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Behavioral economic and value-based decision-making constructs that discriminate current heavy drinkers versus people who reduced their drinking without treatment

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Author note: Study pre-registration, data, and analysis scripts are available and can be found on ResearchBox: https://researchbox.org/597. All authors declare no conflict of interest.

Abstract

Objective: A substantial number of people reduce their consumption of alcohol in the absence of formal treatment; however, less is known about the mechanisms of change. The aim of this study is to explore whether constructs derived from behavioral economics and computational decision-modeling characterize the moderation of alcohol consumption that many heavy drinkers experience without treatment. Method: Case-control, pre-registered design. People who reside in the United Kingdom and who drink heavily (n = 60) or used to drink heavily but now consume alcohol in moderation (n = 60) were recruited. Participants completed self-report behavioral economic measures (alcohol demand and alcohol-related and alcohol-free reinforcement), and a two-alternative forced choice task in which they chose between two alcoholic (in one block) or two soft-drink images (in a different block). A drift-diffusion model was fitted to responses from this task to yield the underlying parameters of value-based choice. Results: Compared to heavy drinkers, moderated drinkers had significantly lower alcohol demand (O_{max}, p = .03, Cohen's d = .36; elasticity, p = .03, rank-biserial correlation (r_{rb}) = .21) and higher proportionate alcohol-free reinforcement (p < .001, Cohen's d = .75). However, contrary to hypotheses, there were no robust between-group differences in VBDM parameters. Conclusions: Self-report behavioral economic measures demonstrate that alcohol moderation without treatment is characterized by lowered alcohol demand, and greater behavioral allocation to alcohol-free reinforcement, in line with behavioral economic theory. However, a computerized VBDM measure yielded inconclusive findings.

Keywords: Alcohol, Behavioral economics, Computational, Decision-making, Moderation

Public Health Significance Statement: It is common for people to reduce their consumption of alcohol, including those who consume alcohol heavily but are not dependent. This study highlights the importance of lowering alcohol demand and shifting behavioral allocation towards activities that do not involve alcohol. Findings may inform interventions for heavy drinkers who would like to moderate their alcohol consumption.

Introduction

Alcohol consumption increases the risk of ill health and premature death and is consequently a global public health concern (Degenhardt et al., 2018; Rehm et al., 2017). People often experience declines in alcohol consumption with age (Britton et al., 2015) commonly referred to as "maturing-out" (O'Malley, 2004), and most people with alcohol problems and alcohol use disorder (AUD) eventually recover, largely without treatment (Heyman, 2013; Tucker et al., 2020). Behavioral economic accounts posit that shifts in behavioral allocation away from alcohol and towards alcohol-free alternative reinforcers at least partially underlie changes in alcohol consumption (Bickel et al., 2014; Murphy, MacKillop, et al., 2012; Rachlin, 1997; Tucker et al., 2021; Vuchinich & Heather, 2003).

In behavioral economic models the primary approach to measuring strength of desire for alcohol, also referred to as alcohol reinforcing value or efficacy, is to construct an alcohol demand curve (Martínez-Loredo et al., 2021). Alcohol demand curves plot level of consumption and alcohol-related expenditures as a function of drink price and can be easily estimated with hypothetical alcohol purchase tasks (e.g., Murphy & MacKillop, 2006). Concurrent choice tasks also measure alcohol reinforcing value (e.g., Hogarth & Hardy, 2018) via a series of choices between an alcohol and alcohol-free alternative reinforcer; the percentage choice of alcohol versus alcohol-free alternative is used to index alcohol value. The value of (or demand for) alcohol is robustly positively associated with AUD symptom severity and consumption, and this has been demonstrated with both alcohol purchase tasks (Martínez-Loredo et al., 2021) and concurrent choice tasks (Hogarth & Hardy, 2018; Rose et al., 2018). Although methodologically different, both approaches capture a common construct of value as evidenced by observed correlations between the two measures (Chase et al., 2013).

These findings are consistent with molar behavioral economic accounts (Bickel et al., 2014; MacKillop, 2016; Murphy, MacKillop, et al., 2012; Rachlin, 1997; Vuchinich & Heather, 2003) which suggest that the relative degree of preference for alcohol over time is related to both the relative availability and price of alcohol as well as the relative availability and price of alcohol-free alternative reinforcers (Rachlin et al., 2018). Originating from Herrnstein's (1974) Matching Law, this is an important extension because it acknowledges, from a *final* cause perspective (Rachlin, 1992), that all behavior derives from choice between engaging in a particular behavior versus engaging in some other behavior (Rachlin et al., 2018). More specifically, that behavior must be understood by looking at temporal patterns over time within a dynamic environmental context (Rachlin, 1995; Tucker & Vuchinich, 2015). Consequently, addiction is often understood to develop over time as a 'reinforcer pathology' comprising hyper and hypo valuation of alcohol and alcohol-free alternatives, respectively (Bickel et al., 2014; Tucker et al., 2016).

An influential laboratory study by Vuchinich and Tucker (1983) found that by raising the magnitude of alternative rewards (i.e., money), this directly influenced human preference for alcohol as captured by lowered alcohol choice. Since then, measures of proportional behavioral allocation and enjoyment have been commonly used to capture the reinforcing value of alcohol relative to other reinforcers in the environment (Murphy et al., 2005). Indeed, across diverse samples and substance types (including alcohol), substance-free reinforcement is inversely related to substance use (Acuff et al., 2019; Ginsburg & Lamb, 2018). For example, a recent longitudinal study (Murphy et al., 2021) found that deprivation of environmental reward is a significant risk factor for future alcohol consumption and AUD symptomatology in young adults. Another study found that reward deficits predicted smoking

escalation longitudinally in young adults (Audrain-McGovern et al., 2011). Both the development and maintenance of addiction may therefore be explained partially by an environmental absence of competing rewarding activities and/or some reduced capacity to derive reinforcement from alcohol-free activities (Garfield et al., 2014; Higgins et al., 2004).

It is common for people to reduce their consumption of alcohol without seeking treatment (Britton et al., 2015; Dawson et al., 2005; Heyman, 2013; Tucker et al., 2020). Behavioral economic accounts (Bickel et al., 2014; Tucker et al., 2021) posit that for such behavior change to occur, the distortions in valuation processes that leave people vulnerable to addiction must be reversed such that alcohol is no longer excessively valued relative to alcohol-free alternative reinforcers. Indeed, prospective studies support the notion that shifts in behavioral allocation away from alcohol and towards alcohol-free alternative reinforcers underlie *natural* recovery[1] from AUD (Tucker et al., 2016, 2021). In line with being recognized as a core target (McKay, 2017), many efficacious treatment and brief interventions are based upon behavioral economic principles and aim to reinforce patterns of behavior that offset distortions in valuation processes (Fazzino et al., 2019). These include contingency management (Petry et al., 2017), behavioral activation (Daughters et al., 2018), and substance-free activity sessions (Murphy, Dennhardt, et al., 2012), for example. However, less is known about how valuation processes change as people who consume alcohol heavily (but who are not dependent) moderate their drinking. This study aimed to address this research question by characterizing alcohol moderation in heavy drinkers[2].

[1] In line with conceptual and empirical advances, the definition of recovery is not limited to abstinence and incorporates moderated drinking (Witkiewitz et al., 2020, 2021).
[2] We use the term 'heavy drinkers' in this study to reflect the inclusion criterion which relates to participants volume of alcohol consumption (i.e., >28 weekly UK units; 1 UK unit = 8g alcohol).

A further aim of this study was to apply recent advances in the measurement of value-based choice, specifically computational work on value-based decision-making (VBDM), to this research question. VBDM provides a framework and experimental procedure that can be used to model the internal processes that may precede observable behavioral choices, postulating that on average, people make momentary decisions guided by things that they value (Berkman et al., 2017; Levy & Glimcher, 2012; Rangel et al., 2008). Contemporary VBDM accounts (e.g., Berkman et al., 2017) posit that once possible response options have been identified (e.g., whether to consume alcohol, or whether to do something else), an overall value for each is computed as the weighted sum of diverse value input signals comprising the anticipated gains (e.g., social approval) and costs (e.g., effort). This is essential because it enables a person to compare and subsequently choose the response option with higher value (Berkman et al., 2017). Core parameters that are hypothesized to underlie value-based choice can be recovered through the application of the drift-diffusion model (DDM; Ratcliff & McKoon, 2008) to behavioral data (reaction time (RT) and accuracy) from two-alternative forced choice tasks. More specifically, the rate at which momentary value evidence is accumulated (EA rate) and how much evidence needs to be accumulated to trigger a response (response threshold) (Stafford et al., 2020). The following assumption underlies the DDM: evidence accumulates noisily until it reaches some threshold for responding, at which point that the decision is acted upon (for a review, see Ratcliff et al., 2016).

VBDM has been tentatively extended to recovery from addiction (Copeland et al., 2021; Field, Heather, et al., 2020)—inspired by Berkman et al.'s (2017) contemporary VBDM framework and informed by behavioral economic research (Bickel et al., 2014). According to this account, behavior change occurs when distortions in valuation processes (i.e., hypervaluation of alcohol and hypovaluation of alcohol-free alternative rewards) are

reversed, and this process can be attributed to alterations in the internal processes that precede discrete behavioral choices. More specifically, either in combination or isolation: suppressed EA rates for alcohol, amplified EA rates for alcohol-free alternatives, and upwards shifts in alcohol-related response thresholds. This neuroscientific account offers a molecular perspective that aligns with identification of *efficient* causes (Rachlin, 1992), but that is independent of the assumption of irrationality: choices are driven by valuation processes and reflect decision-making that may, in the moment, be contextually rational (e.g., consuming alcohol after interpersonal conflict to elevate mood or become intoxicated might maximize utility over a short temporal horizon), even if such choice is regretted subsequently and deemed irrational due to its effect of lowering utility over a longer temporal horizon (e.g., the next day). Interestingly, this introduces a solid parallel between behavioral economics and VBDM despite their respective molar and molecular perspectives: both recognize that behavior depends on the context within which it occurs. Furthermore, this approach may offer an efficient-causal explanation that can serve as the basis for observed final cause patterns of behavior over time (Rachlin, 2017). VBDM therefore offers a complementary neuroscientific extension to behavioral economics which aligns with emerging enthusiasm for interdisciplinary collaborations in the field (Acuff et al., 2022; Amlung et al., 2015) including the application of computational modeling (Bickel & Athamneh, 2020).

This study applies established self-report behavioral economic measures, alongside a computational model of VBDM, in an attempt to characterize the moderation of alcohol consumption that many heavy drinkers experience in the absence of treatment. Design, hypotheses, and analysis strategy were pre-registered[3] before data collection commenced

[3] In line with our previous research, we hypothesized group differences in response thresholds in our study protocol - but forgot to include these in our pre-registration. We still present these hypotheses but would like to ensure that we are transparent about this researcher error.

(https://aspredicted.org/dh7vp.pdf). We hypothesized that, compared to heavy drinkers, moderated drinkers will have i) lower alcohol demand and greater alcohol-free reinforcement; ii) lower EA rates and greater response thresholds for alcohol; iii) greater EA rates and lower response thresholds for soft-drinks.

Method

Design

Between-subject design. Our self-report dependent variables were alcohol demand and alcohol-free reinforcement, and our behavioral dependent variables were EA rates and response thresholds for alcohol and soft-drinks (estimated by fitting the DDM to reaction time and accuracy data during the VBDM task). Independent variables were group membership (heavy drinker or moderated (former heavy) drinker[4]) and drink type (alcohol and soft-drink images). An *a priori* power analysis conducted on G*power (Faul et al., 2007) revealed that to detect a difference between two independent groups with a medium effect (*d* = 0.5; Cohen, 1988), at 80% power with an alpha of 0.05, a sample size of at least 51 per group was required. We oversampled by recruiting 120 (60 heavy and 60 moderated) drinkers to accommodate for potential dropouts that may occur with online testing.

Participants

We recruited 120 participants through Prolific (https://www.prolific.co/), who were aged between 18 and 72 years old (M = 36.56, SD = 13.05). Sixty participants were male and 59 were female (one did not disclose their gender). Inclusion criteria were age ≥ 18 years old, current residence in the United Kingdom (UK), and self-reporting either current consumption

[4] From this point onwards, 'moderated (former heavy) drinkers' will be referred to as moderated drinkers.

of at least 28 units of alcohol[5] per week (to take part as a heavy drinker) or under 14 units per week but having previously consumed at least 28 units per week in the past (to take part as a moderated drinker). Importantly, participants were eligible to take part only if they self-report consuming 28 or more units of alcohol per week for a minimum of 3 months (for heavy drinkers this refers to currently; for moderated drinkers this refers to retrospectively, before they reduced their drinking). The 28-unit threshold was chosen because it represents a doubling of the "low-risk" weekly drinking guideline of 14 units or less recommended by the UK Government (Department of Health, 2016). We also required that participants had a high level of approval from previous participation on Prolific (> 95% approval) to ensure good data quality. Exclusion criteria consisted of any history of treatment for AUD. The study was approved by the University of Sheffield research ethics committee, and all participants gave informed consent. Recruitment took place in December 2020. Participants were reimbursed with £10 Prolific credit for their time.

Materials

Pictorial stimuli for the VBDM task

The 30 alcohol and 30 soft-drink images were taken from the Amsterdam Beverage Picture Set (ABPS; Pronk et al., 2015) and Google. We selected a subsection of images from the ABPS and compiled these with additional images from Google that portrayed English brands of drinks on a white background. This was done to ensure variability in the perceived value of images by increasing the number of recognizable alcohol (e.g., spirit, beer, wine) and soft-drink (e.g., hot drink, fizzy drink, smoothie) options (for more detail, see supplementary materials).

[5] For an American equivalent, this equates to approximately 16 "standard" drinks.

Questionnaire measures

Alcohol Purchase Task (APT; Murphy & MacKillop, 2006): An adapted brief 8-item version of the APT was used to capture alcohol demand. Participants were instructed to report the number of standard alcoholic drinks they would purchase and consume in a typical drinking scenario across a range of escalating price points (for exact wording of the scenario, see supplementary materials). Importantly, moderated drinkers completed the APT in relation to their current desire to purchase (i.e., not a retrospective estimate of what they would have done prior to reducing their consumption). The APT consisted of the following eight price points: free, 50p, £1, £2, £4, £6, £9, £15. Before completing the APT, participants were required to correctly respond to two comprehension check items to ensure that participants read and understood the hypothetical scenario. The use of comprehension checks has also been implemented in other purchase task research (Kaplan & Reed, 2018). Several demand indices can be reliably calculated using the APT, which are: intensity (consumption when price is at zero), O_{max} (maximum expenditure across prices), P_{max} (the price by which demand becomes elastic), breakpoint (first price that suppresses consumption to zero), and elasticity (rate at which consumption becomes dependent upon price) (Acuff & Murphy, 2017).

Activity Level Questionnaire (ALQ; based on Meshesha et al., 2020): This measure was used to measure behavior allocation and enjoyment across alcohol-related and alcohol-free activities. Past month ratings of activity engagement frequency were made on a 7-point scale (0 = 0 times in the past month to 6 = several times per day) and enjoyment on a 5-point scale (0 = unpleasant or neutral to 4 = extremely pleasant). We modified this measure by extending the range of responses for frequency, reducing the number of items, and updating content to include more currently common activities (e.g., asking about virtual socializing instead of writing letters and sending emails). For exploratory purposes (see supplementary materials),

we also added an additional question on a 5-point scale about whether frequency of engagement in each activity has changed since the national COVID-19 lockdowns commenced in the UK in March 2020 (0 = much less often to 4 = much more often). The frequency and enjoyment ratings were multiplied to obtain cross-product scores (range = 0 – 24) which were then averaged across all activities to calculate total alcohol-free and alcohol-related reinforcement scores for each participant. We then computed a reinforcement ratio (range = 0 – 1) by dividing the mean alcohol-free reinforcement by the mean of all available reinforcements (alcohol-free + alcohol-related). Our reinforcement ratio therefore reflects proportionate alcohol-free, rather than alcohol-related, reinforcement because this is the pre-registered outcome of interest.

Other validated questionnaire measures

We also administered the following self-report questionnaires: the 10-item Alcohol Use Disorders Identification Test (AUDIT; Saunders et al., 1993, McDonald's ω = .82 (McDonald, 1970, 1999)) to examine alcohol use and related problems, the 10-item Meaning in Life Questionnaire (MLQ; Steger et al., 2006, presence, ω = .93, search, ω = .92) to measure presence of meaning and search for meaning in life, the 13-item Brief Self-Control Scale (BSCS; Tangney et al., 2004, ω = .85) to measure self-control, the 4-item Stages of Change Readiness and Treatment Eagerness Scale (SOCRATES; Miller & Tonigan, 1996, ω = .89) as used in other research (Morris et al., 2020, 2021) to measure alcohol problem recognition, and the 9-item Drinking Refusal Self-Efficacy Questionnaire (Young et al., 1991) as used in other research (Field, Puddephatt, et al., 2020) to measure drinking refusal self-efficacy across three subscales (social pressure, ω = .84, emotional relief, ω = .91, opportunistic, ω = .85). Finally, we measured participant demographics, duration of current and previous (prior to moderation) level of alcohol consumption, and questions about

COVID-19 (see supplementary materials for a detailed description of all questionnaire measures and the participant demographic breakdown).

Procedure

The study was completed online and took on average 46.92 minutes (SD = 22.78). After providing consent, participants initially completed the AUDIT before completing an image-rating phase and VBDM task (both programmed in PsychoPy and hosted on Pavlovia; Peirce et al., 2019). Subsequently, they completed the remaining questionnaires listed above (randomized order).

Image-rating phase

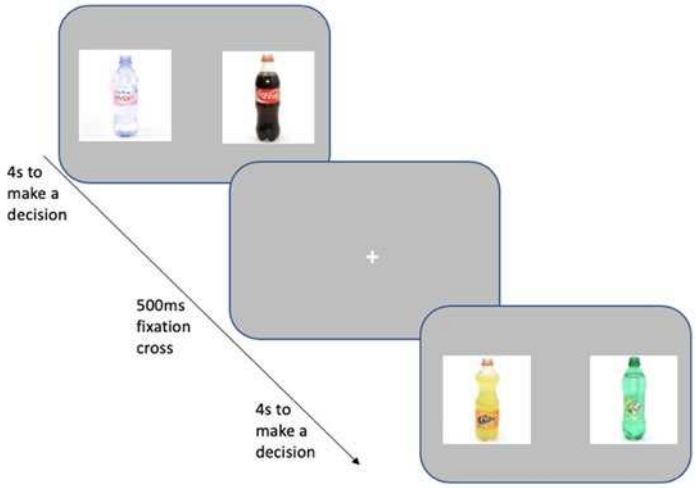
We instructed participants to make value judgements about two separate sets of images (30 soft-drink and then 30 alcohol). Participants used a computer mouse to place each of the images into 1 of 4 boxes to indicate how much they would like to consume the drink depicted *right now*: 'A lot', 'A little bit, 'Not really', and 'Not at all'. For both image sets, five images from each value category were randomly selected for use in the task and these were displayed in the center of the screen for 3 seconds each, followed by a 500ms fixation cross.

Value-based decision-making (VBDM) task

On each trial, two images appeared in the center of the screen (one on the left and one on the right), and participants were instructed to press one of two keys ('Z' for left and 'M' for right) to choose the image that depicts the drink that they would rather consume, as quickly as possible (see Figure 1). After some practice trials, participants completed two blocks (one soft-drink block and one alcohol block; order randomized) of 150 trials (300 trials in total with short, embedded breaks after every 50 trials). On each trial, one of the images was of

higher value than the other image as determined by the initial value judgements, and the (relatively) high value image appeared on the left or right of the screen with equal frequency. Participants were given 4 seconds to respond per trial, responses outside of this response window were classed as "miss trials" as commonly used in VBDM tasks (Polanía et al., 2014).

Figure 1. *Example of typical trials (in the soft-drink block).*



Note. Trial wording was "which would you rather consume?" and participants were instructed to press a key to select either of the images ('Z' for left, 'M' for right). Participants had 4 seconds to make a decision per trial, and each trial was followed by a 500ms fixation cross located in the center of the screen. Images are taken from the Amsterdam Beverage Picture Set (Pronk et al., 2015).

Data preparation and analysis

For the APT, non-systematic data were firstly identified and removed using an established algorithm (Stein et al., 2015) as cases that violate any of the following criteria: *trend*, *bounce*, and *reversals from zero*. This was achieved using the R package "*beezdemand*" (see Kaplan et al., 2019 for more detail). Both observed (intensity, breakpoint, O_{max}, P_{max}) and derived

(elasticity) values were subsequently estimated using the exponentiated demand equation (Koffarnus et al., 2015)[6]:

$$Q = Q_0 * 10^{k(e^{-\alpha Q_0 C}-1)},$$

where Q = consumption; Q_0 = derived intensity of demand (consumption at zero price); k = the difference between the minimum and maximum consumption values in logarithmic units plus the addition of a 0.5 constant (Gentile et al., 2012; Kaplan et al., 2019); C = the price of the commodity; and α = derived elasticity of demand. The exponentiated equation provided a good fit for participant-level data (mean R^2 = 0.87; median R^2 = 0.91), including when split into heavy (mean R^2 = 0.87; median R^2 = 0.91) and moderated (mean R^2 = 0.88; median R^2 = 0.92) drinkers. The aggregated data provided an excellent fit (R^2 = 0.97 for all participants).

On the VBDM task, "miss trials" (responses exceeding 4 seconds) were removed (0.43%) in addition to trials that were under 300ms (1.23%) as these are likely to be fast guesses (Ratcliff et al., 2006) which resulted in the overall removal of 1.66% of trials. We then fitted the DDM (Ratcliff & McKoon, 2008) using the EZ method (Wagenmakers et al., 2007) which takes response accuracy, mean correct RT, and variance of correct RT as input to produce three key parameters which are: EA rate (also termed 'drift rate'; v), response threshold (also termed 'boundary separation'; a), and non-decision time (encoding of stimuli and motor execution; T_{er}). We estimated parameters for each participant and for each drink type separately.

Statistical analyses were conducted in RStudio version 4.0.2 (R Core Team, 2020). Independent samples *t*-tests (one-tailed) were used to analyze the data for the pre-registered hypotheses, supplemented by mixed-design ANOVAs to establish the robustness of any

[6] Q_0 was allowed to be a freely varying parameter.

group differences in the VBDM task. Non-parametric tests were used for data that are not approximately normally distributed[7]. All participants passed at least 6 out of 8 (75%) of the embedded attention checks which was our pre-registered minimum requirement for attentive responding. Six participants had non-systematic demand data on the APT and so were not retained within the analyses that included alcohol demand. Twelve participants misunderstood instructions in the ALQ and so were not retained within the analyses that included proportionate alcohol-free reinforcement (for detail, see supplementary materials). Data and scripts are available and can be found on ResearchBox: https://researchbox.org/597.

Results

See Table 1 for descriptive statistics of questionnaire measures.

Table 1. *Descriptive statistics split by drinker status (values are means and standard deviations).*

	Heavy drinkers (n = 60)	Moderated drinkers (n = 60)	p-value and effect size
Age (years)	40.48 (13.35)	32.63 (11.56)	$p < .001$, $d = .63$
AUDIT score	18.77 (6.59)	11.25 (4.69)	$p < .001$, $d = 1.32$
AUDIT-C score	10.18 (1.56)	6.20 (2.09)	$p < .001$, $r_{rb} = .88$
AUDIT-C score (retrospective)	-	8.52 (1.81)	-
Self-control	2.71 (.61)	2.80 (.67)	$p = .42$, $d = .15$
Presence of meaning in life	20.57 (7.05)	20.15 (7.34)	$p = .75$, $d = .06$

[7] All APT indices apart from elasticity demonstrated skewness or kurtosis values within limits (-2 and 2) that have been deemed acceptable and used in previous research using these variables (e.g., Acuff, Soltis, et al., 2020; Luciano et al., 2019). Attempts to improve the distribution of elasticity via transformation (e.g., square-root and log-transformation) did not produce skewness and kurtosis values within the acceptable limits, and therefore we used a non-parametric test for this index of demand.

Search for meaning in life	22.57 (7.48)	23.68 (6.27)	$p = .38$, $d = .16$
Drinking problem recognition	12.62 (4.57)	9.13 (3.37)	$p < .001$, $d = .87$
Drinking refusal self-efficacy (*social pressure*)	2.41 (1.37)	3.28 (1.38)	$p < .001$, $d = .64$
Drinking refusal self-efficacy (*emotional relief*)	3.53 (1.77)	4.64 (1.63)	$p < .001$, $d = .65$
Drinking refusal self-efficacy (*opportunistic*)	4.45 (1.39)	5.86 (1.15)	$p < .001$, $d = 1.11$
Duration of current pattern of consumption (years)	8.61 (8.88)	5.10 (6.35)	$p = .01$, $r_{rb} = .27$
Duration of consumption pattern before cutting down (years)	-	5.21 (6.18)	-

Note. Effect sizes are Cohen's *d* (for data that are approximately normally distributed) or rank-biserial correlations (r_{rb}) (for data that are not approximately normally distributed). AUDIT scores reflect alcohol use and related problems, whilst AUDIT-C scores reflect hazardous or harmful alcohol consumption (retrospective AUDIT-C refers to the period before cutting down for moderated drinkers). Current pattern of consumption duration (years) reflects how long participants have been consuming alcohol at their current level (i.e., over 28 units for heavy drinkers and under 14 units for moderated drinkers, per week). Consumption pattern before cutting down duration (years) reflects how long moderated drinkers consumed over 28 units of alcohol (per week) prior to cutting down.

Pre-registered analyses

Behavioral economic variables

Alcohol Purchase Task (alcohol demand)

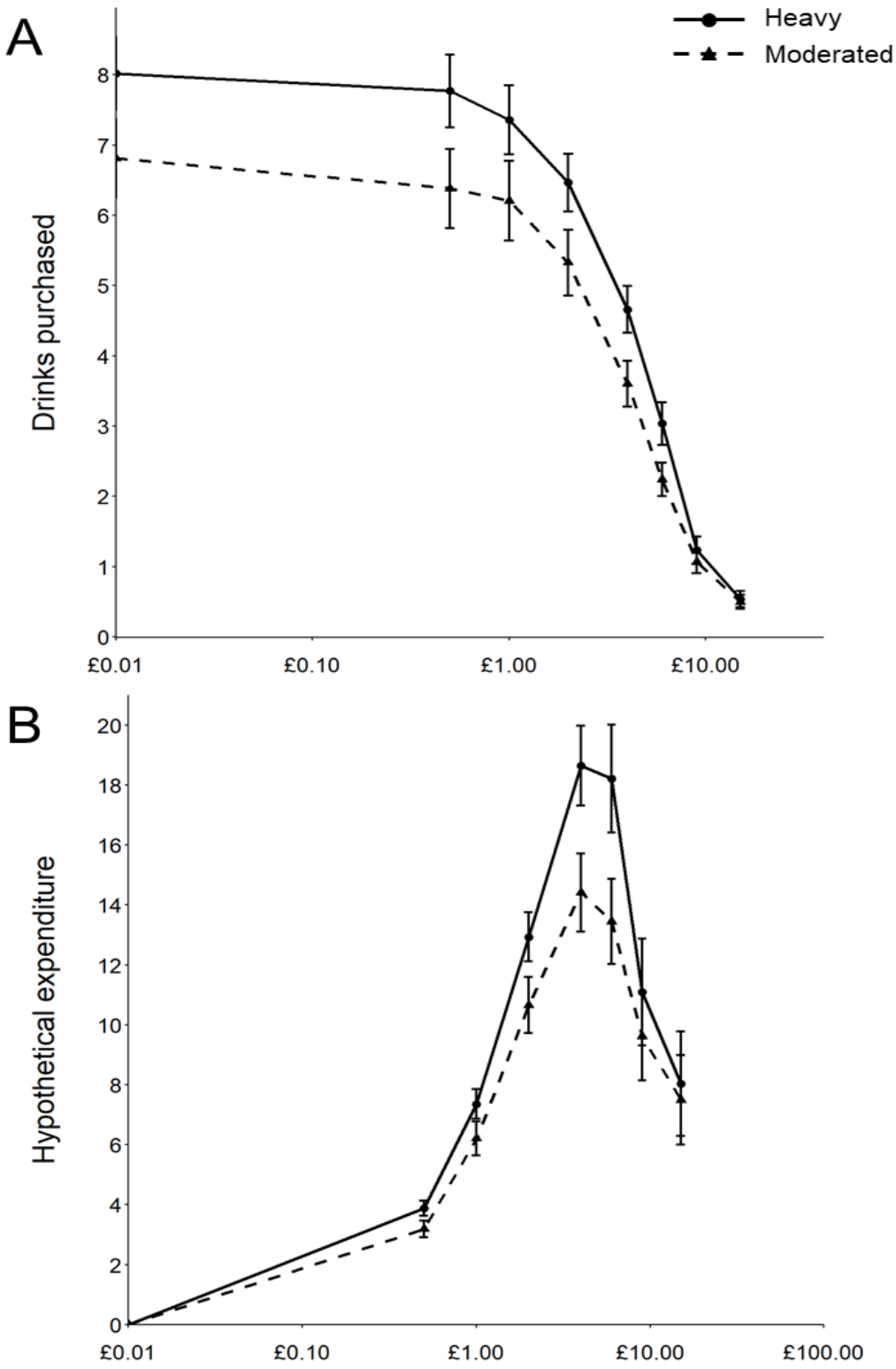
Compared to heavy drinkers, moderated drinkers had significantly lower O_{max} ($t(112) = 1.93$, $p = .03$, $d = .36$) and higher elasticity (W = 1278, $p = .03$, rank-biserial correlation (r_{rb}) = .21). Moderated drinkers also had lower intensity, however this difference was not statistically significant ($t(112) = 1.55$, $p = .06$, $d = .29$). Moderated drinkers did not have lower P_{max} ($t(112) = .58$, $p = .72$, $d = .11$) or breakpoint ($t(112) = .18$, $p = .43$, $d = .03$). See Table 2 for APT descriptive statistics.

Table 2. *Descriptive statistics for the APT split by drinker status (values are means and standard deviations, however for elasticity values represent the median and interquartile range).*

	Heavy drinkers ($n = 56$)	Moderated drinkers ($n = 58$)
Intensity	8.02 (3.95)	6.81 (4.35)
Breakpoint	9.42 (4.53)	9.27 (4.71)
O_{max}	22.50 (12.83)	18.13 (11.28)
P_{max}	6.47 (3.51)	6.89 (4.09)
Elasticity	.006 (.004)	.008 (.012)

Note. Elasticity is reported to 3 decimal places to show the distinction in values.

Figure 2. *Alcohol demand curves (Panel A) and expenditure (Panel B) split by heavy drinkers and moderated drinkers.*



Note. Each data point represents average hypothetical consumption at a particular price on the APT (Panel A) or average expenditure (consumption multiplied by price; Panel B) for both current heavy drinkers and moderated drinkers. The x-axis is log-transformed (zero values

are replaced by trivial nonzero values (0.01) to permit logarithmic units). Error bars represent the standard error of the mean (SE).

Activity Level Questionnaire (behavioral allocation)

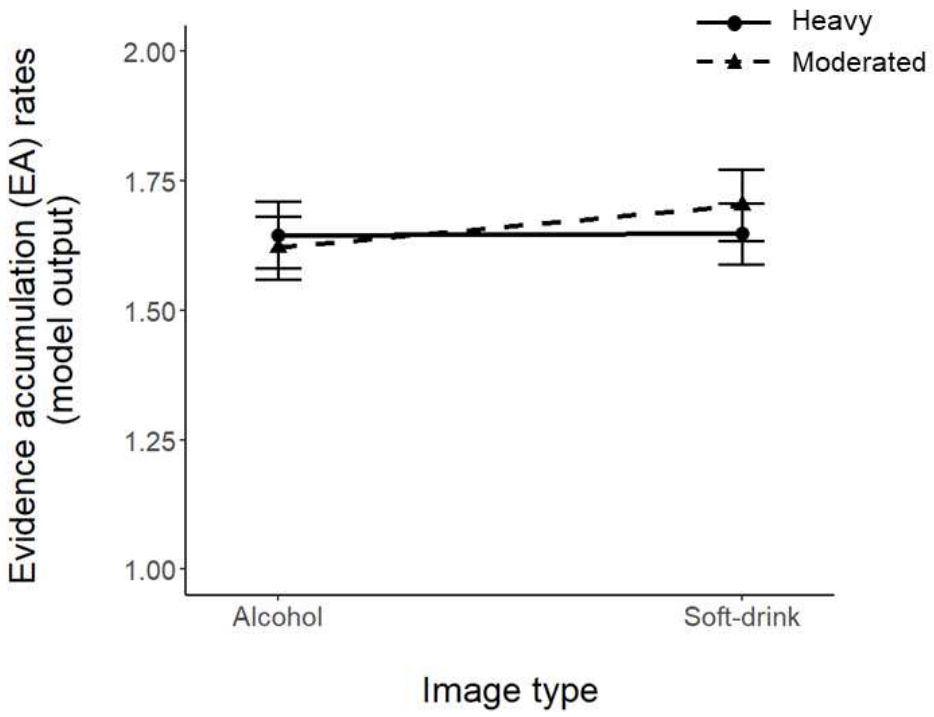
Moderated drinkers (M = .76, SD = .15) had significantly higher proportionate reinforcement from alcohol-free activities compared to heavy drinkers (M = .65, SD = .14; $t(106) = -3.90$, $p < .001$, $d = .75$).

Computational VBDM parameters

When making alcohol decisions, moderated drinkers (M = 1.62, SD = .47) did not have significantly lower EA rates compared to heavy drinkers (M = 1.65, SD = .50; $t(118) = .28$, $p = .39$, $d = .05$). Furthermore, moderated drinkers (M = 1.57, SD = .28) did not have significantly higher response thresholds compared to heavy drinkers (M = 1.66, SD = .27; $t(118) = 1.93$, $p = .97$, $d = .35$).

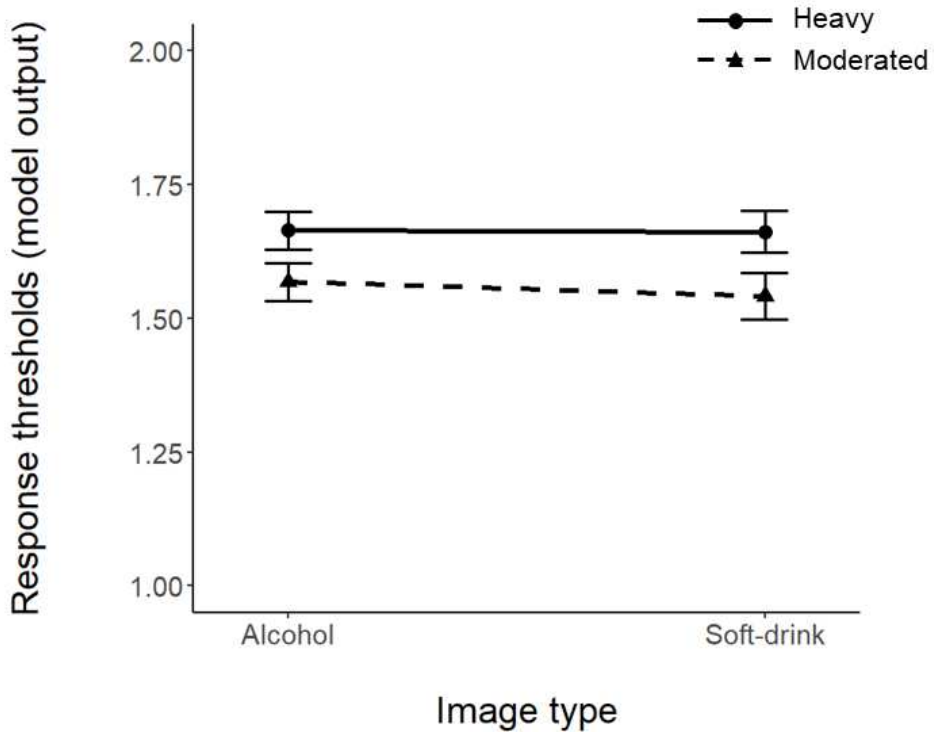
When making soft-drink decisions, moderated drinkers (M = 1.70, SD = .54) did not have significantly higher EA rates compared to heavy drinkers (M = 1.65, SD = .45; $t(118) = -.61$, $p = .27$, $d = .11$). However, moderated drinkers (M = 1.54, SD = .34) had significantly lower response thresholds compared to heavy drinkers (M = 1.66, SD = .31; $t(118) = 2.04$, $p = .02$, $d = .37$).

Figure 3. *Mean evidence accumulation (EA) rates for alcohol and soft-drink choices split by heavy drinkers and moderated drinkers.*



Note. Error bars represent the standard error of the mean.

Figure 4. *Mean response thresholds for alcohol and soft-drink choices split by heavy drinkers and moderated drinkers.*



Note. Error bars represent the standard error of the mean.

To aid interpretation of the VBDM results presented above, we conducted exploratory mixed ANOVAs on EA rates and response thresholds using a within-subject factor of drink type (2: alcohol; soft-drink), and a between-subject factor of drinker status (2: heavy; moderated). However, in line with our pre-registration, our study was powered specifically to detect differences in means between two independent groups rather than an interaction effect. When looking at EA rates, there were no significant main effects of drink type ($F(1, 118) = .91$, $p = .34$, $\eta_p^2 = .01$) or drinker status ($F(1, 118) = .04$, $p = .84$, $\eta_p^2 = .00$), and no interaction ($F(1, 118) = .82$, $p = .37$, $\eta_p^2 = .01$). When looking at response thresholds, there was a significant main effect of drinker status ($F(1,118) = 4.68$, $p = .03$, $\eta_p^2 = .04$). There was however no significant main effect of drink type ($F(1, 118) = .42$, $p = .52$, $\eta_p^2 = .00$) and no interaction ($F(1,118) = .30$, $p = .58$, $\eta_p^2 = .00$). Post-hoc tests for the significant main effect of drinker status revealed that, collapsed across alcohol and soft-drink images, response thresholds were higher in heavy drinkers (M = 1.66, SD = .29) compared to moderated drinkers (M = 1.55, SD = .31; $p = .03$). This analysis demonstrates that there was a main effect of drinker status which was not robustly moderated by drink type.

Discussion

The aim of this study was to explore whether alterations in self-report behavioral economic measures and value-based choice parameters characterize the moderation of alcohol consumption that many heavy drinkers experience without treatment. Providing partial support for the first hypothesis, we found that moderated drinkers had lower behavioral economic demand for alcohol and greater proportionate alcohol-free reinforcement, compared to heavy drinkers. These findings align with empirical evidence demonstrating positive associations between alcohol demand and consumption (Martínez-Loredo et al.,

2021; Murphy & MacKillop, 2006), however, in the current study only O_{max} and elasticity significantly discriminated heavy and moderated drinkers. In other words, compared to current heavy drinkers, moderated drinkers showed greater sensitivity to constraints because they were less willing to allocate economic resources to obtain alcohol and were more sensitive to price increases. Interestingly, these indices of demand are derived from the 'persistence' latent component of demand (MacKillop et al., 2009), which reflects the (in)sensitivity of heavy drinking to environmental constraints. These findings support a recent claim (Acuff et al., 2021) that researchers should try to distinguish the contextual factors that enable a person to continue drinking heavily from those contextual factors that prompt a person to reduce their alcohol intake. These findings also align with research distinguishing alcohol moderation specifically from other drinking outcomes (i.e., abstinence and continued heavy drinking) as characterized by behavioral flexibility that facilitates favorable contextual and monetary allocation patterns (Tucker et al., 2016, 2021). Therefore, this may provide one potential explanation as to why some of the APT indices (i.e., Omax and elasticity) significantly differentiate between drinker type, but others do not. Another potential explanation may be that unlike contemporary accounts of VBDM which acknowledge that a diverse range of input processes (internal and external) contribute to value (Berkman et al., 2017), purchase tasks such as the APT are confined to price. Indeed, a recent commentary (Acuff & Murphy, 2021) speculated upon the potential to modify hypothetical purchase tasks in future research by including constraints beyond price, which will in turn facilitate future opportunities for idiographic measurement using these tools.

Our findings also align with existing research demonstrating inverse associations between substance-free reinforcement and substance use (Acuff et al., 2019; Ginsburg & Lamb, 2018; Murphy et al., 2021; Vuchinich & Tucker, 1983). More specifically, our finding that alcohol

moderation is characterized by shifts in patterns of behavior away from alcohol-related activities and towards activities that do not involve alcohol corroborates findings from behavioral economic research using measures of monetary resource allocation (Tucker et al., 2016, 2021). Crucially, however, our findings expand upon the existing research because to the best of our knowledge, this is the first cross-sectional study to apply a behavioral economic framework to characterize alcohol moderation without treatment in people who were heavy—rather than dependent—drinkers. A further novel contribution of this study is that prior to reducing their consumption, moderated drinkers were on average drinking heavily for a shorter timeframe than reported in previous studies conducted in the USA (Tucker et al., 2016, 2021). For example, in Tucker et al. (2016) the mean duration was approximately 17 years whereas in the current study this estimate was approximately 5 years.

Although we did not recruit a clinical sample, our findings are consistent with efficacious treatment and brief interventions which broadly aim to increase substance-free reinforcement (Daughters et al., 2018; Fazzino et al., 2019; Murphy, Dennhardt, et al., 2012; Petry et al., 2017) as well findings that alongside recovery, anhedonia diminishes (Garfield et al., 2014), potentially reflecting shifts to more alcohol-free reinforcement via interests and hobbies. Our findings cannot speak to causal mechanisms that underpin alcohol moderation. However, increasing the availability of, and capacity to derive reinforcement from, alcohol-free alternatives have been highlighted as important targets to promote behavior change (McKay, 2017). Consistent with molar behavioral economic accounts (Bickel et al., 2014; Murphy, MacKillop, et al., 2012; Rachlin, 1997; Tucker et al., 2021; Vuchinich & Heather, 2003) then, alcohol moderation in heavy drinkers is characterized by higher value ascribed to sources of alcohol-free reinforcement relative to value ascribed to alcohol. In relation to the computational VBDM analysis, findings did not provide robust support for the second and

third hypotheses and therefore contrast with predictions from recent theoretical advances (Copeland et al., 2021; Field, Heather, et al., 2020). To elaborate, EA rates are hypothesized to represent value evidence accumulation, and we did not identify the changes in EA rates that we would expect to see based on overt preferences between alcohol and alcohol-free alternative reinforcers that have been observed in other studies (e.g., Hardy et al., 2018; Hardy & Hogarth, 2017; Hogarth & Hardy, 2018). However, it is difficult to directly reconcile the findings from this study with previous research because the tasks used differ methodologically, with only ours enabling disambiguation between alcohol and alcohol-free alternative value (Field, Heather, et al., 2020). Furthermore, because moderated drinkers still consume alcohol (albeit at a reduced level), it is likely that they still attach some value to alcohol which in turn may obscure clear divergence in EA rates among comparisons with heavy drinkers. Moreover, moderated drinkers had lower response thresholds overall, and although this group difference may be more pronounced for soft-drinks, there was no significant interaction effect between drinker status and drink type and therefore these findings are largely inconclusive. However, the groups differed in a number of ways: moderated drinkers were slightly younger in age than the heavy drinkers (potentially indicative of successful "maturing-out"; Britton et al., 2015; O'Malley, 2004) for example, which may in part explain the overall group difference in response thresholds (Theisen et al., 2021).

There are several important limitations to consider. Firstly, although all participants self-reported consumption of at least 28 alcohol units per week either currently or in the past, we could not establish if people who had successfully moderated their alcohol consumption had historically been drinking at the same high level as the group who were currently drinking heavily. Indeed, comparison of retrospective AUDIT-C scores in the moderated drinker

group with current AUDIT-C scores in the heavy drinker group (see Table 1) suggest that the groups were not perfectly matched in this regard. There may also have been other unmeasured variables that discriminated the groups prior to moderation (e.g., self-control) that were not captured in this study. Secondly, this study took place in the UK with a predominantly white sample and during a global pandemic (COVID-19) which may have inadvertently affected our variables of interest, therefore limiting the generalizability of these findings to other contexts and populations. For example, due to lockdown restrictions, many people are expected to have experienced unprecedented barriers to engagement with alcohol-free alternative reinforcers (Acuff et al., 2020). Thirdly, we took and then modified an existing measure of alcohol-free reinforcement to address some of the existing limitations (e.g., updating item content; Acuff et al., 2019), however there is likely a reasonable degree of measurement error in the quantification of alcohol-free reinforcement because many of the updated items comprise social activities. Furthermore, although we did not observe group differences in some demand indices (e.g., breakpoint), this may be due to the fact that the limited range of price points (8 values including 0) on the APT reduced measurement precision (Kaplan et al., 2018; Zvorsky et al., 2019) and requires further validation. Fourthly, the cross-sectional nature of the study means that it is not possible to establish any causal or temporal relationships between the variables measured in this study and alcohol consumption. Finally, patterns of alcohol consumption were assessed online which mean that responses could have been biased. However, our online recruitment took place via Prolific which has extremely high levels of data quality, including attention and honesty from participants (Peer et al., 2021).

To address these limitations, future research could employ longitudinal designs (e.g., following a person over repeated time points) to explore how behavioral economic and

VBDM parameters alter during behavior change. This might encompass studies of drinkers recruited from both community (Hardy et al., 2021) and treatment (Meshesha et al., 2020) settings with careful matching of potential confounding variables such as socioeconomic status and severity comorbidity. It is also important to explore how cultural and societal changes might facilitate or impede transitions from heavy to moderate drinking and attempt to identify how behavioral economic constructs and VBDM parameters may mediate these transitions. For example, there has been a substantial increase in the availability of alcohol-free and low alcohol alternatives to standard alcoholic beverages in the UK, and a considerable number of people report consuming these products to cut down their consumption of alcohol (Alcohol Change UK, 2020). These products may act as *substitute* reinforcers (Rachlin et al., 2018), which given their novelty, might require low levels of decision caution before committing to the choice of consumption, possibly indexed by alterations in alcohol-free response thresholds. As some drinks presented in the soft-drink block may have been indirectly associated with alcohol among participants who frequently consume mixed drinks (e.g., an image of a bottle of Coca-Cola may be associated with alcohol among people who regularly drink rum and coke), future studies might mitigate this concern by excluding such potentially ambiguous drinks from the soft-drink block.

To conclude, this study contributes a novel understanding of what characterizes alcohol moderation in heavy drinkers who do not receive treatment. Although cross-sectional, findings from self-report measures are compatible with molar behavioral economic accounts (e.g., Rachlin et al., 2018) which emphasize the importance of lowered demand for alcohol and heightened behavioral allocation towards activities that do not involve drinking as important correlates of the transition from heavy to moderated drinking. This is an important extension to the literature because 20% of heavy drinkers in England are attempting to reduce

their consumption (Beard et al., 2017) and these findings may inform intervention targets for this population. Evidence from a computational VBDM analysis is less clear, however it may be that alterations in response thresholds represent how, in the moment, people decide to engage with alcohol-free alternatives. Alongside the development of novel measurement tool that be used to monitor cognitive processes, we conducted the first empirical test of recent theoretical predictions (Copeland et al., 2021; Field, Heather, et al., 2020), although the findings were inconclusive. In line with enthusiasm (Acuff et al., 2022; Amlung et al., 2015; Bickel & Athamneh, 2020), we believe this study opens exciting interdisciplinary avenues for future research.

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Supplementary materials for "Behavioral economic and value-based decision-making constructs that discriminate current heavy drinkers versus people who reduced their drinking without treatment".

Content list:

1. Participant demographic breakdown (Table S1)

Table S1. *Demographic breakdown of the sample split by drinker status (values represent the number of participants and percentage).*

	Heavy drinkers (*n* = 60)	Moderated drinkers (*n* = 60)	Overall sample (*n* = 120)
Gender			
Male; n (%)	30 (50%)	30 (50%)	60 (50%)
Female; n (%)	29 (48.33%)	30 (50%)	59 (49.17%)
Other; n (%)	1 (1.67%)	0	1 (.83%)
Ethnic group			
White; n (%)	59 (98.33%)	53 (88.33%)	112 (93.33%)
Mixed / multiple ethnic groups; n (%)	1 (1.67%)	0	1 (.83%)
Asian / Asian British; n (%)	0	4 (6.67%)	4 (3.33%)
Black / African / Caribbean / Black British; n (%)	0	3 (5%)	3 (2.50%)
Highest education			
Postgraduate; n (%)	13 (21.67%)	8 (13.33%)	21 (17.50%)
Undergraduate; n (%)	23 (38.33%)	26 (43.33%)	49 (40.83%)
A levels, vocational level 3 and equivalents; n (%)	14 (23.33%)	22 (36.67%)	36 (30%)
GCSE/ O Level A* to C, vocational level 2 and equivalents; n (%)	10 (16.67%)	4 (6.67%)	14 (11.67%)
Student status			
Part-time; n (%)	1 (1.67%)	3 (5%)	4 (3.33%)
Full-time; n (%)	8 (13.33%)	18 (30%)	26 (21.67%)
Not a student; n (%)	51 (85%)	39 (65%)	90 (75%)
Employment status			
Unemployed; n (%)	14 (23.33%)	13 (21.67%)	27 (22.50%)

Part-time; n (%)	11 (18.33%)	16 (26.67%)	27 (22.50%)
Full-time; n (%)	32 (53.33%)	30 (50%)	62 (51.67%)
Retired; n (%)	3 (5%)	1 (1.67%)	4 (3.33%)
COVID-19 and employment			
Unaffected; n (%)	41 (68.33%)	41 (68.33%)	82 (68.33%)
Furloughed; n (%)	6 (10%)	8 (13.33%)	14 (11.67%)
Salary cut; n (%)	1 (1.67%)	3 (5%)	4 (3.33%)
Made redundant; n (%)	3 (5%)	2 (3.33%)	5 (4.17%)
Other; n (%)	9 (15%)	6 (10%)	15 (12.50%)
COVID-19 and mental health			
Much better	0 (0%)	2 (3.33%)	2 (1.67%)
Slightly better	5 (8.33%)	10 (16.67%)	15 (12.50%)
No change	14 (23.33%)	13 (21.67%)	27 (22.50%)
Slightly worse	29 (48.33%)	25 (41.67%)	54 (45%)
Much worse	12 (20%)	10 (16.67%)	22 (18.33%)
COVID-19 and alcohol consumption			
Much less	0 (0%)	16 (26.67%)	16 (13.33%)
Slightly less	7 (11.67%)	16 (26.67%)	23 (19.17%)
No change	8 (13.33%)	5 (8.33%)	13 (10.83%)
Slightly more	32 (53.33%)	17 (28.33%)	49 (40.83%)
Much more	13 (21.67%)	6 (10%)	19 (15.83%)
Household annual income bracket			
Below 7.5k; n (%)	2 (3.33%)	2 (3.33%)	4 (3.33%)
7.5 – 15.5k; n (%)	6 (10%)	3 (5%)	9 (7.50%)
15.5 – 28.5k; n (%)	8 (13.33%)	20 (33.33%)	28 (23.33%)
28.5k – 46.5k; n (%)	19 (31.67%)	11 (18.33%)	30 (25%)
46.5k – 88.5k; n (%)	20 (33.33%)	12 (20%)	32 (26.67%)

Above 85k; n (%)	3 (5%)	5 (8.33%)	8 (6.67%)
Prefer not to say; n (%)	2 (3.33%)	7 (11.67%)	9 (7.50%)
Relationship status			
Single; n (%)	17 (28.33%)	17 (28.33%)	34 (28.33%)
In a relationship; n (%)	18 (30%)	26 (43.33%)	44 (36.67%)
Married; n (%)	23 (38.33%)	17 (28.33%)	40 (33.33%)
Divorced; n (%)	2 (3.33%)	0	2 (1.67%)
Cohabiting with partner; n (%) *(only for those in a relationship or married)*	37 (90.24%)	34 (79.07%)	71 (84.52%)
Parent status			
Yes	24 (40%)	18 (30%)	42 (35%)
No	36 (60%)	42 (70%)	78 (65%)
Cohabiting with child(ren); n (%) *(only for those who are parents or carers)*	17 (70.83%)	14 (77.78%)	31 (73.81%)
Breakdown of AUDIT scores			
Low risk (below 8); n (%)	1 (1.66%)	12 (20%)	13 (10.83%)
Hazardous (between 8 and 15); n (%)	18 (30%)	37 (61.66%)	55 (45.83%)
Harmful (between 16 and 19); n (%)	14 (23.33%)	9 (15%)	23 (19.17%)
Possible dependence (above 19); n (%)	27 (45%)	2 (3.33%)	29 (24.17%)

2. Full description of questionnaire measures that were not primary dependent variables

Alcohol Use Disorders Identification Test (AUDIT; Saunders et al., 1993): The full 10-item AUDIT was used to measure alcohol use and related problems. Total scores range between 0 and 40, with scores > 7 indicating hazardous consumption. The AUDIT had good internal reliability in this study, McDonald's ω = .82 (McDonald, 1970, 1999).

Brief self-control scale (BSCS; Tangney et al., 2004): This 13-item scale captures the extent to which people feel that they can resist external influences and control their behavior, for example "I am able to work effectively toward long-term goals". Participants responded on a 1 (not at all like me) to 5 (very much like me) scale with higher scores indicating higher levels of self-control. In the current sample, the BSCS had good internal reliability, ω = .85.

The Meaning in Life Questionnaire (MLQ; Steger et al., 2006): This 10-item scale measures two dimensions: presence of meaning (how much respondents feel their lives have meaning), and search for meaning (how much respondents are striving to find meaning in their lives). Questions included "I have discovered a satisfying life purpose" and "I am looking for something that makes my life feel meaningful". Participants responded on a scale ranging from 1 (absolutely untrue) to 7 (absolutely true). Higher scores indicate higher presence of meaning or search for meaning. In the current study, each subscale had excellent internal reliability; presence, ω = .93, search ω = .92.

Stages of Change Readiness and Treatment Eagerness Scale (SOCRATES; Miller & Tonigan, 1996): we administered 4-items from the original SOCRATES to assess alcohol

problem recognition which has been used in previous research (Morris et al., 2020, 2021). Questions included “There are times when I wonder if I drink too much” and “My drinking is causing a lot of harm”. Participants responded on a 5-point Likert scale, rating each item from 1 (strongly disagree) to 5 (strongly agree). Scores range from 4 to 20, with higher scores indicating a higher level of problem recognition. This measure had good internal reliability (ω = .89).

Drinking Refusal Self-Efficacy Questionnaire (Young et al., 1991): In line with previous research (Field, Puddephatt, et al., 2020), we used a 9-item version of the original 31-item measure to assess participants' belief in their ability to resist alcohol. This measures self-efficacy across three subscales: social pressure (e.g., “When I am with friends”), emotional relief (e.g., “When I am worried”), and opportunistic (e.g., “When I am watching TV”). Participants responded on a 7-item scale ranging from 1 (very difficult to refuse) to 7 (very easy to refuse). Higher scores indicate higher drinking refusal self-efficacy. The measure had good internal reliability for all three subscales (all ωs > .84). More specifically, social pressure (ω = .84), emotional relief (ω = .91), and opportunistic (ω = .85).

Questions about COVID-19: We asked exploratory questions about COVID-19, mental health, and alcohol consumption. Participants were asked to indicate using a 5-point scale whether they felt they were drinking 1 (much less) or 5 (much more) and whether their mental health was 1 (much better) or 5 (much worse), since national lockdowns started in March 2020.

Demographic questions: Participants answered questions about their age, gender, highest educational attainment, student status, employment status (and whether COVID-19 has

impacted this), household income, relationship status, whether they have any children, and cohabitation (whether they live with partner and / or children).

3. Exact wording of the hypothetical scenario in the Alcohol Purchase Task and comprehension checks

Hypothetical scenario: "Please respond to these questions as if you were actually in a TYPICAL SITUATION when you drink alcohol. Imagine where you typically drink, what you typically drink, and who you typically drink with, if anyone. The available drinks are a pint of beer or lager, wine (medium glass), and shots of spirits (25ml) or mixed drinks with one shot of spirits. Assume that you did not drink alcohol before you are making these decisions and will not have an opportunity to drink elsewhere after making these decisions. In addition, assume that you would consume every drink you request; that is, you cannot stockpile drinks for a later date".

Comprehension check questions: "In the typical situation above, should you assume you will consume every drink that you request?" and "In the typical situation above, should you assume you will have an opportunity to drink elsewhere after making these decisions?". These were administered to ensure that participants read and understood the scenario they were instructed to imagine.

4. Activity Level Questionnaire – Revised Items and further detail on participants who misunderstood questionnaire instructions

"The following is a list of activities, events, and experiences. For the time frame of **the last 30 days**, please rate **how often you have engaged** in each activity, and **how much you enjoyed** each activity when you were **not** drinking alcohol. Please also rate whether **how often you have engaged** in each activity has **changed** since the **COVID-19 lockdown restrictions** came into place in March 2020. If you have experienced an activity more than once in the past month, try to rate how enjoyable it was on the average. **Do not make an enjoyment rating if you have not engaged in the activity in the past 30 days".**

	Frequency	**Enjoyment**	**COVID-19**
	How often did you do this without drinking alcohol, over the past 30 days Remember, you should only include things in the count if you were not drinking alcohol, or were not under the influence of alcohol, when you did them	If you did this at least once, how enjoyable did you find it	Did you do this activity more or less often compared to before the COVID lockdown restrictions were introduced in March 2020?
1. Meeting individuals and small groups (up to 6 people)			

E.g., Meeting friends, going for a meal, going for coffee			
2. Larger group meetups (over 6 people) *E.g., Large gatherings and parties, society meetups, sports club socials*			
3. Virtual socialising *E.g., Texting, social media, phone calls, FaceTime*			
4. Sport and exercise *E.g., Playing sport, going to the gym*			
5. Entertainment at home *E.g., Video games, reading a book, watching a movie, streaming show, listening to a podcast or audiobook*			
6. Entertainment outside the home *E.g., Going to the cinema, going to the theatre, visiting*			

museums or art galleries			
7. Hobbies *E.g., Photography, gardening, painting, playing an instrument*			
8. Work *E.g., Doing paid work*			
9. University *E.g., Being a student, time spent studying*			
10. Volunteering *E.g., Helping out locally or for a charity*			
11. Relaxing *E.g., Napping, meditation, taking a bath*			
12. Being alone *E.g., Spending time by yourself and not focused on an activity*			
13. Religion and politics *E.g., Going to church, going to protest*			
14. Sexual activity *E.g., Use your imagination*			

15. Caring for others *E.g. Baby, children, elderly, pets, bathing a child, playing with a child*			
16. Domestic activity *E.g., Housework, grocery shopping, cooking, cleaning*			
17. Time in nature *E.g., Going for walks, sitting in a park, visiting green-spaces*			

Were there any alcohol-free activities that you either do often or enjoy doing that did not fit into any of the categories or questions above? If so, please write this down: _____

Scoring:

Frequency	Enjoyment	COVID-19
0 = 0 times	*0 = unpleasant or neutral*	*0 = much less often*
1 = once	*1 = mildly pleasant*	*1 = slightly less often*
2 = a few times	*2 = moderately pleasant*	*2 = no change*
3 = about once per week	*3 = very pleasant*	*3 = slightly more often*
4 = several times per week	*4 = extremely pleasant*	*4 = much more often*
5 = daily or almost daily		
6 = several times per day		

Note. If participants did not take part in the activity in the past month (i.e., they selected "*0 times*" under frequency), then 0 was scored in the enjoyment column. The example in this supplementary material refers to the alcohol-free reinforcement version of the ALQ. For the

alcohol-related version we used the same 17-items but with the wording changed to "when you **were** drinking alcohol, or under the influence of alcohol".

Misunderstanding of questionnaire instructions

In the manuscript (p.15), we wrote that data from twelve participants who misunderstood questionnaire instructions on the ALQ were not retained in the analyses that included proportionate alcohol-free reinforcement. To clarify, this is referring to responses on the Activity Level Questionnaire. Participants were instructed to "not make an enjoyment rating if you have not engaged in the activity in the past 30 days". However, some participants (n = 12) either selected "0 times" (frequency) for an activity but then did not select "I didn't do this at least once" (enjoyment), or the reverse, they did not select "0 times" but then selected "I didn't do this at least once" (enjoyment). Our survey was not optimized to avoid this, and our interpretation is that these participants misunderstood the questionnaire instructions. Therefore, their data were removed on this basis.

5. Images used in the VBDM task to depict alcohol and soft-drinks (Table S2)

The 30 alcohol and 30 soft-drink images that were used in the task were taken from Amsterdam Beverage Picture Set (ABPS; Pronk et al., 2015) and Google. Ideally, we would have only used images from a validated and open source image set (such as the ABPS), however piloting work where we instructed peers (n = 6) to list their favourite and least favourite 3 beverages indicated that the range of drink images required to elicit varied evaluations (i.e., want to consume a lot, not want to consume at all) exceeded what was available from the ABPS alone (e.g., having a variety drinks common in England, such as Irn Bru and Baileys). Below we detail the content of the images used so that other researchers can use similar image sets if they wish to replicate this study in the future. Every image depicted a single drink beverage in its packaging with a plain white background.

Table S2. *Description of the content in the images used in the task to depict alcohol and soft-drinks.*

Alcohol	**Soft-drinks**
Can of Fosters	Bottle of Coke*
Bottle of Budweiser	Bottle of Dr Pepper
Bottle of Corona	Bottle of 7UP*
Can of Brewdog Punk IPA	Bottle of Irn Bru
Can of Guinness	Bottle of Orangina
Can of John Smiths Extra Smooth	Bottle of Lucozade (Original)
Can of Old Speckled Hen	Bottle of Fanta (Orange)*
Bottle of Caribbean Twist (Mixed Mango)	Bottle of San Pellegrino Sparkling Water
Can of Archers Schnapps	Can of Monster Energy
Bottle of WKD (blue)	Can of San Pellegrino Limonata
Bottle of Smirnoff Ice*	Bottle of Lipton Ice Tea*

Can of Strongbow (Dark Fruit)	Tropicana Apple Juice
Can of Strongbow (Original)	Tropicana Orange Juice
Bottle of Stella Artois Apple Cidre	Capri-Sun Orange
Can of Scrumpy Jack	Capri-Sun Cherry
Bottle of Kopparberg (Pear)	J20 Orange and Passion Fruit
Bottle of Kopparberg (Strawberry and Lime)	J20 Apple and Raspberry
Bottle of Smirnoff Vodka*	Ribena Blackcurrant
Bottle of Baileys (Irish Cream Liqueur)	Bottle of Evian Still Water*
Bottle of Gordon's Gin	Naked Green Machine Smoothie
Bottle of Jack Daniel's Whiskey	Naked Orange Carrot Smoothie
Bottle of Pimm's	Milk (1 pint; semi-skimmed)
Bottle of Apple Sourz	Frijj Chocolate Milkshake
Bottle of Sierra Tequila	Frijj Strawberry Milkshake
Bottle of Captain Morgan's Spiced Rum	Lipton Green Tea
Bottle of Aperol	Twinings Earl Grey Tea
Bottle of Rosé Wine (Blossom Hill)	Breakfast Tea*
Bottle of White Wine (Blossom Hill)	Latte
Bottle of Red Wine (Blossom Hill)	Americano
Bottle of Prosecco*	Iced Coffee

Note. Images from the ABPS are denoted by *.

6. Within-subject differences and establishing a 'difficulty effect' on the VBDM task (Figure S1)

Pre-registered exploratory analyses

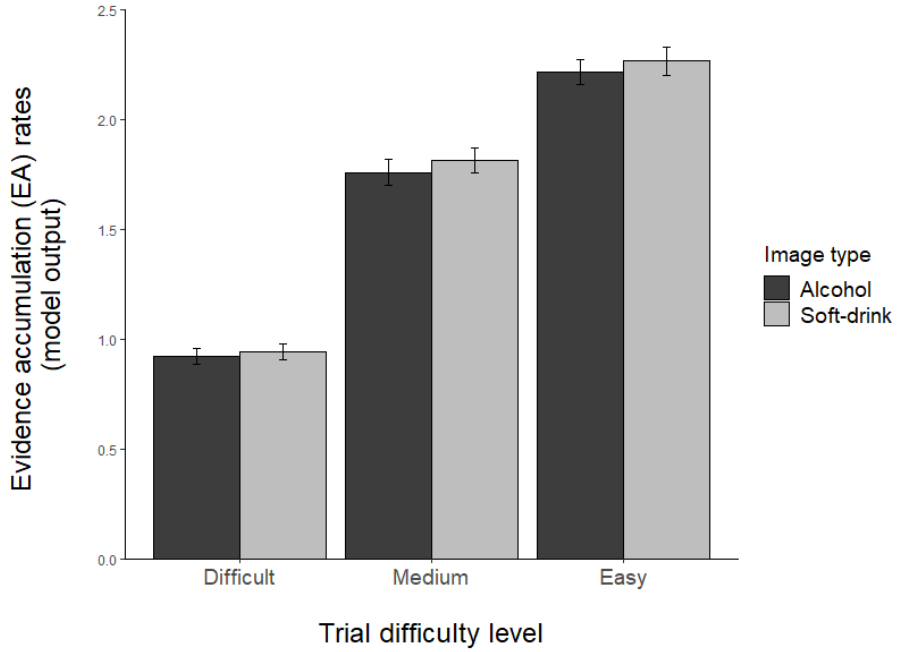
We explored within-subject differences in EA rates and response thresholds across drinker type[8]. In both heavy and moderated drinkers, there were no significant differences in EA rates for alcohol compared to for soft-drinks (both ps $\geq .26$, ds $\leq .15$). Similarly, in both heavy and moderated drinkers, there were no significant differences in response thresholds for alcohol compared to for soft-drinks (both ps $\geq .43$, ds $\leq .10$) which supplement the non-significant interaction effect reported previously.

Finally, we were interested in establishing whether there is a 'difficulty effect', such that on trials in the VBDM task where the difference between the value ratings for the competing images is large (i.e., rating difference 3, e.g., 'A lot' versus 'Not at all'), EA rates were increased compared to when the differences between the value ratings for the competing images is minimal (i.e., rating difference 1, e.g., 'A little bit' versus 'Not really'). One-way repeated measures ANOVAs were used to compare EA rates across difficulty levels (i.e., easy, medium, and difficult trials) for alcohol and soft-drinks. There was a significant main effect of difficulty on alcohol EA rates ($F(2, 238) = 422.80$, $p < .001$, $\eta p^2 = .78$). Subsequent post-hoc tests (applying Holm-Bonferroni correction) revealed that alcohol EA rates in the easier trials (M = 2.22, SD = .61) were significantly increased compared to medium trials (M = 1.76, SD = .66; $p < .001$) and difficult trials (M = .92, SD = .39; $p < .001$). Furthermore, alcohol EA rates on medium trials were significantly increased compared to EA rates on difficult trials ($p < .001$). There was also a significant main effect of difficulty on soft-drink

[8] The within-subject t-tests are two-tailed because unlike the core hypotheses of the study, we did not hypothesize directional effects for these exploratory analyses.

EA rates (F(1.90, 225.58) = 349.09, $p < .001$, $\eta p^2 = .75$). Post-hoc tests revealed that soft-drink EA rates in the easier trials (M = 2.27, SD = .70) were increased compared to medium trials (M = 1.82, SD = .63; $p < .001$) and difficult trials (M = .95, SD = .40; $p < .001$). Furthermore, soft-drink EA rates on medium trials were significantly increased compared to EA rates on difficult trials ($p < .001$).

Figure S1. *Mean evidence accumulation rates (including all participants) for alcohol and soft-drink choices split by trial difficulty level.*



Note. Error bars represent the standard error of the mean (SE).

7. DDM analyses conducted on each individual difficulty level in isolation (Table S3)

Table S3. *Core analyses repeated on each difficulty level in isolation split by DDM parameter.*

Contrast	Easy trials	Medium trials	Difficult trials
EA rate / drift			
Alcohol: heavy vs. moderated drinkers	$p = .47$, $r_{rb} = .01$	$p = .30$, $d = .10$	$p = .37$, $d = .06$
Soft-drink: heavy vs. moderated drinkers	$p = .17$, $d = .17$	$p = .39$, $d = .05$	$p = .42$, $d = .04$
Heavy drinkers: alcohol vs. soft-drink	$p = .48$, $d = .007$	$p = .54$, $d = .01$	$p = .52$, $d = .01$
Moderated drinkers: alcohol vs. soft-drink	$p = .14$, $d = .14$	$p = .15$, $d = .13$	$p = .24$, $d = .09$
Response threshold / boundary			
Alcohol: heavy vs. moderated drinkers	$p = .95$, $d = .30$	$p = .97$, $d = .34$	$p = .85$, $d = .19$
Soft-drink: heavy vs. moderated drinkers	$p = .14$, $d = .20$	$p = .06$, $d = .28$	**$p < .01$, $d = .53$**
Heavy drinkers: alcohol vs. soft-drink	$p = .58$, $d = .03$	$p = .31$, $d = .07$	$p = .75$, $d = .09$
Moderated drinkers: alcohol vs. soft-drink	$p = .48$, $d = .01$	$p = .77$, $d = .09$	**$p < .001$, $d = .43$**

Note. d = Cohen's d effect size, r_{rb} = rank biserial correlation effect size.

The finding that moderated drinkers have significantly lower response thresholds for soft-drinks reported in the manuscript appears to be carried by trials that are difficult. Interestingly, although the within-subject comparison in moderated drinkers between average alcohol and soft-drink response thresholds was non-significant, when looking at difficulty

levels in isolation, moderated drinkers have significantly reduced soft-drink response thresholds compared to their alcohol response thresholds, but only on trials that are difficult.

8. Order of blocks of trials on the VBDM task: does this matter?

The order of blocks in the decision-making task was randomized, such that for some participants the soft-drink trials were completed first, whilst for others the alcohol trials were completed first. To explore the importance of order of blocks presented in the decision-making task, we conducted a two-way between-subjects ANOVA with drinker type (2: heavy; moderated) and order (2: soft-drink first; alcohol first). In the data, order of blocks is coded as 1 = soft-drink first, and 2 = alcohol first. Overall, for EA rates and response thresholds for both alcohol and soft-drinks, there was no evidence to suggest that the order in which participants completed the blocks altered the decision-parameters (all *p*s > .05, see below).

EA rates

There was no significant main effect of drinker status ($F(1,116) = .13$, $p = .72$, $np^2 = .00$) or order of blocks ($F(1, 116) = .35$, $p = .56$, $np2 = .00$) on alcohol EA rates. Furthermore, there was no significant interaction between drinker status and order of blocks ($F(1, 116) = .19$, $p = .66$, $np^2 = .00$). There was no significant main effect of drinker status ($F(1,116) = .49$, $p = .48$, $np^2 = .00$) or order of blocks ($F(1, 116) = 1.43$, $p = .23$, $np^2 = .01$) on soft-drink EA rates. Furthermore, there was no significant interaction between drinker status and order of blocks ($F(1, 116) = .13$, $p = .72$, $np^2 = .00$).

Response thresholds

There was no significant main effect of drinker status ($F(1,116) = 3.11$, $p = .08$, $np^2 = .03$) or order of blocks ($F(1, 116) = .66$, $p = .42$, $np^2 = .01$) on alcohol response thresholds. Furthermore, there was no significant interaction between drinker status and order of blocks ($F(1, 116) = 1.21$, $p = .27$, $np^2 = .01$). There was a marginally significant main effect of

drinker status ($F(1,116) = 3.78$, $p = .05$, $np^2 = .03$) on soft-drink response thresholds. There was however no significant main effect of order of blocks ($F(1, 116) = .00$, $p = 1.00$, $np^2 = .00$) or interaction between drinker status and order of blocks ($F(1, 116) = 1.13$, $p = .29$, $np^2 = .01$).

9. Activity Level Questionnaire: exploring whether self-reported frequency of engagement with activities has changed since lockdown restrictions were introduced in March 2020 (Table S4 and Table S5).

On the Activity Level Questionnaire, we added an additional column containing a question on a 5-point scale about whether people's frequency of engagement in each activity has changed since the national COVID-19 lockdowns began in March 2020 (0 = *much less often*, 1 = *slightly less often*, 2 = *no change*, 3 = *slightly more often*, 4 = *much more often*). The scores were then averaged across all activities to compute a mean value reflecting self-reported change for alcohol-related and alcohol-free scores.

Total sample

The mean score for alcohol-free reinforcement was 1.96 (SD = .35) and alcohol-related reinforcement was 1.89 (SD = .34); these were significantly different (p = .03, d = .21). Therefore, since lockdown restrictions in March 2020, overall means are located within *slightly less often* and *no change*. Alcohol-related reinforcement declined (slightly but significantly) more in response to the lockdown, compared to alcohol-free reinforcement.

Comparison by drinker type

When comparing moderated and heavy drinkers, there were no significant differences in self-reported change in frequency of engagement in alcohol-related (p = .35, d = .18) or alcohol-free (p = .40, d = .16) activities since COVID-19 lockdown restrictions were introduced in March 2020.

The Activity Level Questionnaire comprises 17 different items, and a further breakdown by activity revealed that changes in frequency of engagement in some of the **alcohol-related**

activities since COVID-19 lockdown restrictions were more pronounced than others. Meeting up with people and entertainment outside the home were estimated to be less frequent (scores below 2), whilst entertainment within the home and virtual socialising were estimated to be more frequent (scores above 2), compared to before COVID-19 lockdown restrictions, for example (see table below for means and standard deviations). Some activities remained relatively unchanged, such as work and time in nature. There was a significant difference between heavy drinkers and moderated drinkers in the frequency of entertainment at home with alcohol since COVID-19 lockdown restrictions were introduced (see Table S4 below).

Table S4. *A table to show whether engagement with alcohol-related activities changed since national lockdown restrictions began in March 2020 (values are means and standard deviations).*

Activities with alcohol	**Total sample**	**Heavy drinkers**	**Moderated drinkers**	***p*-value**
Meeting individuals and small groups	1.11 (1.23)	1.02 (1.18)	1.21 (1.27)	$p = .44$
Larger group meet-ups	1.04 (1.28)	.93 (1.19)	1.15 (1.38)	$p = .52$
Virtual socialising	2.36 (1.13)	2.48 (1.03)	2.23 (1.23)	$p = .29$
Sport and exercise	1.73 (.80)	1.77 (.66)	1.69 (.94)	$p = .64$
Entertainment at home	2.43 (.85)	2.62 (.84)	2.21 (.80)	**$p < .01$***
Entertainment outside the home	1.46 (.90)	1.43 (.85)	1.50 (.96)	$p = .76$
Hobbies	1.92 (.74)	1.96 (.63)	1.87 (.84)	$p = .78$
Work	1.95 (.48)	1.96 (.42)	1.94 (.54)	$p = 1.00$

University	1.89 (.59)	1.91 (.44)	1.87 (.71)	$p = .72$
Volunteering	1.86 (.52)	1.88 (.54)	1.85 (.50)	$p = .50$
Relaxing	2.20 (.75)	2.30 (.78)	2.10 (.69)	$p = .13$
Being alone	2.25 (.87)	2.30 (.93)	2.19 (.79)	$p = .37$
Religion and politics	1.90 (.51)	1.89 (.45)	1.90 (.57)	$p = .94$
Sexual activity	1.80 (.99)	1.80 (.96)	1.79 (1.04)	$p = .80$
Caring for others	1.95 (.54)	1.95 (.59)	1.96 (.48)	$p = 1.00$
Domestic activity	2.07 (.71)	2.14 (.72)	2.00 (.69)	$p = .35$
Time in nature	1.97 (.72)	2.04 (.74)	1.90 (.69)	$p = .62$

Note: *p*-values and effect sizes correspond to comparisons in heavy drinkers and moderated drinkers. Significance is in bold. Meeting individuals and small groups refers to under 6 people. Larger group meet-ups refers to 6 or more people. Responses are scored on a 5-point scale (0 = much less often; 1 = slightly less often; 2 = no change; 3 = slightly more often, 4 = much more often).

A further breakdown by activity revealed that changes in frequency of engagement in some of the **alcohol-free activities** since COVID-19 lockdown restrictions were more pronounced than others (see table below). For example, activities such as meeting up with people and entertainment outside the home were estimated to be less frequent (scores below 2), whilst entertainment within the home, domestic activity, and virtual socialising were estimated to be more frequent (scores above 2), compared to before COVID-19 lockdown restrictions. Some activities remained relatively unchanged, such as work and university. There was a significant difference between heavy drinkers and moderated drinkers in the frequency of

engagement in religion and politics without alcohol since COVID-19 lockdown restrictions were introduced (see Table S5).

Table S5. *A table to show whether engagement with alcohol-free activities changed since national lockdown restrictions began in March 2020 (values are means and standard deviations).*

Activities without alcohol	**Total sample**	**Heavy drinkers**	**Moderated drinkers**	***p*-value**
Meeting individuals and small groups	1.18 (1.46)	1.05 (1.44)	1.31 (1.48)	$p = .27$
Larger group meet-ups	1.15 (1.45)	1.04 (1.43)	1.27 (1.48)	$p = .37$
Virtual socialising	2.69 (1.16)	2.54 (1.14)	2.85 (1.16)	$p = .11$
Sport and exercise	1.70 (1.19)	1.77 (1.13)	1.63 (1.25)	$p = .57$
Entertainment at home	2.80 (0.92)	2.73 (0.94)	2.87 (0.91)	$p = .40$
Entertainment outside the home	1.06 (1.24)	0.95 (1.17)	1.17 (1.32)	$p = .39$
Hobbies	2.18 (1.04)	2.18 (1.06)	2.17 (1.02)	$p = .78$
Work	1.84 (0.98)	1.86 (0.90)	1.83 (1.06)	$p = .89$
University	1.98 (0.79)	1.95 (0.59)	2.02 (0.96)	$p = .49$
Volunteering	1.81 (0.80)	1.82 (0.77)	1.81 (0.84)	$p = .87$
Relaxing	2.32 (0.93)	2.29 (1.00)	2.37 (0.84)	$p = .58$
Being alone	2.26 (1.24)	2.32 (1.18)	2.19 (1.31)	$p = .64$
Religion and politics	1.81 (0.55)	1.93 (0.42)	1.67 (0.65)	**$p < .01$***

Sexual activity	1.63 (1.01)	1.70 (0.93)	1.56 (1.09)	$p = .33$
Caring for others	2.15 (0.97)	2.05 (0.84)	2.25 (1.10)	$p = .36$
Domestic activity	2.50 (0.89)	2.43 (0.81)	2.58 (0.98)	$p = .24$
Time in nature	2.20 (1.14)	2.20 (1.15)	2.21 (1.14)	$p = .78$

Note: *p*-values and effect sizes correspond to comparisons in heavy drinkers and moderated drinkers. Significance is in bold. Meeting individuals and small groups refers to under 6 people. Larger group meet-ups refers to 6 or more people. Responses are scored on a 5-point scale (0 = much less often; 1 = slightly less often; 2 = no change; 3 = slightly more often, 4 = much more often).

10. Exploratory correlations between self-report variables and DDM parameters split by drinker status (Table S6 and Table S7).

Table S6. *Correlations between self-report variables and DDM parameters in moderated drinkers.*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Alcohol drift																				
2. Soft-drink drift	.36***																			
3. Alcohol boundary	-.19	-.23																		
4. Soft-drink boundary	-.10	-.27*	.69***																	
5. AUDIT	.07	.01	.00	.07																
6. Problem recognition	-.07	-.27*	-.02	.00	.42***															
7. Self-efficacy (social)	-.20	-.18	.01	-.02	-.36**	-.21														
8. Self-efficacy (emotional)	-.08	-.10	.12	.18	-.21	-.35**	.42***													
9. Self-efficacy (opportunity)	-.05	.03	-.02	-.06	-.12	-.24	.23	.43**												
10. Presence of meaning	.05	.15	-.22	-.32*	-.10	-.21	.12	.11	-.20											

11. Search for meaning	.07	-.05	.14	.00	-.15	-.02	-.06	-.12	-.11	-.42***									
12. Brief self-control	.09	.06	-.05	-.04	-.24	-.40**	.14	.26*	.06	.37**	-.12								
13. Alcohol-free reinforcement	.17	.26	-.12	-.11	.01	-.03	-.02	-.05	-.02	.15	-.17	.13							
14. Alcohol-related reinforcement	-.10	-.16	-.14	-.06	.44**	.24	-.21	-.26	-.46**	.17	-.15	-.09	.21						
15. Reinforcement ratio	.21	.24	.09	-.02	-.38**	-.21	.20	.22	.43**	-.11	.13	.08	.18	-.91***					
16. Intensity	.15	-.00	.11	.13	.42**	.08	-.36**	-.10	.08	-.09	-.10	-.18	.01	.15	-.15				
17. Breakpoint	.28*	.05	-.19	-.23	.19	-.08	-.11	-.08	-.03	.12	-.16	-.00	.11	.02	-.08	.19			
18. Omax	.29*	-.12	.01	.07	.28*	-.09	-.24	-.10	-.02	.02	-.23	-.13	.01	.00	.02	.60***	.64***		
19. Pmax	.13	.01	-.30*	-.29*	.13	-.01	-.04	-.05	.04	.03	-.10	-.04	.08	-.09	.18	-.08	.84***	.48***	
20. Elasticity	-.27*	.06	-.05	-.02	-.24	.09	.26*	.14	.05	.08	.13	.06	-.04	-.02	-.03	-.55***	-.67***	-.97***	-.49***

Note. ***p <.001, **p <.01, *p <.05. Reinforcement ratio here is calculated to reflect proportionate substance-free reinforcement (see methods section of manuscript for description and rationale).

Table S7. *Correlations between self-report variables and DDM parameters in heavy drinkers.*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Alcohol drift																				
2. Soft-drink drift	.59***																			
3. Alcohol boundary	-.21	-.10																		
4. Soft-drink boundary	-.02	-.19	.70***																	
5. AUDIT	-.04	-.04	.26*	.26*																
6. Problem recognition	.03	.10	.20	.21	.70***															
7. Self-efficacy (social)	-.02	-.18	.02	-.05	-.31*	-.38**														
8. Self-efficacy (emotional)	-.04	-.14	-.06	.09	-.51***	-.55***	.55***													
9. Self-efficacy (opportunity)	-.04	.07	-.13	-.20	-.34***	-.50***	.16	.41**												
10. Presence of meaning	-.25	-.22	.24	.25	-.10	-.16	.11	.24	.04											
11. Search for meaning	-.00	-.08	-.16	-.09	.09	.15	-.22	-.21	.01	-.23										
12. Brief self-control	-.07	-.20	-.12	-.10	-.32*	-.42***	.28*	.39**	.18	.44***	-.01									

13. Alcohol-free reinforcement	.15	.19	-.04	-.21	-.35**	-.49***	.08	.06	.26	.06	.02	.36**						
14. Alcohol-related reinforcement	.13	.14	.14	.10	.08	-.15	-.15	-.24	-.14	.08	-.14	.05	.21					
15. Reinforcement ratios	.07	.05	-.14	-.23	-.34*	-.22	.19	.22	.22	.04	.09	.27*	.58***	-.61***				
16. Intensity	-.21	-.02	.15	-.06	.33*	.08	-.14	-.11	-.09	.00	-.12	-.22	-.21	.02	-.21			
17. Breakpoint	-.03	-.02	-.20	-.24	.01	-.10	-.07	-.21	-.16	.21	-.08	.13	.13	.23	-.08	.13		
18. Omax	.16	.10	-.04	-.15	.11	-.14	-.05	-.10	-.05	.03	-.04	-.04	.20	.21	-.06	.52***	.48***	
19. Pmax	-.10	-.05	-.11	-.06	-.05	-.17	-.14	-.14	.06	.33*	-.06	.19	.23	.27	-.01	-.20	.64***	.23
20. Elasticity	-.13	-.10	.00	.14	-.13	.15	.08	.12	.07	-.12	.07	-.01	-.15	-.20	.07	-.48***	-.59***	-.96***	-.29*

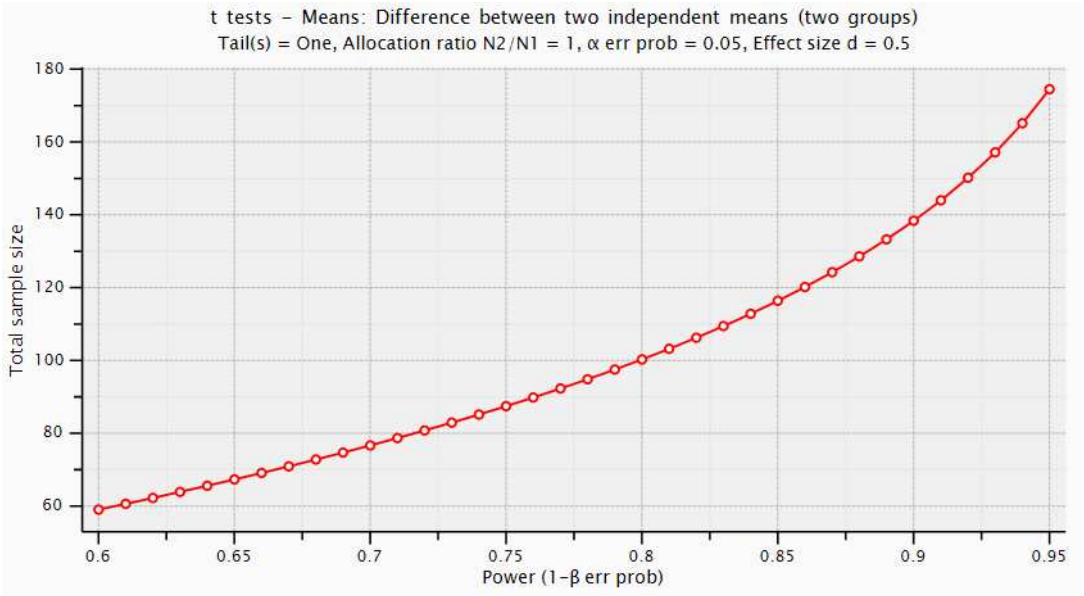
Note. ***p <.001, **p <.01, *p <.05. Reinforcement ratio here is calculated to reflect proportionate substance-free reinforcement (see methods section of manuscript for description and rationale).

11. *A priori* power analysis output (Figure S2)

t tests – Means: Difference between two independent means (two groups)

Analysis:	A priori: Compute required sample size		
Input:	Tail(s)	=	One
	Effect size d	=	0.5
	α err prob	=	0.05
	Power (1−β err prob)	=	0.80
	Allocation ratio N2/N1	=	1
Output:	Noncentrality parameter δ	=	2.5248762
	Critical t	=	1.6602343
	Df	=	100
	Sample size group 1	=	51
	Sample size group 2	=	51
	Total sample size	=	102
	Actual power	=	0.8058986

Figure S2. *A graph to show the relationship between sample size and power level.*



12. Further detail on participant recruitment.

For moderated drinkers, we used built-in pre-screen filters that are available on Prolific (e.g., residency in the UK, consumption of less than 14 UK units of alcohol per week, > 95% approval from previous studies) and we supplemented these filters with text on various instances (see below) to identify our target sample of moderated drinkers:

1. Study details that are initially advertised to participants prior to their enrolment in the study "**IMPORTANT** - PLEASE ONLY PROCEED IF YOU **USED** TO CONSUME **28 OR MORE** UNITS OF ALCOHOL PER WEEK IN THE PAST (FOR AT LEAST 3 MONTHS), **BUT HAVE NOW CUT DOWN**".

2. Information sheet

In the information sheet presented for participants to read before they participate, we explicitly stated that "we are looking for people who used to consume over 28 units of alcohol per week in the past (for a period of at least three months), but now consume less than 14 units of alcohol per week". This was accompanied by a lay summary / example of what a unit of alcohol is to facilitate accurate judgements from participants about their drinking:

"What is a unit of alcohol?

A pint (568ml) of beer or a medium (175ml) glass of wine both contain approximately two and a half units, whereas a double measure (50ml) of spirits such as gin, vodka, whisky contains approximately 2 units.

So, 28 units of alcohol corresponds to around 3 bottles of wine, 14 double spirits, or 12 pints of beer; 14 units of alcohol is about 1.5 bottles of wine, 7 double spirits, or 6 pints of beer".

3. Consent form

In the consent form, participants had to actively tick a box to confirm the following (they could only proceed to participate in the study if this was the case):

- "I have read and understood the project information sheet dated 05/11/2020 (Please only proceed with this consent form when you are fully aware of what your participation in the project will mean.)"
- "I can confirm that I currently consume under 14 units of alcohol per week, but that in the past I used to consume 28 or more units of alcohol per week, and this was for at least 3 months"

For current heavy drinkers, we used built-in pre-screen filters that are available on Prolific (e.g., residency in the UK, consumption of more than 14 UK units of alcohol per week (this is the highest option available on Prolific), > 95% approval from previous studies) and we supplemented these filters with text on various instances (see below) to identify our target sample of heavy drinkers:

1. Study details that are initially advertised to participants prior to their enrolment in the study "**IMPORTANT** - PLEASE ONLY PROCEED IF YOU CONSUME **28 OR MORE** UNITS OF ALCOHOL PER WEEK, AND HAVE DONE SO FOR AT LEAST 3 MONTHS

2. Information sheet

In the information sheet presented for participants to read before they participate, we explicitly stated that “we are looking for people who currently consume over 28 units of alcohol per week and have done so for a period of at least three months”. This was accompanied by a lay summary / example of what a unit of alcohol is to facilitate accurate judgements from participants about their drinking:

“What is a unit of alcohol?
A pint (568ml) of beer or a medium (175ml) glass of wine both contain approximately two and a half units, whereas a double measure (50ml) of spirits such as gin, vodka, whisky contains approximately 2 units.

So, 28 units of alcohol corresponds to around 3 bottles of wine, 14 double spirits, or 12 pints of beer; 14 units of alcohol is about 1.5 bottles of wine, 7 double spirits, or 6 pints of beer”.

3. Consent form

In the consent form, participants had to actively tick a box to confirm the following (they could only proceed to participate in the study if this was the case):

- “I have read and understood the project information sheet dated 05/11/2020 (Please only proceed with this consent form when you are fully aware of what your participation in the project will mean.)”
- “I can confirm that I currently consume 28 or more units of alcohol per week and have done so for at least 3 months”.