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RESEARCH REPORT

ADDICTION SSA

Purpose in life, neural alcohol cue reactivity and daily alcohol use in social drinkers

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Abstract

Background and Aim: Alcohol craving is an urge to consume alcohol that commonly precedes drinking; however, craving does not lead to drinking for all people under all circumstances. The current study measured the correlation between neural reactivity and alcohol cues as a risk, and purpose in daily life as a protective factor that may influence the link between alcohol craving and the subsequent amount of consumption.

Design: Observational study that correlated functional magnetic resonance imaging (fMRI) data on neural cue reactivity and ecological momentary assessments (EMA) on purpose in life and alcohol use.

Setting: Two college campuses in the United States.

Participants: A total of 54 college students (37 women, 16 men, and 1 other) recruited via campus-based groups from January 2019 to October 2020.

Measurements: Participants underwent fMRI while viewing images of alcohol; we examined activity within the ventral striatum, a key region of interest implicated in reward and craving. Participants then completed 28 days of EMA and answered questions about daily levels of purpose in life and alcohol use, including how much they craved and consumed alcohol.

Findings: A significant three-way interaction indicated that greater alcohol cue reactivity within the ventral striatum was associated with heavier alcohol use following craving in daily life only when people were previously feeling a lower than usual sense of purpose. By contrast, individuals with heightened neural alcohol cue reactivity drank less in response to craving if they were feeling a stronger than their usual sense of purpose in the preceding moments ($b_{interaction}$ = −0.086, P < 0.001, 95% CI = −0.137, −0.035).

Conclusions: Neural sensitivity to alcohol cues within the ventral striatum appears to be a potential risk for increased alcohol use in social drinkers, when people feel less purposeful. Enhancing daily levels of purpose in life may promote alcohol moderation among social drinkers who show relatively higher reactivity to alcohol cues.

KEYWORDS
Alcohol use, college students, craving, cue reactivity, ecological momentary assessment, experience sampling, fMRI, purpose in life, ventral striatum

INTRODUCTION

Heavy alcohol use in young adulthood is associated with a wide range of adverse outcomes, such as violence [1], personal injuries [2], suicidal ideation [3], risky sexual behaviors [4], and academic failure [5]; as well as longer-term health conditions such as increased risk for cardiovascular disease [6] and cancer [7]. Alcohol craving, or an urge to consume alcohol, commonly precedes alcohol use, particularly among heavy drinkers and alcohol-dependent individuals [8]. Alcohol craving is also considered a risk for alcohol use in non-dependent college-age social drinkers [9] and may result from exposure to alcohol cues that are common in college environments from peers [10] and media [11]. However, avoiding alcohol to preempt craving in daily life is difficult for some and may be perceived as socially costly in college environments [12]. Therefore, identifying individual risk and protective factors that influence drinking decisions in the face of alcohol craving may inform interventions to prevent increased drinking before it becomes problematic.

Neural reactivity to alcohol cues as a risk for alcohol use

People experience varying degrees of affective, physiological, and/or behavioral reactivity when they encounter alcohol cues. Such individual differences in cue reactivity can be tracked via functional magnetic resonance imaging (fMRI), and a core system of alcohol cue-induced activation has been identified in limbic and prefrontal brain regions [13]. In particular, ventral striatum responds robustly to appetitive cues such as images of alcohol [13, 14], as well as other drugs and natural reward stimuli [15]. The ventral striatum receives dopaminergic inputs from regions involved in motivation [16] and is a central component of the neural system underlying reward processing [17, 18]. For this reason, increased alcohol cue reactivity within the ventral striatum is thought to reflect reward expectation and craving [19]. Consistent with this view, the ventral striatum was responsive to alcohol cues among individuals with a history of alcohol-use disorders [20–22] as well as non-treatment seeking social drinkers [23]. Cue-elicited ventral striatum activity, in turn, was associated with self-reported craving [21, 24]. Hypersensitivity within the ventral striatum is also a risk for heavier alcohol use, whereas reduced reactivity might signal reduced risk. For example, heightened ventral striatum activity in response to neutral images predicted higher cue-induced alcohol craving as well as more severe and shorter time to relapse among alcohol-dependent individuals [25]. Reduction in alcohol cue reactivity in ventral striatum also tended to follow successful alcohol cessation treatments [13, 26–28]. Although less is known about the relationship between cue-elicited ventral striatum activity and subsequent alcohol use among non-dependent drinkers, evidence collectively suggests the potential risk for increased drinking associated with the ventral striatum activity during alcohol cue exposure.

Purpose in life as a protective factor in alcohol use

Purpose in life refers to having a sense that one's life has goals and directions that guide behavior [29]. An individual's purpose in life is a function of goals associated with core values, which then provide a clear sense of priorities in response to competing choices [30–32]. Purpose in life may promote healthy choices by providing an orientation toward long-term goals and motivating actions that are aligned with those goals [33]. Supportive of this view, purpose in life was uniquely associated with increased longevity [34, 35] and healthier lifestyles including better alcohol-related outcomes [36]. Stronger purpose in life was longitudinally associated with greater decreases in temptation to consume alcohol [37] and greater likelihood of remission status at a later point [38]. The link between purpose and health may be in part because of the ease of making healthy decisions when people are feeling purposeful. For example, individuals with stronger purpose showed lower conflict-related processing in the brain while considering health advice, suggesting less effortful processing, which in turn was associated with greater endorsement of health recommendations [31]. Specifically in the alcohol use context, decision-making processes in response to alcohol craving may be governed by individuals' conscious and/or unconscious evaluation of whether the reward of drinking will outweigh that of not drinking [39, 40]. At each step of the decision-making process, purpose in life may counterbalance the immediate reward of drinking by making the value of longer-term goals more salient and encouraging healthier behavior. Further, purpose in life might be particularly effective for alcohol moderation for individuals with heightened neural reactivity to alcohol cues, who may experience greater craving and expect greater rewards by consuming alcohol [13], even if they are not alcohol-dependent [23].

The current study

The current study examined the interplay between neural reactivity to alcohol cues within the ventral striatum, measured via fMRI, as a risk factor, and daily levels of purpose in life as a protective factor, that may moderate the link between alcohol craving and subsequent alcohol consumption in non-dependent, college-aged social drinkers. Specifically, we tested whether feeling purposeful in the moment would be protective during high-risk situations for subsequent alcohol use, such as when individuals with heightened neural reactivity to alcohol cues crave alcohol.

METHODS

Participants and procedure

Students in two urban universities who belonged to a campus group (as part of a parent study) were invited to participate. Based on the initial online responses, 111 participants who met the fMRI eligibility

criteria completed an fMRI visit and had usable data. All participants who completed fMRI were invited to an initial round of ecological momentary assessment (EMA) that did not contain any purpose in life questions, and hence was not able to be used in the current report. Approximately 9 months (mean = 307.8 days; median = 280 days; SD = 135.75; range = 85–533) after the fMRI scan, at the start of the coronavirus disease (COVID)-19 pandemic, all participants were once again invited to complete an additional 28-day EMA, which included both the relevant drinking and the purpose in life measures relevant to the current investigation. In this round, 54 of the participants who completed the fMRI also completed the EMA portion of the study with usable data (M_{age} = 20.35 years; SD_{age} = 1.32; 37 women, 16 men, 1 other; 26 White, 16 Asian, 2 Black, 3 Latino/a, and 7 other). Given the focus of the current study on alcohol use outcomes, participants were excluded if they had a history of alcohol use disorders, never drank alcohol in their life, or consumed less than one drink in a typical drinking occasion. Please see Supporting information S1 for further recruitment and eligibility details. This study was approved by the University of Pennsylvania and the Army Research Office Institutional Review Boards. All participants provided informed consent and were paid for their participation. Online surveys were conducted via Qualtrics, scanner tasks were presented using PsychoPy2, and the EMA prompts and participants' responses were delivered via the LiveData app (www.lifedatacorp.com).

Measures and tasks

fMRI alcohol cue reactivity task

To measure neural reactivity to alcohol cues, we used an alcohol cue reactivity task that identified neural regions responsive to alcohol cues in previous studies [13, 15]. Participants were presented with images of beer, wine, and liquor [41] and asked to respond in different ways. For the present investigation, we focus on trials in which participants were asked to "simply look at them and respond according to your initial gut reaction." Participants were then asked to indicate their craving rated on a 1 (not at all) to 5 (very much) scale (craving scores not reported here). Across four task runs, participants completed 96 trials of different types, of which 24, 32, or 48 trials were of interest for the current report, depending on the condition assignment as part of a larger parent study (Supporting information S2). Each block began with a trial condition cue (3 seconds) followed by 4 trials, each consisting of an image presentation (6 seconds) and a craving rating (3 seconds). Each event was separated by a jittered fixation cross (mean = 4.0 seconds, SD = 2.6 seconds).

Ecological momentary assessment surveys

Throughout the 28-day EMA period, participants received two surveys per day via mobile app in the morning (8 AM) and evening (6 PM) that assessed current levels of purpose in life (morning only) and alcohol-related questions (morning and evening) (Supporting information S3).

Daily purpose in life

Once a day during each morning survey, participants reported their current levels of purpose in life ("Right now, I feel that I have a sense of direction and purpose in my life") on a scale of 1 (not at all) to 100 (extremely) with higher scores indicating stronger purpose on a given day. The question was modified from the Psychological Well-Being Scales [29] into an EMA format [42] to assess state levels of daily purpose.

Alcohol craving and consumption

Twice a day, participants indicated their current levels of alcohol craving ("How strongly are you craving alcohol right now?") on a scale of 1 (not at all) to 100 (extremely) with higher scores indicating greater craving. Participants also retroactively reported the amount of alcohol consumption since the last survey. First, participants were asked whether they had alcohol ("Since your morning/evening survey, have you consumed any alcohol?" yes/no). Answering "Yes" prompted subsequent questions about the amount of alcohol consumption based on the standard servings for beer (12 fl oz), wine (5 fl oz), and liquor (1.5 fl oz). Following methods from a previous study that used EMA to assess daily alcohol use [43], we summed responses across alcoholic beverage categories to obtain the total servings of alcohol consumed for each assessment. If participants responded "No" to having consumed alcohol, then they were redirected to answer questions about other non-alcohol-related health questions to ensure that all surveys had the same length.

Demographics

Participants self-reported their age, gender, race/ethnicity, and perceived status within the campus group they belonged to using the MacArthur Scale of Subjective Social Status [44]. The race/ethnicity variable was converted to indicate White, Asian, Black, Latino/a, and other status (Table 1).

fMRI data acquisition, modeling, and ROI analysis

Neuroimaging data were acquired on 3 Tesla Siemens Prisma scanners equipped with a 64-channel head coil. High-resolution T1-weighted structural images were collected using a magnetization-preparged rapid gradient-echo (MPRAGE) sequence (inversion time [TI] = 1100 ms, voxel size = 0.9 × 0.9 × 1 mm, 160 slices, field of view [FOV] = 256, repetition time [TR] = 1850 ms, echo time [TE] = 3.91 ms, flip angle = 8°). T2*-weighted functional images were also collected (voxel size = 3 × 3 × 3 mm, 42 slices, FOV = 70, TR = 1000 ms, TE = 30, flip angle = 62°). The anatomic and functional data were preprocessed using fMRIPrep. The cue reactivity task was modeled including the following regressors: trials during which

TABLE 1 Demographic characteristics (n = 54).

Characteristic	
Age	
Mean (SD)	20.35 (1.32)
Median	20.00
Range	18–23
Gender, *n* (%)	
Women	37 (68.5)
Men	16 (29.6)
Other	1 (1.9)
Race/ethnicity, *n* (%)	
White	26 (48.1)
Asian	16 (29.6)
Black or African American	2 (3.7)
Latino/a	3 (5.6)
Other	7 (13.0)
Status in group	
Mean (SD)	4.92 (2.20)
Median	5
Range	1–10

Notes: Status in group = perceptions of one's status within the campus group measured by the MacArthur Scale of Subjective Social Status, with their social group as the reference (1 = low, 10 = high) [44].

participants were instructed to: "react naturally" to alcohol cues (trials of interest), "react naturally" to non-alcohol cues, downregulate response to alcohol cues, and upregulate response to alcohol cues. Models also included nuisance regressors of no interest: rating period and five motion regressors. Please see Supporting information S2 for further details about the fMRI data preprocessing and modeling. To index alcohol cue reactivity, we extracted mean parameter estimates from the "react naturally" to alcohol cues > resting fixation contrast within the ventral striatum region of interest (ROI). The ventral striatum ROI was taken from a meta-analysis of 206 studies that reported neural signals associated with reward and positive value processing [18]. As an exploratory analysis, we also extracted a functionally defined map of craving-related activity from Neurosynth (https://neurosynth.org/analyses/terms/craving/) using the search term "craving" (80 studies; $P < 0.01$, corrected) (Supporting information S4).

Analysis plan

To account for the zero-inflated data (i.e. alcohol consumption) and to focus on within-person relationships, time-varying variables were within-person standardized to z scores, which allowed us to test within-person changes while holding the between-person differences constant. Please see Supporting information S3 for further details about data preparation. A multilevel analysis model included daily purpose, ventral striatum activity, alcohol craving, and their interaction terms as predictors of the subsequent amount of alcohol consumption. We focused on the (i) link between alcohol craving and consumption, and (ii) three-way interaction (purpose * ventral striatum * craving) predicting consumption. We selected the model with maximal random effects structure by removing terms that accounted for no variance until the model converged and all parameters were identified. This resulted in a structure that allowed craving scores to vary randomly across participants (Supporting information S5).

We also conducted follow-up simple slopes analyses [45] to explore whether the relationship between alcohol craving and consumption varied across three different levels of purpose, including one SD below the participant's own mean, at their own mean, and one SD above their own mean levels of daily purpose. Adopting previous procedures [45], all continuous variables were mean-centered (within-person mean-centered from raw scores for time varying EMA data, between-person mean-centered for ventral striatum activity) for this portion of the analysis. The simple slopes were specified a priori, and no correction was planned; the results were robust to false discovery rate correction (Supporting information SI5).

As a part of a parent study, participants were randomly assigned to intervention conditions designed to influence alcohol use, which is not the focus of the current investigation; all models therefore controlled for the condition as a covariate. Analyses also controlled for demographic variables including age, gender, race/ethnicity, and perceived social status. All results remained robust without controlling for these potential covariates (Supporting information S6). Analyses were performed in R (v3.6.1, www.r-project.org) using the R-studio interface (v1.2.1335).

RESULTS

Alcohol use, purpose in life, and cue reactivity descriptives

Throughout the 28-day EMA period, 43 of 54 participants (79.6%) reported that they drank at least once (62.5% men, 86.5% women). This rate was higher than the average monthly prevalence of 54.3% (53.9% men, 54.7% women) among the United States (US) adults ages between 18 and 25 [46]. The average number of drinking occasions was slightly more than once per week (mean = 5.296 in 28 days, SD = 6.70; range = 0–27). Of the participants who reported having had alcohol at least once throughout the EMA period, the within-person average number of drinks per drinking occasion was 2.57 (SD = 1.79; range = 1–10).

The daily purpose in life measure provided sufficient variability to detect within-person relationships (mean within-person coefficient of variation [CV] = 34.83%, $range_{CV}$ = 5.31–237.26, SD_{CV} = 33.02). Intra-class correlation (ICC) analysis indicated that, of the total variance in purpose, 37.08% was attributable to within-person variation. For ROI analyses, we focused on the variability in cue reactivity across individuals; in terms of the average activity, viewing alcohol images, on average, did not significantly increase activity from rest within the ventral

striatum (mean parameter estimate = −0.131, SD = 1.078; t[53] = −0.891, P = 0.377) in our non-dependent social drinker sample.

Daily purpose, neural alcohol cue reactivity, and alcohol craving predicting subsequent alcohol consumption

Among the predictor variables, higher ventral striatum cue reactivity was associated with greater average alcohol craving throughout the EMA period (r = 0.286, P = 0.036, $CI_{95\%}$ = [0.019, 0.514]), but no issues of multicollinearity was detected (Supporting information S5). The coefficients and statistics for all models are reported in Table 2.

We found that greater alcohol craving from a previous time point was associated with a larger amount of alcohol consumption at a later time point among non-dependent social drinkers (b = 0.209, P < 0.001). In the same model, we also observed a significant three-way interaction between daily purpose in life, alcohol cue reactivity within the ventral striatum, alcohol craving, and their interaction terms simultaneously as predictors of subsequent alcohol use (b = −0.086, P < 0.001). Results from follow-up simple slopes analyses showed that alcohol cue reactivity within the ventral striatum strengthened the link between alcohol craving and the subsequent amount of consumption when people previously reported lower than their mean levels of purpose (b = 0.012, P = 0.015). By contrast, when people were previously at near their mean (b = 0.008, P = 0.073) or higher than their usual levels of daily purpose (b = 0.005, P = 0.320), neural alcohol cue reactivity did not affect the relationship between alcohol craving and the subsequent amount of alcohol consumption (Figure 1).

Please see Supporting information S7 for the significant interaction results between purpose in life and ventral striatum activity predicting alcohol consumption, which showed no significant relationship between ventral striatum activity and alcohol consumption across different levels of purpose. All results remained robust to the inclusion of the number of days between the fMRI and EMA data collection as a covariate (Supporting information S8).

DISCUSSION

What factors nudge social drinkers into drinking more on some days and less on others? Answering this question can inform prevention guidelines for healthy alcohol use before individuals start developing problematic behavior and help understand how people make health decisions more generally. Our results showed that greater alcohol craving predicted larger amounts of subsequent alcohol consumption. This link was moderated by individual differences in neural reactivity to alcohol cues and purpose in life, such that greater alcohol cue reactivity within the ventral striatum was associated with heavier alcohol use following craving when people were previously feeling a weaker sense of purpose.

Overall, the frequency and amount of alcohol use in our sample was slightly higher than the national average, but was still within the range of healthy, non-problematic levels of consumption. Therefore, our data suggest that previous findings on the relationships among alcohol craving, neural alcohol cue reactivity, and alcohol consumption among alcohol-dependent individuals [8, 20, 25] might be generalizable to non-dependent social drinkers. Mainly, craving preceded drinking in our non-alcohol-dependent college samples, parallel to previous evidence that highlighted craving as a risk for alcohol use among alcohol-dependent individuals [8]. Further, greater alcohol cue reactivity within the ventral striatum was associated with higher average craving throughout the EMA period. These results suggest that alcohol craving and neural reactivity to alcohol cues might be a health risk not only for alcohol-dependent individuals studied in prior work [13], but also for non-dependent social drinkers who were part of the current study.

TABLE 2 Multilevel analyses of alcohol craving, neural reactivity to alcohol cues within the ventral striatum, and purpose in daily life predicting the amount of alcohol consumed.

	β	*b*	*SE*	*t*	P	*95% CI*	d
Craving	0.209	0.209	0.050	4.147	<0.001	0.110, 0.308	1.514
Purpose in life	0.019	0.019	0.026	0.731	0.465	−0.032, 0.070	0.040
Ventral striatum	−0.020	−0.018	0.027	−0.683	0.495	−0.071, 0.034	−0.038
Craving * Purpose in life	−0.018	−0.017	0.027	−0.645	0.519	−0.069, 0.035	−0.035
Craving * Ventral striatum	0.027	0.025	0.048	0.531	0.599	−0.068, 0.118	0.197
Purpose in life * Ventral striatum	−0.058	−0.053	0.024	−2.165	0.031	−0.101, −0.005	−0.118
Craving * Purpose in life * Ventral striatum	−0.093	−0.086	0.026	−3.316	<0.001	−0.137, −0.035	−0.181

Notes: Standardized (β) and unstandardized (b) regression coefficients, 95% CI, standard error for unstandardized regression coefficients (SE), and Cohen's *d* scores (*d*) are displayed. Time-varying variables (purpose in life, alcohol craving, and amount of later alcohol consumption) were within-person standardized (n = 54; 1358 observations). All analyses controlled for potential covariates, including demographic variables (age, gender, race/ethnicity, and perceived social status) and the condition assignment as part of a parent study. Please see https://github.com/cnlab/purpose_craving for the complete model output statistics. The phrase "ventral striatum" indicates the neural reactivity to alcohol cues within the ventral striatum while viewing images of alcoholic beverages.

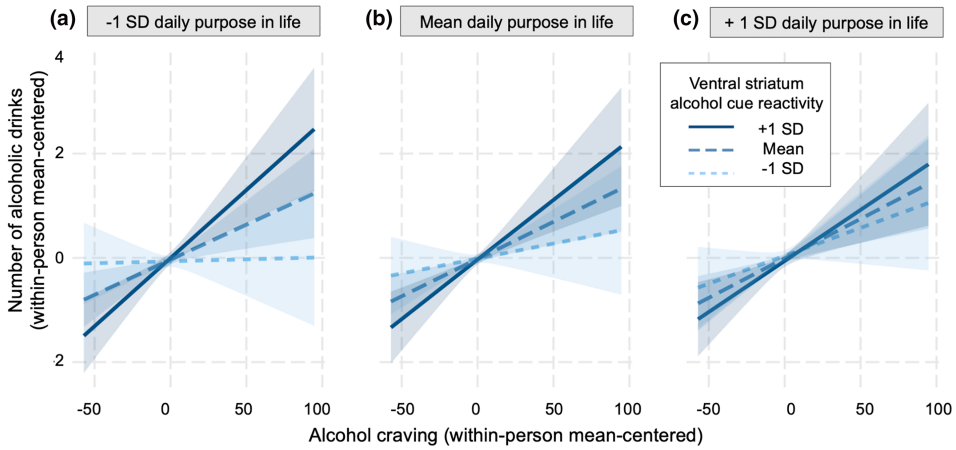

FIGURE 1 Simple slopes analysis. Individuals with heightened ventral striatum alcohol cue reactivity consumed a larger amount of alcohol following craving only when they were previously feeling weaker **(a)** levels of purpose in life. By contrast, neural reactivity did not affect the link between alcohol craving and subsequent drinking when people were previously feeling a mean **(b)** or stronger sense of purpose in life **(c)**. The ventral striatum variable was between-person mean-centered, and purpose in life, alcohol craving, and alcohol consumption variables were within-person mean-centered. SD = standard deviation [Color figure can be viewed at wileyonlinelibrary.com]

Individuals with heightened cue-induced neural reactivity in the ventral striatum consumed more alcohol in response to craving only when their sense of purpose was weak. One possibility is that the benefit of purpose in life may be the greatest when there is a need to regulate impulses and manage behavior. This result may also help explain previously mixed findings on the relationship between cue reactivity within the ventral striatum and alcohol use habits among light drinkers [23, 47], underscoring the importance of subjective contexts within which non-dependent drinkers make decisions to drink. That is, whereas baseline neural reactivity alone might not pose a significant health risk for non-dependent individuals, it may exacerbate the risk for drinking more than a person's usual amount, when combined with other conditions that facilitate alcohol use.

Feeling purposeful was especially protective for individuals with higher neural reactivity, such that when they craved alcohol, they still consumed a smaller amount of alcohol if they were previously feeling a strong sense of purpose. This result adds to the growing literature that connects purpose in life to a wide range of health benefits [48], and further supports the potential use of purpose-based interventions to promote healthy alcohol use. Our data also indicate that within-person variations in purpose in daily life, beyond what has been previously shown for between-person differences in dispositional purpose, are associated with health behavior. Purpose in life is traditionally treated as a relatively stable trait [29], and indeed, the ICC value of daily purpose in our sample (0.63) was greater than those observed in previous studies that examined more state-like experiences (e.g., 0.38–0.48 for positive affect) [49]. However, recent studies suggest that an individual's purpose in life may vary from baseline throughout the days and weeks, much like the way a number of other personality traits relevant to health may fluctuate over various timescales [43, 50]. Considering how daily dynamics in purpose in life may be associated with immediate health outcomes can provide more fine-grained information about optimal timing of intervention. For example, temporarily boosting purpose in life before or during at-risk situations (e.g. exposure to alcohol cues that may trigger craving) might be an effective prevention strategy among non-dependent social drinkers.

At least two potential pathways may explain how feeling purposeful may subsequently weaken the link between alcohol craving and alcohol consumption among individuals who show heightened neural alcohol cue reactivity. One possibility is that when individuals feel a strong sense of purpose, they may experience lower than usual levels of alcohol cue reactivity. Although the average levels of daily purpose throughout the EMA period were not significantly associated with the neural reactivity within the ventral striatum in our data (r = −0.143, P = 0.303, $CI_{95\%}$ = [−0.396, 0.130]), future studies may assess synchronous dynamics between neural cue reactivity and purpose in life. In particular, purpose in life may concurrently influence the reward calculation processes within the brain's reward system, by foregrounding the value of longer-term goals that counterbalances the immediate reward of drinking [40]. Another non-mutually exclusive possibility is that feeling purposeful in the moment may help downregulate reactivity once it is activated. Purpose in life has also been associated with better regulation of stress [51] and psychological [31] and physical pain [52], suggesting more efficient regulatory processing. Future studies could examine precise regulatory mechanisms that might be associated with purpose in life.

We note several limitations of this study. First, although alcohol cue-induced reactivity of the ventral striatum was associated with craving in our data, it may also reflect a number of other cognitive, affective, and physiological responses, not all of which are specific to impulses and motivations to consume alcohol. Especially for non-dependent social drinkers, as in our sample, the neural reactivity to alcohol cues may signal other processes in addition to craving, such as expectation of social reward that tends to accompany alcohol use or more general hypersensitivity to any reward cues. Given the

correlational nature of our data, it is also possible that people, who crave alcohol more, paired with drinking, might then develop stronger neural cue reactivity. Second, it is unclear whether purpose in life is partly societally determined by one's immediate context (structures of oppression, dimensions of marginalization, differences in safety, affluence, etc.), and hence could be correlated with factors of privilege [53]. Although we controlled for demographic variables to statistically account for this potential relation, future studies may benchmark purpose in life across diverse samples to determine its effects across different racial and ethnic identities, and across variations in socioeconomic status. Third, we used a group-based sampling method as part of a parent study. Although we used multilevel models to account for the nesting of individuals within the groups, the current findings should be tested in general populations to be more generalizable. Fourth, as part of a larger study, a subset of participants (n = 34) were asked to regulate their reactions to alcohol images in some trials during the fMRI cue reactivity task, which we did not analyze in the current manuscript. The current block design (36 seconds for the same trial type) and the inclusion of the condition as a covariate may have addressed this issue to some degree. Future replication studies may test the current results outside intervention contexts. Finally, the current study was not pre-registered and the results should be considered exploratory.

To conclude, our results show that while neural reactivity to alcohol cues is a potential risk for increased drinking among non-dependent social drinkers, feeling purposeful in the moment can help promote alcohol moderation. Having a strong sense of purpose in daily life might be especially beneficial during health decision-making that involves regulatory demands for reactivity to reward cues. Future studies are warranted to identify precise mechanisms through which purpose in life promotes successful regulation of cue reactivity among individuals with heightened alcohol cue reactivity.

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DECLARATION OF INTERESTS

V.S. is a founder and chief executive officer for Kumanu, a digital well-being company. E.B.F. is on the scientific advisory board for Kumanu and has consulted for Google in the past year. D.C. has consulted for Lotic AI in the past year. The rest of the authors have no conflict of interest to declare.

AUTHOR CONTRIBUTIONS

Yoona Kang: Conceptualization; formal analysis; funding acquisition; investigation; project administration. **Danielle Cosme:** Formal analysis. **David Lydon-Staley:** Conceptualization; formal analysis. **Jeeesung Ahn:** Formal analysis; validation. **Mia Jovanova:** Validation. **Faustine Corbani:** Formal analysis; project administration. **Silicia Lomax:** Investigation; project administration. **Ovidia Stanoi:** Investigation; project administration. **Victor Strecher:** Conceptualization. **Peter Mucha:** Funding acquisition; investigation; project administration. **Kevin Ochsner:** Funding acquisition; investigation; project administration. **Dani Bassett:** Funding acquisition; investigation; project administration. **Emily Falk:** Conceptualization; funding acquisition; investigation; project administration; supervision.

POSITIONALITY STATEMENT

Mindful that our identities can influence our approach to science, the authors wish to provide the reader with information about our backgrounds. With respect to gender, when the manuscript was drafted, eight authors self-identified as women, four as men, and one as non-binary. With respect to race, 10 authors self-identified as White, two as Asian, and one as Black.

CITATION DIVERSITY STATEMENT

Recent work in several fields has identified a bias in citation practices such that papers from women and other minority scholars are under-cited relative to the number of such papers in the field [54, 55]. Here, we sought to consider choosing references that reflect the diversity of the field in thought, form of contribution, gender, and other factors. We obtained the predicted gender of the first and last author of each reference by using databases that store the probability of a first name being carried by a woman [56]. By this measure, our references contain 22.66% woman (first)/woman (last), 17.18% man/woman, 26.85% woman/man, and 33.3% man/man. This method is limited in that (i) names, pronouns, and social media profiles used to construct the databases may not, in every case, be indicative of gender identity and (ii) it cannot account for intersex, non-binary, or transgender people.

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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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