77.0	3.6	45.3	80.2	51.1
Latent class Severe								
1	100.0	45.8	10.5	100.0	54.2	0.0	49.1	45.8
2	100.0	54.5	12.3	100.0	45.5	0.0	57.3	54.5
3	100.0	62.7	14.6	100.0	37.3	0.0	64.9	62.7
4	100.0	68.5	16.8	100.0	31.5	0.0	70.4	68.5
5	100.0	76.0	21.0	100.0	24.0	0.0	77.5	76.0
6	100.0	81.4	25.6	100.0	18.6	0.0	82.5	81.4
7	*97.0*	*85.7*	*30.2*	*99.8*	*14.3*	*3.0*	*86.4*	*82.7*
8	*93.9*	*89.0*	*35.2*	*99.6*	*11.0*	*6.1*	*89.3*	*82.9*
9	78.8	91.7	37.7	98.5	8.3	21.2	90.9	70.5

Note: Se, sensitivity; Sp, specificity; PPV, positive predictive value; NPV, negative predictive value; FPR, false positive rate; FNR, false negative rate; Correct, percentage of correctly classified individuals.

sample), *moderate* (32.9%) and *severe* (6.0%). Empirical cutoff points for the CAST in reference to CUD and dependence (three and five, respectively) and in reference to the latent *moderate/severe* and the *severe* classes (three and eight, respectively) were identified. We checked that this classification and the CAST thresholds are robust to various LCA modelling hypotheses.

The prevalence rates for CUD, dependence, *moderate/severe* or *severe* symptoms among individuals scoring positive were relatively low. This was expected because PPV is linked to the prevalence of the disorder (Murphy *et al.*, 1987) and inevitable in samples from the general population (Altman and Bland, 1994). The false positive rates showed that the CAST overestimated the real prevalence of DSM-IV diagnoses. However, a substantial proportion of these false positive individuals met two or more DSM-IV criteria and might need clinical attention (Degenhardt *et al.*, 2008).

Comparison with other CAST validations

The internal structure of the CAST was found bidimensional: the first factor refers to non-recreational use (*smoking alone*, *smoking before midday*), the second is related to associated problems (although a unidimensional solution is acceptable), with a high correlation between the

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two. This corroborates previous studies among young adults in Spain (Cuenca-Royo *et al.*, 2012; Fernandez-Artamendi *et al.*, 2012). Studies among French adolescents (Legleye *et al.*, 2013) or Hungarian pupils and students (Gyepesi *et al.*, 2014) found a unidimensional structure. Overall, the internal structure in adults or young adults seems thus rather robust.

Using the DSM-IV as gold-standard, the present study found higher CAST cutoff points for screening CUD (three versus two) and dependence (five versus three) than in French adolescents (Legleye *et al.*, 2011), despite similar discriminating power indexes (Youden Index and AUC), suggesting that the theoretical construct of dependence is not totally robust if age is considered. Lower cutoffs for CUD and dependence (namely two for each) as measured by the M-CIDI were also found in Hungary (Gyepesi *et al.*, 2014): as acknowledged by the authors, this may reflect the lower prevalence of cannabis use and specific historical and cultural facts in Hungary. Compared to a similar study in Spain (Cuenca-Royo *et al.*, 2012), the thresholds for CUD and dependence were lower in this study (three versus nine, five versus 12, respectively). This may be due to differences in sampling (volunteer versus random), age range (18–25 versus 15–64), and implementation of the DSM-IV criteria (PRISM versus M-CIDI) or the fact that cannabis use is more prevalent in Spain.

When using LCA to build an empirical DSM-derived gold standard, the optimal thresholds for screening individuals with *moderate/severe* and *severe* symptoms in this study (respectively three and seven or eight) were identical to those found in adolescents (Legleye *et al.*, 2013). This result is noteworthy because the *severe* class was smaller in the general population (6.0%) than in adolescents (9.0%), reflecting differences in patterns of cannabis use with age (Chung *et al.*, 2004; EMCDDA, 2011). We also found a similar three-class latent structure of the M-CIDI.

Age, gender and gender × age invariance of the DSM

The sensitivity of the DSM-IV to gender was found by the rejection of the invariance test. It has already been observed among adolescents (Martin *et al.*, 2006; Piontek *et al.*, 2011) and adults (Grant *et al.*, 2006). In our final latent model, differences between men and women for the prevalence of some DSM-IV abuse criteria were reflected in the higher proportion of females in the *severe* class compared to in the *moderate* class. The results also showed some sensitivity to age by the rejection of the invariance test. In the final model, the mean number of endorsed criteria also decreased with age, young users being overrepresented in the *severe* class, although modestly. This robustness to age has also been reported in an Australian study, where *Hazardous use* was the only DSM-IV criterion functioning differently in 18–24 year-olds and older cannabis users (Mewton *et al.*, 2010). Finally, we found that the DSM-IV may be invariant for gender × age but a larger sample size would be necessary to confirm this finding.

Comparison with the DSM-5

By the time of the survey design, the DSM-5 was not published and we were forced to use the DSM-IV. However, in line with the DSM-5, which considers the sum of criteria representing a severity continuum (Regier *et al.*, 2013), the present study confirmed the unidimensional structure of the DSM-IV found in earlier studies among French adolescents aged 17 (Piontek *et al.*, 2011; Legleye *et al.*, 2013). The mean number of DSM-IV criteria were 2.27 (SD = 1.13) for the *moderate* class and 6.51 (SD = 1.82) for the *severe* class. These means are similar to the corresponding cutoffs for "mild disorder" (2–3) and "severe disorder" (6+) as defined in the DSM-5. There is no latent class that would correspond to the "mild disorder" (4–5) but the LCA model for four classes had a significant lower fit than the three-class solution (Table 4). Such a difference may be due to the sample or to the use of DSM-IV criteria.

Limitations

The evaluation of both substance use and substance-related problems was based on CATI questionnaires. Face-to-face interviews may be preferred over telephone interviews for diagnostic interviews, but are hardly feasible in population surveys. However, responses to sensitive topics in the presence of interviewers may be subject to the social desirability bias (De Leeuw *et al.*, 2008), but as the reliability and validity of the M-CIDI have been established for computer assisted face-to-face interviews (Lachner *et al.*, 1998), the potential bias should be even lower in telephone interviews. The CIDI itself was studied in various settings and found satisfactory (Wittchen, 1994; Haro *et al.*, 2006; Kessler *et al.*, 2009). Because of the cross-sectional study design, there was no information available on the test–retest reliability of the CAST. Furthermore, it has been found to be high (Cuenca-Royo *et al.*, 2012) or excellent (Bastiani *et al.*, 2013) in adolescent or young adult populations. Last, the final LCA model of the DSM-IV includes covariates and assumes gender × age invariance, although it was not achieved for age and gender respectively. A simpler model with fewer assumptions might be preferred. However, the

comparison of the results of various modelling hypotheses with or without covariates and age or gender invariance indicated the robustness of our approach.

Future work

This study suggests that the CAST can serve as a screening test in general as well as adolescent populations with similar psychometric properties and with the same cutoffs. Nevertheless, more research is needed to validate the CAST with the DSM-5 and to assess its cross-cultural invariance in order to enhance cross-national comparisons.

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