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RESEARCH REPORT

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Behavioral economics indices predict alcohol use and consequences in young men at 4-year follow-up

Jacques Gaume[1] | James G. Murphy[2] | Joseph Studer[1] | Jean-Bernard Daeppen[1] | Gerhard Gmel[1] | Nicolas Bertholet[1]

[1]Department of Psychiatry—Addiction Medicine, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland
[2]Department of Psychology, University of Memphis, Memphis, TN, USA

Correspondence
Jacques Gaume, Department of Psychiatry—Addiction Medicine, Lausanne University Hospital, Rue du Bugnon 23, 1011 Lausanne, Switzerland.
Email: jacques.gaume@chuv.ch

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Abstract

Background and Aims: The alcohol purchase task (APT), which presents a scenario and asks participants how many drinks they would purchase and consume at different prices, generates indices of alcohol reward value that have shown robust associations with alcohol-related outcomes in numerous studies. The aim was to test its prospective validity at 4-year follow-up.

Design: Prospective cohort study.

Setting: General population sample of young Swiss men.

Participants: A total of 4594 Swiss young men (median age = 21, 25th - 75th quartiles = 20.5 - 21.5) completed baseline questionnaires; among those, 4214 (91.7%) were successfully followed-up 4 years later.

Measurements: Alcohol reward value parameters (i.e. intensity, the planned consumption when drinks are free; breakpoint, the price at which consumption would be suppressed; O_{max}, the maximum alcohol expenditure; P_{max}, the price associated with O_{max}; and elasticity, the relative change in alcohol consumption as a function of the relative change in price) were derived from the APT at baseline and used to predict self-reported weekly drinking amount, monthly binge drinking, alcohol-related consequences and DSM-5 alcohol use disorder criteria.

Findings: Regression analyses, adjusting for the baseline alcohol measure, age, linguistic region and socio-economic indicators showed that intensity, breakpoint, O_{max} and elasticity significantly predicted all tested outcomes in the expected direction (e.g. standardized incidence rate ratio [95% confidence interval] = 1.11 [1.07–1.15], 1.07 [1.03–1.10], 1.08 [1.04–1.11], and 0.92 [0.89–0.95], respectively, for weekly drinking amount, all $P < 0.001$). P_{max} did not significantly predict any outcomes. Non-adjusted correlations, baseline adjusted regression and ancillary analyses using (1) latent alcohol variables, (2) multiple imputation for missing data and (3) replications in training and testing subsamples to evaluate predictive accuracy provided consistent findings.

Conclusions: The alcohol purchase task demand curve measures of alcohol reward value are useful in characterizing alcohol-related risk in young men and have long-term predictive utility.

KEYWORDS
Alcohol purchase task, alcohol reward value, alcohol use disorder criteria, alcohol-related consequences, behavioral economics, long-term predictive utility, prospective cohort study

INTRODUCTION

The alcohol purchase task (APT) is a behavioral economic hypothetical choice task that asks participants how many drinks they would purchase and consume across a range of drink prices [1]. Studies using the APT and laboratory observations of drinking in relation to price have demonstrated a clear relationship wherein consumption decreases as a function of price increases, consistent with the economic law of demand [2–4]. The characteristic form of the decelerating function, also known as the demand curve, has been replicated across individuals and the specific values of the curve parameters (e.g. intercept, slope, acceleration) have demonstrated important individual differences that are linked to alcohol problem severity [2]. By plotting consumption and expenditures across a range of prices, the APT captures individual differences in maximum desired consumption, maximum expenditure and sensitivity of consumption level to change in price. These APT parameters reflect elements of the reinforcing value of alcohol that may provide information on alcohol problem severity and likelihood of change that is not redundant with existing indices of recent consumption and alcohol problems [5,6]. Importantly, although the hypothetical APT generates stable and reliable estimates of demand, these estimates can change in response to contextual events including treatment, and the APT thus has potential utility as a marker of change in alcohol reward value [6–8].

A recent meta-analysis (k = 50 studies; n = 18 466) found that alcohol demand indices were significantly associated with alcohol use (weekly and heavy episodic drinking) and problems, with the most robust (moderate to large effect size) associations occurring for indices of maximum consumption when drinks are free (demand intensity) and maximum overall alcohol expenditure (O_{max}) [5]. Fewer studies have tested the predictive validity of APT indices. Three studies suggested that APT indices significantly predict weekly drinking and/or alcohol problems up to 6 months after college student drinkers completed a brief alcohol intervention [6–8]. To our knowledge, however, no study has tested the long-term predictive validity of APT indices outside a treatment context or with general adult (non-college) samples.

In a prior study [9], our group administered the APT to a large sample (n = 4790) of young men aged 21 years from the general population in Switzerland who reported drinking in the past year. Demand curves were estimated and showed that, as expected, alcohol demand decreased as drink price increased. APT indices were correlated with measures of alcohol use, alcohol-related consequences and alcohol use disorder criteria. In the present study, we used these APT indices to predict alcohol outcomes 4 years later. This period, from ages 21 to 25 years, is especially critical, given that it reflects the developmental apex of alcohol risk and a point that often demarcates age-limited versus developmentally persistent heavy drinking. The present study evaluated the central yet heretofore untested behavioral economic assumption that elevated demand measured during the early stage of this critical developmental juncture will predict drinking levels and related problems over time.

METHODS

Sample

Data were drawn from the Cohort Study on Substance Use Risk Factors (C-SURF, see https://www.c-surf.ch/), a longitudinal study on substance use among Swiss young men [10]. All young men at three of six army conscription centers, covering 21 of the 26 Swiss cantons, were invited to participate between 23 August 2010 and 15 November 2011. Army conscription is mandatory for all Swiss males at age 19 years to determine their eligibility for military or civil service. This population is therefore largely representative of Swiss young men of that age in the general population. Participants were men only; women are allowed to join the military service on a voluntary basis, but were not included in the present study due to their scarcity.

Participants were informed about the study goals and procedures by trained research staff, reassured that the research staff had no connection with the army and that all information would be kept confidential, and asked to provide informed consent and contact details to receive further questionnaires. Study procedures were approved by the Ethics Committee for Clinical Research of the University of Lausanne Medical School (Protocol no. 15/07). Participation was independent of whether or not conscripts had to serve in the army. Within 2 weeks after enrolment, participants were invited by postal mail or e-mail to complete the first cohort study questionnaire. A second questionnaire, which comprised baseline alcohol demand, alcohol use and demographic measures used in the present study, was sent to participants 15 months after the first assessment and was completed between March 2012 and January 2014. A third questionnaire, which comprised follow-up alcohol measures used in the present study, was sent to participants 4 years after the second assessment and was completed between April 2016 and March 2018. Participants were included in the present analysis if they completed the APT and alcohol measures in the second questionnaire and alcohol measures in the third questionnaire. We further refer to these questionnaires as baseline and 4-year follow-up questionnaires.

Measures

The cohort study questionnaires were self-reported on-line or paper-and-pencil questionnaires (according to the participant preference, approximately 80% preferring on-line).

Alcohol purchase task

The APT, adapted from Murphy & MacKillop [1], was included in the baseline questionnaire [9]. In this task, we presented a scenario and asked participants how many drinks they would purchase and consume at 11 different prices ['Imagine you are in a situation where you usually drink alcohol (at a bar, at a party, at home, etc.). You did not drink alcohol beforehand nor will you go to have a drink elsewhere afterwards. How many drinks would you have if each drink was free/50cts/1, 2, 3, 4, 6, 8, 10, 15, 20 Swiss francs?']. An illustration was provided to define standard drinks, i.e. 1 dl of wine, 2.5 dl of beer, one mixed drink or 2 cl of strong liquor (∼10 g of ethanol). At the time of data collection, one Swiss franc was equivalent to $US 1.1, £UK pound 0.7 or € (euro) 0.8. The APT has good test–retest reliability [11], and strong associations have been observed between hypothetical drink purchases and subsequent laboratory-based actual purchases [12]. As described in Bertholet *et al*. [9], five indices were derived from the APT: (1) intensity, i.e. planned consumption when drinks are free; (2) break-point, i.e. price at which consumption would be suppressed; (3) O_{max}, i.e. maximum alcohol expenditure; (4) P_{max}, i.e. the price associated with O_{max} which also corresponds to the price at which demand became elastic (see next point); and (5) elasticity, i.e. the relative change in alcohol consumption as a function of the relative change in price across the entire 11 price points (demand relatively sensitive to changes in price is referred to as elastic; demand relatively insensitive as inelastic). Demand curves were fitted according to Hursh & Silberberg [13].

Alcohol measures

Alcohol use and related consequences were measured at baseline and 4-year follow-up. All measures were framed in the last 12 months; the same illustration as for the APT was provided to define standard drinks. Weekly drinking amount (i.e. usual number of drinks per week) was estimated by multiplying typical number of drinking days per week by typical number of drinks per drinking day. Heavy drinking was measured as having or not having heavy drinking episodes (six drinks or more in a single episode) on a monthly basis (yes/no). Alcohol-related consequences were measured using a nine-item questionnaire [13] commonly used to assess the occurrence of a series of typical alcohol-related consequences among young adults (e.g. argue with friends, engage in unplanned sexual activity, get into trouble with police) [14,15]. The number of positive responses was summed providing a possible range of 0–9. Finally, we measured the number of DSM-5 alcohol use disorder criteria (0–11 criteria). Criteria were assessed with specific questions adapted from the semi-structured assessment for the genetics of alcoholism [16,17] to elicit self-reporting of DSM-5 alcohol use disorder criteria [18].

Baseline covariates

As differences in alcohol use exist as a function of age and linguistic region (French-speaking versus German-speaking) in Switzerland [19], analyses were adjusted for these variables. Of note, age was 21 at baseline and 25 at follow-up for most participants, but there was nevertheless some variability, as young men can ask to bring forward or postpone mandatory army conscription procedures (see Table 1).

We used three indicators to control for individual economic status. We first evaluated how participants estimated the financial situation of their family compared to the average Swiss situation ('How well off is your family compared to other families in your country?'). Responses were provided on a seven-point scale from 'very much better off' to 'very much less off' and were recoded as 'better off', 'about the same' and 'less well off'. Secondly, we evaluated whether the participants covered their own life expenses by themselves (three categories: totally, partially or not, i.e. life expenses covered by parents, grant or social welfare). Thirdly, we evaluated how the participants estimated their own wages (please indicate to what extent you agree or disagree with the following statement: 'My wages are good'). Responses were provided on a five-point scale from: 'I strongly disagree' to 'I agree strongly' and were recoded as 'agreed' or 'not agreed'. A third category was computed to consider participants not having wages (i.e. studying or unemployed). These three indicators were entered as dummy-coded variables.

Statistical analyses

We first computed descriptive statistics for APT indices, as well as baseline and follow-up alcohol measures. Continuous variables were described using percentiles, as data were not normally distributed. We then computed cross-sectional correlations between APT indices and alcohol measures at baseline and prospectively at 4-year follow-up. We used Spearman's rank correlation for continuous variables by continuous variables and point-biserial correlation coefficients for continuous variables by dichotomous variables. Then, we tested the predictive value of APT indices at baseline on alcohol measures at 4-year follow-up, while controlling for baseline alcohol measure (i.e. baseline adjustment) in regression models. We computed one regression model per APT index and alcohol measure (i.e. five APT indices × four alcohol measures = 20 models). We repeated all models while adjusting for potential confounding variables, i.e. age, linguistic region and economic indicators (see Measures, above). We used negative binomial regression for weekly drinking amount,

TABLE 1 Alcohol purchase task indices and alcohol measures descriptive statistics.

	10th pct	25th pct	Median	75th pct	90th pct
Alcohol purchase task indices					
Intensity	3	5	8	10	17
Breakpoint	8	10	20	20	20
O_{max}	8	16	24	45	66
P_{max}	3	4	6	10	15
Elasticity	0.001	0.002	0.003	0.007	0.014
Baseline alcohol variables					
Weekly drinking amount	1	2	6	13	21
Heavy drinking episodes: Monthly (*n*, %)	2177	51.8			
Less often (*n*, %)	2030	48.3			
Alcohol-related consequences (0–9 scale)	0	0	1	2	4
Number of DSM-5 criteria (0–11 scale)	0	0	1	2	4
Follow-up alcohol variables					
Weekly drinking amount	0	2	5	11	18
Heavy drinking episodes: Monthly (*n*, %)	2468	58.6			
Less often (*n*, %)	1742	41.4			
Alcohol-related consequences (0–9 scale)	0	0	1	2	3
Number of DSM-5 criteria (0–11 scale)	0	0	1	2	3
Socio-economic covariates					
Age (years)	20	20.5	21	21.5	22.5
Linguistic region: French-speaking (*n*, %)	2194	52.5			
German-speaking (*n*, %)	1982	47.5			
Financial situation:[a] Less well off (*n*, %)	523	13.0			
About the same (*n*, %)	1639	40.6			
Better off (*n*, %)	1872	46.4			
Cover own life expenses: Partially (*n*, %)	999	23.7			
Totally (*n*, %)	1768	42.0			
Not (*n*, %)[b]	1442	34.3			
'My wages are good': Not agreed (*n*, %)	1408	33.5			
Agreed (*n*, %)	1287	30.6			
No wages (*n*, %)[c]	1511	35.9			

DSM, Diagnostic and Statistical Manual of Mental Disorders; O_{max}, maximum response output (maximum alcohol expenditure); pct, percentile; P_{max}, price at which maximum response output is predicted.
[a]Financial situation of participant's family compared to the average Swiss situation;
[b]life expenses covered by parents, grant or social welfare;
[c]participants studying or unemployed.

alcohol-related consequences and number of DSM-5 AUD criteria, as data were over-dispersed. For monthly heavy drinking episodes, we used robust Poisson regression, as the outcome was dichotomous and common. Robust Poisson regression with dichotomous outcomes allows estimation of the risk ratio (RR) [20]. *P*-values were adjusted for multiple testing using Dubey/Armitage–Parmar Sidak method [21] as implemented in the SISA on-line calculator [22] specifying 20 tests, alpha = 0.05 and r = 0.53 (i.e. mean correlation between dependent/independent variables).

In addition, we used structural equation modeling (SEM) to test the four alcohol measures in a latent variable. Indeed, these are correlated, and evaluating them in separate models might result in

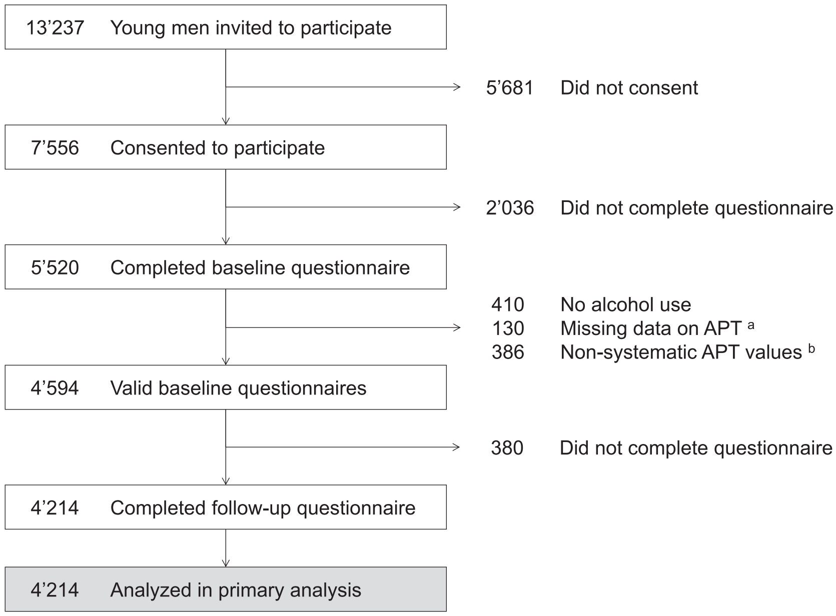

FIGURE 1 Recruitment flow diagram. [a]Missingness patterns: *n* = 68 with all 11 alcohol purchase task (APT) items missing; among the remaining (*n* = 62), median number of missing items was 3.5 (interquartile range: 2–7) and median number of missing values per item was 39.5 (interquartile range: 36–41). [b]Non-systematic APT data were assessed based on guidelines and detection limits suggested by Stein *et al.* [27]. There were *n* = 338 non-systematic data on the Trend criterion, *n* = 51 on the Bounce criterion, *n* = 91 on the Reversal to Zero criterion, and *n* = 386 with any criterion.

predicting at least some portion of common variance. One SEM was built for each APT index. Models were built using two latent variables, one for the four alcohol measures at follow-up (dependent variable) and one for these measures at baseline (covariate). Standardized estimates and 95% confidence intervals (CIs) were estimated using Mplus version 8.3 [23].

Attrition analyses were computed to explore potential differences between participants followed-up and lost to follow-up. APT indices and baseline alcohol measures were compared using non-parametric tests (Wilcoxon's rank-sum test for continuous variables and Pearson's χ^2 test for categorical variables). In addition, we repeated the primary analysis using multiple imputation [24] for missing data. We used multivariate imputation using chained equations in Stata BE version 17.0 [25] with 10 imputations, and distributions similar to those in the primary analysis (i.e. negative binomial or binomial).

An additional ancillary analysis was computed to estimate the added value of APT indices and how well the APT indices predict subsequent alcohol use. To do so, we calculated measures of predictive accuracy [i.e. mean absolute error (MAE) and mean squared error (MSE) for continuous outcomes; area under the receiver operating characteristic curve (AUROC) for dichotomous outcome] for models with and without the relevant APT-based index [26]. We calculated these measures 'out-of-sample' because evaluating predictive accuracy in the sample used to estimate the prediction can result in over-fitting. The full sample was randomly separated into an estimation/training sample (80% of the full sample) and an evaluation/test sample (20%). Negative binomial models were estimated in the training sample, and MAE and MSE were then evaluated in the test sample using the 'predict' function in Stata BE version 17.0 [25]. AUROC were tested in the same way after logistic regression models using the 'estat classification' and 'lroc' functions.

Because participants were invited to enroll into the study at different conscription centers, we replicated analyses using mixed models with random intercept by centers. All findings were similar with all models showing no effect of centers. These analyses are not reported for parsimony.

This study's analyses were not pre-registered, and the results should be considered exploratory.

RESULTS

Recruitment flow is presented in Fig. 1. Descriptive statistics for APT indices, baseline and follow-up alcohol measures, as well as socio-demographic indicators are presented in Table 1. Demand curves were described elsewhere [9]; exponential equation provided a satisfactory fit to individual responses (mean $R^2 = 0.79$, median $R^2 = 0.80$).

Correlations between APT indices and alcohol measures at baseline (i.e. cross-sectional) and at 4-year follow-up (i.e. prospectively) are presented in Fig. 2. Correlation patterns were similar across alcohol measures. Correlations were significant (Dubey/Armitage–Parmar adjusted $P < 0.012$) and moderate-to-large for intensity and O_{max}, and smaller but still significant for breakpoint and elasticity. Correlations were very small and significance inconsistent for P_{max}. Patterns were similar between cross-sectional and prospective correlations. The coefficients were nevertheless consistently smaller for 4-year follow-up measures.

Regression analyses of the 4-year follow-up alcohol outcomes, adjusting for the baseline alcohol measure, and those additionally adjusting for socio-demographic confounders, provided consistent results. For parsimony, we present only the fully adjusted models in Table 2. The only exception was breakpoint, which was significantly related with monthly heavy drinking in the fully adjusted

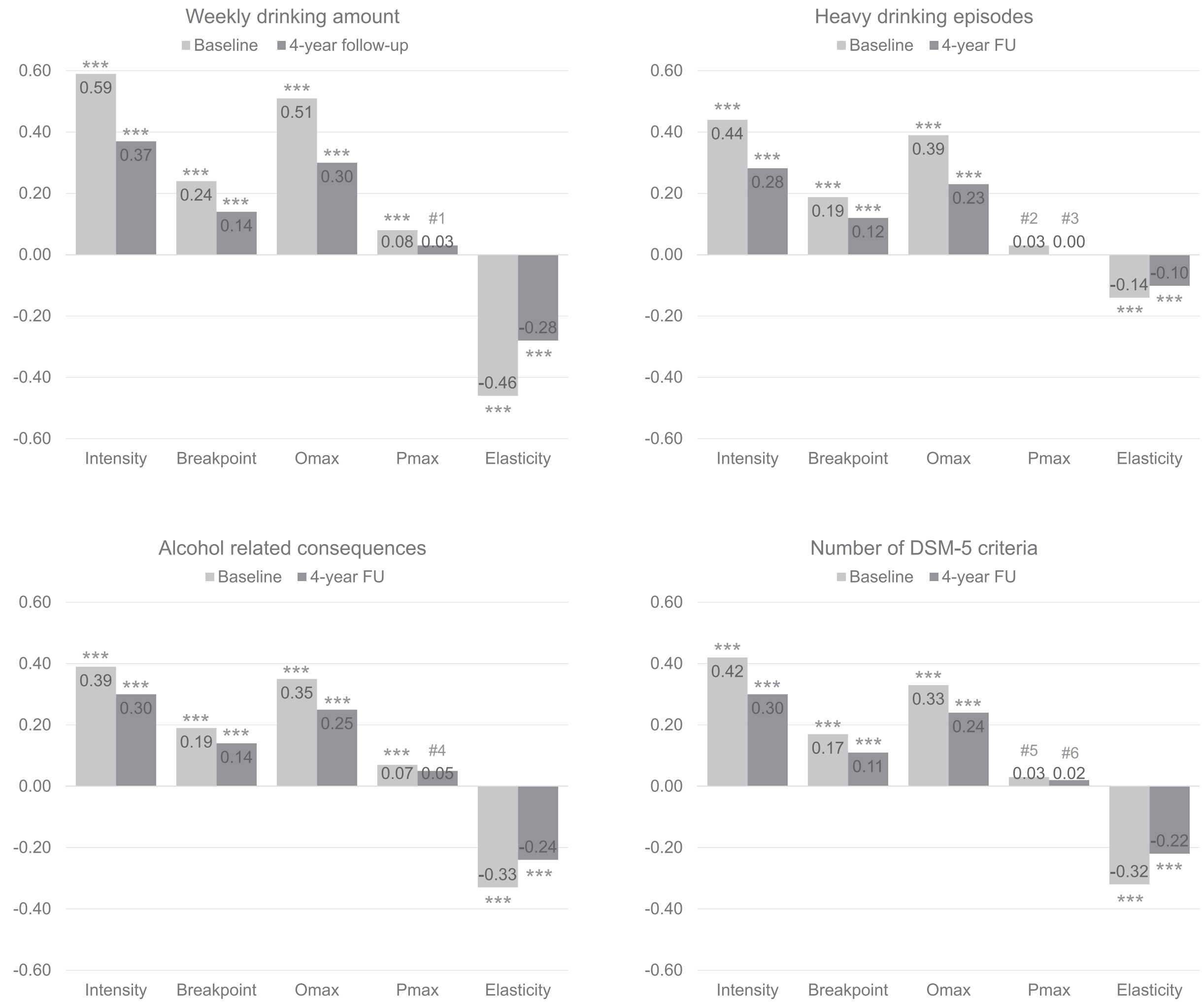

FIGURE 2 Correlation between alcohol purchase task indices and alcohol measures at baseline and 4-year follow-up. Alcohol purchase task indices were measured at baseline; n = 4214 participants with follow-up data. Spearman's rank correlation coefficients for weekly drinking amount, alcohol related consequences and number of DSM-5 criteria, point-biserial correlation coefficients for heavy drinking episodes (dichotomous, monthly versus less often). FU = follow-up; DSM = Diagnostic and Statistical Manual of Mental Disorders.***P < 0.001, #1 P = 0.06, #2 P = 0.02, #3 P = 0.82, #4 P = 0.003, #5 P = 0.04, #6 P = 0.16.

model but not in the alcohol baseline adjustment only (RR = 1.01, 95% CI = 1.00–1.01, P = 0.05). Breakpoint was significantly related with the other three outcomes. Intensity and O_{max} were significantly related with all tested outcomes. Elasticity was significantly related with all tested outcomes except monthly heavy drinking (P = 0.03). P_{max} did not significantly predict any outcomes. Effect sizes were modest. For instance, incidence rate ratio (IRR) = 1.02 indicates that planning to drink one additional standard drink when drinks are free (intensity) would be related to a weekly drinking amount 2% higher at follow-up. The corresponding standardized IRR = 1.11 indicates that an increase of 1 standard deviation (SD) in intensity would be related with a weekly drinking amount 11% higher 4 years later.

Patterns of results were similar when using SEM with alcohol latent variables (see Table 2 and full models in Supporting information, Figs S1–S5).

Attrition analyses showed that there were no statistical differences between participants followed-up and lost to follow-up on APT indices and alcohol measures (Supporting information, Table S1). When repeating the primary analysis using multiple imputation for missing data, all patterns of findings were confirmed (Supporting information, Table S2).

Ancillary analyses using train/test subsamples are presented in Supporting information, Table S3. These analyses confirmed that intensity and O_{max} had an incremental value above adjustment variables alone for all outcomes (i.e. reduced MAE and MSE, increased AUROC and narrower CIs). Consistent with the modest effect sizes noted above, errors were important and incremental value of intensity and O_{max} was of small magnitude (e.g. the mean absolute error between predicted weekly drinking amount and observed weekly drinking amount in the test sample was of 6.91 standard drinks per week when using only adjustment variables, and this error was

TABLE 2 Modeling of alcohol outcomes at 4-year follow-up on baseline APT indices

Weekly drinking amount	IRR	95% CI	Std. IRR	95% CI	P
Intensity	1.02	[1.01–1.02]	1.11	[1.07–1.15]	<0.001
Breakpoint	1.01	[1.006–1.02]	1.07	[1.03–1.10]	<0.001
O_{max}	1.002	[1.001–1.004]	1.08	[1.04–1.11]	<0.001
P_{max}	1.003	[0.997–1.009]	1.01	[0.98–1.05]	0.41
Elasticity	0.15	[0.07–0.31]	0.92	[0.89–0.95]	<0.001
Monthly heavy drinking episodes	**RR**	**95% CI**	**Std. RR**	**95% CI**	**P**
Intensity	1.01	[1.01–1.02]	1.10	[1.07–1.13]	<0.001
Breakpoint	1.01	[1.002–1.02]	1.05	[1.01–1.09]	0.009
O_{max}	1.002	[1.001–1.003]	1.07	[1.04–1.10]	<0.001
P_{max}	1.00	[0.99–1.004]	0.98	[0.95–1.02]	0.34
Elasticity	0.06	[0.005–0.72]	0.88	[0.78–0.99]	0.03
Alcohol-related consequences	**IRR**	**95% CI**	**Std. IRR**	**95% CI**	**P**
Intensity	1.02	[1.01–1.03]	1.14	[1.09–1.18]	<0.001
Breakpoint	1.01	[1.01–1.02]	1.08	[1.04–1.13]	<0.001
O_{max}	1.004	[1.002–1.005]	1.11	[1.07–1.16]	<0.001
P_{max}	1.003	[0.995–1.01]	1.02	[0.98–1.06]	0.43
Elasticity	0.11	[0.03–0.43]	0.91	[0.85–0.96]	0.002
Number of DSM-5 criteria	**IRR**	**95% CI**	**Std. IRR**	**95% CI**	**P**
Intensity	1.02	[1.01–1.02]	1.13	[1.09–1.16]	<0.001
Breakpoint	1.02	[1.01–1.02]	1.09	[1.05–1.13]	<0.001
O_{max}	1.003	[1.002–1.004]	1.09	[1.06–1.13]	<0.001
P_{max}	1.01	[0.998–1.01]	1.03	[0.99–1.06]	0.13
Elasticity	0.02	[0.004–0.08]	0.83	[0.77–0.89]	<0.001
Alcohol use and consequences latent variable	**Std. Est.**	**95% CI**			**P**
Intensity	0.38	[0.35–0.42]			<0.001
Breakpoint	0.18	[0.14–0.22]			<0.001
O_{max}	0.33	[0.29–0.36]			<0.001
P_{max}	0.04	[0.003–0.08]			0.04
Elasticity	−0.22	[-0.27–0.17]			<0.001

Note: Models are negative binomial regression for weekly drinking amount, alcohol-related consequences, and number of DSM-5 criteria, robust Poisson regression for monthly heavy drinking episodes, and structural equation modeling (SEM) for alcohol use and consequences latent variable (i.e. a latent variable constructed of the four alcohol measures). All models are controlling for baseline alcohol measure, age, linguistic region, and individual economic indicators.

Abbreviations: APT, alcohol purchase task; CI, confidence interval; DSM, Diagnostic and Statistical Manual of Mental Disorders; Est., estimate; IRR, incidence rate ratio; O_{max}, maximum response output (maximum alcohol expenditure); P_{max}, price at which maximum response output is predicted; RR, risk ratio; Std., standardized.

decreased by 0.54 standard drinks per week when including intensity in the model). Incremental value for breakpoint and elasticity was smaller and less consistent. Conversely, P_{max} had no incremental value on any outcomes.

DISCUSSION

In this study among young men from the Swiss general population, four of five APT measures were consistently correlated with alcohol use, alcohol-related consequences and number of DSM-5 AUD criteria, both cross-sectionally and prospectively 4 years later. All models and ancillary analyses indicated that the predictive validity of these measures on alcohol outcomes was robust and independent from baseline values of the outcome, age, linguistic region (i.e. French- versus German-speaking) and indicators of individual economic status.

Similar to meta-analytical findings [2,5], relatively larger correlations were found for intensity and O_{max}, followed by smaller ones for breakpoint and elasticity, and small inconsistent effects for P_{max}. In our study we observed these same patterns both cross-sectionally and prospectively, although effects were predictably weaker in the latter case, as other contextual and individual difference variables probably contributed to these long-term outcomes during the critical young adult developmental period. Statistically significant standardized IRRs indicated that an increase of 1 SD on the APT indices was related to outcomes between 7 and 17% higher (i.e. lowest significant effect: standardized IRR = 1.07 for breakpoint on weekly drinking amount; highest significant effect: standardized IRR = 0.83 for elasticity on DSM-5 criteria). Nonetheless, effects were similar in all regression and ancillary analyses.

Despite small effect sizes and limited predictive accuracy, the consistency and robustness of these findings up to 4 years later are striking. Previous indications of predictive validity of APT measures were limited to a shorter time-frame, i.e. 1 and 6 months [6] and 6 months [7,8] and to studies that evaluated brief alcohol interventions. These previous findings were also limited to specific alcohol outcomes (e.g. weekly alcohol use and heavy drinking [7] and typical alcohol use and alcohol problems [6]) and specific APT measures (e.g. intensity and O_{max} [6]). The latter studies also had inconsistent findings. For example, intensity predicted 1-month alcohol use and 6-month alcohol problems, while other tests were not significant in Murphy *et al.* [6]; breakpoint, O_{max}, P_{max} and elasticity significantly predicted weekly drinking but only breakpoint and O_{max} significantly predicted heavy drinking in MacKillop & Murphy [7]; intensity significantly predicted 6-month binge drinking and alcohol problems, but not typical drinking; and O_{max} and elasticity significantly predicted 6-month binge drinking and typical drinking, but not alcohol problems in Dennhardt *et al.* [8]). It should be noted that sample sizes were much smaller in these studies (*ns* ≤ 133) compared with our sample (*n* = 4214) and that all findings were in the expected direction based on theoretical hypotheses. Thus, the current study replicates and extends previous research by demonstrating in a large sample that alcohol demand indices predict change in drinking across a 4-year period spanning early to late emerging adulthood.

Strengths and limitations

Whereas the large sample size, long-term follow-up that spanned an important developmental period and high follow-up rate (91.7%) are noticeable strengths of the present study, it also comes with some limitations. First, the sample is limited to Swiss young men included in a prospective cohort study and being aged 21 years at baseline. Although this is a high-risk group, in that young men aged 20–24 years report higher levels of drinking than any other age or demographic group [28], our study thus does not provide indications for women, younger adolescents and older adults. Martinez-Loredo *et al.* [5] found stronger associations between demand intensity and alcohol-related outcomes (consumption and problems) in studies that included a larger proportion of women, but more robust associations between elasticity and alcohol consumption in studies with a larger proportion of men. Also related to the study design, participation rate in the C-SURF study indicates that our sample might not be representative of all Swiss men in this age range, and we were not able to model changes in drinking over time with repeated assessments. An additional limitation is that alcohol outcomes relied upon self-report, although we used established measures of alcohol use and consequences and participants were assured that their responses would be confidential and that reports of drinking would not result in any legal or military sanctions. Furthermore, recent research has suggested that the delivery/design/structure/framing of the APT may moderate the relationship between APT indices and consumption/consequences and may explain between-study variation in findings [29,30]. In this study, we described task delivery (online/paper-and-pencil), state/trait perspective, setting and number of price points. However, there were no specific instructions regarding whether participants could stockpile or share drinks, faced their usual income constraint and had a limited time to consume their purchase(s). Finally, our study was focused upon establishing the predictive utility of alcohol demand indices independently of baseline drinking and potential socio-demographic confounds. Future research is needed to evaluate relative predictive utility and potential interactions with other established predictors of drinking trajectories (e.g. family history, disinhibition, impulsivity, sensation-seeking, other drug use, alcohol use expectancies, norms, or motives), including the possibility of demand as a mediator between these risk factors and alcohol use/problems [31].

Findings' implication and conclusions

Despite these limitations, our results provide further support for behavioral economic models of addiction, which assume that alcohol consumption is price-sensitive and view elevated demand as a central feature of harmful alcohol use that is not redundant with recent drinking reports [4,5,32]. In particular, a desire to drink a larger amount in a scenario of minimal constraints (free alcohol) or a willingness to spend more on alcohol expressed on the alcohol purchase task predicts greater drinking levels by the mid-20s, a time-period where decisions about drinking are increasingly made in the context of potential impacts upon other life domains (work, graduate/professional school, family, etc.) that may be less salient at age 21, and when the cumulative effects of frequent heavy drinking may emerge. Although effect sizes are small and further research is required to establish clinical utility, the APT is a brief and convenient measure that could be administered in clinical, military, educational or health-care settings to gauge risk for drinking and need for a brief intervention. Demand intensity and O_{max} indices are the most robust predictors of alcohol outcomes and can be generated from a brief three-item APT and scored without any need for computations [33]. Importantly, previous research suggests that the APT is sensitive to acute changes in alcohol reward value in response to intervention [6–8]. Thus, the APT can be administered before and after an intervention or some other event that might be expected to change motivation to drink in order to gauge treatment outcome and guide stepped-care decisions. More generally, these results might provide support for prevention programs that increase drink price and other constraints on drinking and decrease constraints on alternatives to drinking [32, 34-38].

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DECLARATION OF INTERESTS

None.

AUTHOR CONTRIBUTIONS

Jacques Gaume: Conceptualization; data curation; formal analysis; methodology; software; supervision; validation; visualization. **James G. Murphy:** Conceptualization; data curation; formal analysis; methodology; software; supervision; validation; visualization. **Joseph Studer:** Data curation; formal analysis; methodology; project administration; validation. **Jean-Bernard Daeppen:** Funding acquisition; supervision. **Gerhard Gmel:** Conceptualization; data curation; funding acquisition; investigation; methodology; project administration; resources; supervision; validation. **Nicolas Bertholet:** Conceptualization; data curation; methodology; validation.

ORCID

Jacques Gaume https://orcid.org/0000-0002-9149-0994
James G. Murphy https://orcid.org/0000-0001-9378-8754
Joseph Studer https://orcid.org/0000-0002-1390-7707
Gerhard Gmel https://orcid.org/0000-0001-9403-9405
Nicolas Bertholet https://orcid.org/0000-0001-5064-6377

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SUPPORTING INFORMATION

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

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