Exploring associations between drinking contexts and alcohol consumption: An analysis of photographs

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Abstract

Drinking contexts are theorized to represent a core factor driving hazardous consumption and ultimately susceptibility to alcohol use disorder (AUD). Yet capturing and characterizing contextual influences on alcohol consumption has posed a significant challenge. In the current study, we employ objective ambulatory assessment methods to test a multi-axial framework for understanding contextual influences on drinking. Specifically, we propose a novel SPAIS framework, comprising five exogenous, objectively measurable domains of drinking context (Schedule/Timing, Physical, Activity, Interpersonal, and Substance/Drink-type), corresponding loosely to the when, where, what, how, and (with) whom of alcohol consumption. Contextual effects are examined through a database comprising 6,259 photographs of everyday life (1,422 drinking contexts), with participants including individuals with normative consumption patterns (N=48) as well as those meeting criteria for AUD (N=60). Participants wore transdermal alcohol biosensors during an ambulatory assessment period, while also taking photographs of their surroundings in response to random prompts. Computer vision methods were employed to extract contextual features from photographs. Results indicated numerous and often potent links between contextual features and patterns of consumption across SPAIS dimensions. Specifically, evening and weekend drinking, drinking during celebrations, drinking in bars, the presence of alcohol-related cues, distracting activity, and crowded, mixed-gender spaces were all associated with elevated levels of consumption. Results represent a step towards the identification of behavioral and structural change targets for alcohol use intervention programs, while at the same time providing new methods for capturing context in the field of addiction science.

Keywords: context, setting, alcohol, alcohol use disorder, ambulatory methods

General Scientific Summary: Environmental characteristics play a key role in shaping patterns of alcohol use behavior. This study proposes a novel framework for identifying characteristics of drinking contexts and identifies several aspects of these settings that may serve as the strongest influences on alcohol consumption. Specifically, evenings and weekends, celebrations, bars, the presence of alcohol-related cues, distracting activities, and crowded, mixed-gender spaces were all associated with elevated levels of consumption.

Problematic drinking is driven by the combined influence of both intrinsic as well as contextual determinants (Crabbe, 2002; Schuckit, 1998; Sher et al., 2005). But in studying factors that might lead individuals to drink at hazardous levels and so accrue risk for developing alcohol use disorder (AUD), research in the field of addiction science has historically been characterized by a focus on individual-level traits (Beck et al., 1993; Blane & Leonard, 1999; Fairbairn & Sayette, 2014; Sher et al., 2005). As such, a range of individual-level factors have been identified as robust predictors of AUD, ranging from family history and genetic profile (Finn & Pihl, 1987), to gender (Fairbairn et al., 2015), to age (Kuntsche et al., 2006), to religious background and personality (Hefner & Curtin, 2012). Yet psychological theories of addiction have long pointed to context as key to understanding drinking, indicating few more potent influences on acute alcohol effects than the immediate settings in which drinking takes place (e.g., de Wit & Sayette, 2018; Hull, 1981; Steele & Josephs, 1990). Still, research exploring and dissecting these contexts has not consistently kept pace with theory, and thus our understanding of how diverse contextual factors might act together in driving hazardous consumption remains at a relatively early stage.

Although a range of challenges have slowed progress towards a contextual understanding of AUD, including traditional conceptualizations of AUD as a stable between-person trait (Hoffmann et al., 1974; Jellinek, 1946), some of the more formidable of these challenges lie in the domain of measurement. Contextual factors are multifarious and transient, shifting both between and also sometimes within drinking episodes (Ehret et al., 2012; Keough et al., 2015; Rauthmann et al., 2014; Stevely, Holmes, & Meier, 2020). Real-world environments feature a complex contextual landscape, including factors capable of monopolizing attention and driving seismic emotional shifts, impacting resources available for self-reflection and in-depth report

(Kiecolt-Glaser et al., 2020; Kuppens & Verduyn, 2017; Leary & Kowalski, 1995; Richeson & Shelton, 2007). Prior research in this domain has often isolated a single contextual feature and/or relied on retrospective measures (e.g., Stevely, Holmes, & Meier, 2020). The current study aims to further build this body of work by leveraging new-generation tools for objective ambulatory assessment, including photo-based methods for extracting multiple environmental features combined with continuous transdermal measurement of drinking, so providing a platform for examining a novel multi-axial organizational framework for understanding immediate contextual effects on heavy alcohol use and thereby informing our knowledge of AUD risk.

Context and Alcohol Use

Theories of substance use indicate a variety of mechanisms through which elements of the immediate environment might impact consumption. These elements are far ranging in their mechanism of action, including those operating through the medium of attention/salience (Everitt & Robbins, 2005; Martins et al., 2019), distraction (Witkiewitz et al., 2005), reasoning/decisional processes (Vuchinich & Heather, 2003), and even pharmacology (Hull, 1981; Steele & Josephs, 1990). Elements of the drinking environment might either inspire or curtail consumption through directing drinkers' attention towards alcohol cues, increasing the salience of drinking related social norms (e.g., social modeling; Clapp & Shillington, 2001), or manipulating drinkers' sense of self-awareness (e.g., via dim lighting; Buvik & Rossow, 2015; Hull, 1981). Alternatively, contexts might impact alcohol use quantity by introducing distracting activity and entertainment simultaneous with drinking (e.g., Johnson & Sheets, 2004), so potentially diminishing cognitive resources available for simultaneous monitoring and awareness of consumption levels. Regarding pharmacology, theories within basic addiction science have long indicated effects of context on acute drug response, with alcohol's reinforcing effects being

magnified in the presence of specific forms of environmental and social stressors (Fairbairn & Sayette, 2014; Hull, 1981; Steele & Josephs, 1990) so potentially driving additional consumption. Finally, in the domain of decisional processes, the same immediate consequence of consuming alcohol might be judged differentially depending on the context in which alcohol is consumed, with both positive/desirable as well as negative/undesirable consequences of drinking being perceived as differentially weighty depending on the drinking occasion (Stevely, Holmes, & Meier, 2020; Vuchinich & Heather, 2003).

For years researchers both within and outside addiction science have constructed multi-axial frameworks for organizing and understanding contextual influences on behavior, so aiming towards chipping away at the colossal task of a comprehensive taxonomization of environmental features (Davis & Tunks, 1991; Moos, 1973; Parrigon et al., 2017; Price & Blashfield, 1975; Rauthmann et al., 2014). Currently within the field of addiction science, there exists no unified theoretical framework for operationalizing and organizing key elements of drinking contexts. Recent contributions propose initial organizational models (Stanesby et al., 2019; Stevely, Holmes, & Meier, 2020). Stevely et al.'s (2020) mapping review highlighted several interrelated and commonly reoccurring features of drinking contexts that are typically studied in the alcohol literature. These features are broad and encompass a mix of person-level characteristics (e.g., motives, affect, craving), interpersonal characteristics (e.g., quality and length of relationships of individuals present), and environmental-level characteristics (e.g., venue location). While this work represents a crucial step towards the characterization of drinking contexts, it also highlights just how far-reaching and heterogeneous context definitions can be, thus reifying the need for a more precise focus as we seek to clarify the contribution of these key environmental factors. In the current study we build on these prior contributions, presenting a novel conceptual framework

aimed at moving towards a comprehensive and precise understanding of immediate environmental influences on drinking.

The SPAIS Framework

Our aim in developing the SPAIS framework was to present a novel model for identifying and organizing exogenous, objectively measurable characteristics of situations likely to impact alcohol consumption. The process of framework development proceeded in two stages. First, a literature search was conducted aimed at providing a comprehensive view of prior empirical studies that have examined associations between contextual characteristics and drinking outcomes. Second, and informed by previously proposed models of contextual influences on behavior (Moos, 1973; Parrigon et al., 2017; Price & Blashfield, 1975; Rauthmann et al., 2014; Stevely, Holmes, & Meier, 2020), variables were organized into facets based on their characteristics. In selecting categories for inclusion in our framework, a proposed contextual dimension was required to meet three criteria: a) Identified in prior research as a dimension potentially relevant to drinking outcomes (our dimensions were explicitly a-theoretical; we sought to build upon extant empirical work); b) Discrete, in that dimensions were differentiable/non-overlapping with each other; c) Observable, in that they did not require participants' interpretations (e.g. perceived social familiarity) or internal experiences (e.g. participants' moods) but rather reflected attributes of the external environment.

Regarding the literature search of empirical studies, several discrete themes emerged within our review of research exploring contextual elements in relation to drinking behavior (see Table 1). Specifically, prior studies indicate important influences for *physical* characteristics of drinking environments, with heavy consumption more likely in venues characterized as bars and clubs (Clapp et al., 2003; Kypri et al., 2010), as well as in physical spaces featuring dim lighting

(Buvik & Rossow, 2015), prominent alcohol advertisements, and alcohol bottles on display (Courtney et al., 2018; Puac-Polanco et al., 2020). Research also indicates a potential influence for *social* characteristics of the drinking environment, with heavy drinking being more likely in contexts characterized by heavy-drinking peers (Clapp & Shillington, 2001), mixed-gender gatherings (Sykes et al., 1993; Tabernero et al., 2019), as well as large crowds that foster a sense of anonymity (Lewis et al., 2011; Reed et al., 2013). Initial evidence suggests that drinking contexts are linked with higher consumption when also featuring distracting *activity* simultaneous with drinking, including dancing, drinking games, and sports (Johnson et al., 1998; Pennay et al., 2021 Zamboanga et al., 2014). Finally, regarding *timing*, research indicates consumption levels are higher on occasions when negative drinking consequences (e.g., hangover, intoxicated impairment) might be perceived by drinkers as less problematic, including on weekends and holidays (Patrick et al., 2016; Stevely, Holmes, & Meier, 2020).

This process ultimately yielded a novel five-factor framework for taxonomizing drinking contexts, with domains that correspond loosely to the where, what, when, how, and (with) whom of alcohol consumption. Specifically, we propose a novel SPAIS framework, organizing contexts according to the following categories: **S**chedule/timing, **P**hysical characteristics, **A**ctivity/entertainment, **I**nterpersonal/social factors, and **S**ubstance/drink characteristics. In consolidating evidence regarding contextual influences on drinking from across research paradigms, the SPAIS model seeks to provide a framework for holistic examination of environmental impacts on drinking behaviors, recognizing that the factors act not in isolation, but in concert.

Methodological Challenges

Of note, while offering an informative starting place in the examination of context, extant empirical research has involved methodological limitations. These include a disproportionate representation of social (vs. problem) drinkers (Dawson, 2000; Gonzalez & Skewes, 2013), as well as a tendency to focus on a single contextual feature while neglecting potential confounding effects of other elements within the same domain (Stevely, Holmes, & Meier, 2020). Thus, our understanding of context is as yet somewhat piecemeal.

The tendency of prior studies to focus on individual contextual features in isolation might be attributable, in part, to methodological challenges inherent to the study of context. Contexts are innately complex, featuring multiple discrete components (e.g., 30+ identified in review by Stevely, Holmes, McNamara, et al., 2020). Asking participants to identify and provide information on multiple contextual features in-vivo represents a significant burden unlikely to yield precise data. Further, and importantly, the same context-level factors theorized to exert such a powerful influence on drinking, including level of distraction (Steele & Josephs, 1990), self-awareness (Hull, 1981), and salience of social norms (Maisto et al., 1999), also all can exert powerful effects on an individual's approach to a self-report assessment completed in-vivo. It is thus unsurprising that much prior research examining drinking contexts has relied on retrospective recall methods, in which participants report on drinking in aggregate during retrospective laboratory assessment (Clapp et al., 2006; Lewis et al., 2011; Stevely, Holmes, McNamara, et al., 2020). Added to these are widely known challenges introduced by alcohol consumption, where cognitive and memory impairment linked with excessive consumption not only impact an individuals' ability to self-report on drinking, but also further complicate the already formidable task of objective contextual reporting (Northcote & Livingston, 2011; Weissenborn & Duka, 2003; White, 2003).

Concerns exist that observed relationships between drinking and context in prior studies might reflect, at least in part, confounds from common methods variance linked with shared sources of noise for self-reported predictor and outcome.

In sum, when it comes to capturing the interplay between alcohol consumption and context, our standby self-report measures can often fall short. We therefore as yet lack a comprehensive understanding of effects of setting that extends across contextual features and individuals with variable drinking patterns.

The Current Study

In the present research we employ novel objective ambulatory assessment methods to test a multi-axial SPAIS framework for understanding contextual influences on drinking behavior. We examine these contextual dimensions using methods aimed at moving beyond self-reports and so circumventing confounds linked therewith. Specifically, we explore contextual effects through a database comprising thousands of photographs of everyday life, featuring participants ranging from those with normative consumption to individuals with AUD. Computer vision methods were used in combination with human coders to extract multiple discrete contextual features from photographic images, while transdermal alcohol biosensors continuously assess participants' alcohol consumption in their day-to-day drinking settings. In broad terms, the primary aim of this research is to explore multiple objectively assessed environmental features as predictors of participants' acute consumption levels in everyday life. A secondary aim of this project was to explore whether the relationship between drinking contexts and drinking outcomes differ depending on disordered drinking patterns.

Methods

Transparency and Openness

We report how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in this ambulatory research (for additional measures unrelated to the current analyses, see supplementary material; Caumiant et al., 2023; Bresin & Fairbairn, 2019; Fairbairn et al., 2018). All data and code needed to replicate results are available at: https://osf.io/9x36v/?view_only=d46ef88999354d1bb09cf2b670967ae9 (Ariss et al., 2024). Study design and hypotheses were pre-registered prior to data analysis: https://osf.io/hrpka (Ariss & Fairbairn, 2022); of note, the study involved both exploratory and confirmatory primary aims. Procedures were approved by the University of Illinois at Urbana-Champaign Institutional Review Board (IRB Protocol Number 16263) under the study title *Understanding Alcohol Reinforcement in Social Context*.

Participants

The current research leveraged data collected from two ambulatory study samples. The first sample was drawn from research recruiting non-problem drinkers (Sample 1; N=48) and the second from individuals with AUD (Sample 2; N=60). The samples are combined here as studies employing nearly identical photographic prompting and alcohol assessment procedures, yielding a pooled dataset with strong statistical power for capturing contextual effects and substantial representation of variable drinking problem levels.

Participants from both studies were recruited through advertisements posted in the local community, online advertisements, and friend referrals. Subjects were excluded if they qualified for any of the following criteria: (a) <21 years old; (b) a diagnosis of a mental disorder (e.g., schizophrenia, bipolar disorder, major depressive disorder); (c) reporting being uncomfortable with the procedures of the study (e.g., wearing the transdermal sensor in public); (d) currently seeking treatment for an alcohol use disorder; (e) using illicit drugs. In addition, for Sample 1,

participants were excluded if they demonstrated medical or psychiatric symptoms for which the consumption of alcohol is contraindicated (see Fairbairn et al., 2018) and, for Sample 2, reported history of traumatic brain injury.[1] The full sample consisted of 108 drinkers (M_{age} = 22.59, SD= 2.51). Of participants, 49% identified as female, 51% as male, 61.11% were White/Caucasian, 19.44% Asian, 10.19% African American, 13.89% Hispanic, 1.85 % Pacific Islander, and 3.70% identified as Other or Multiracial. Demographics subdivided by study sample are presented in Table 2. Prior publications have examined other elements of ambulatory data for Sample 1, including social anxiety, social familiarity, and mood (Bresin & Fairbairn, 2019; Caumiant et al., 2023; Fairbairn et al., 2018) . The current report is the first to examine contextual features beyond social familiarity for Sample 1, and the first report of any kind based on data yielded from Sample 2. Power analyses were conducted in G*power 4 software according to a repeated measures univariate model for examining within-subjects effects and within-by-between interactions. Results indicated the dataset provides 80% power to detect main effects of contextual factors on drinking levels that are small in magnitude (R = .077) and interactions between drinking problem severity levels and contextual effects that are small to moderate in magnitude (R = .141; see Table S1; Faul et al., 2007).

Study Procedure

Eligible participants were invited into the laboratory for an ambulatory orientation visit. Upon arriving in the lab, participants signed study consent and provided breathalyzer readings to ensure a 0.00% BAC (Intoximeters Alco Sensor IV). Participants were then fitted with a transdermal alcohol biosensing ankle monitor (SCRAM; Alcohol Monitoring Systems, Inc., Littleton, CO). SCRAM was chosen as a widely researched transdermal alcohol sensor,

[1] This exclusion criterion was necessary because participants completed an electroencephalogram task during one of the laboratory visits which is unrelated to the ambulatory procedure.

producing readings highly correlated with BACs (Fairbairn et al., 2019, 2020; Fairbairn & Kang, 2019; Leffingwell et al., 2013; Yu et al., 2022). Also during this baseline visit, participants completed questionnaires assessing demographics and alcohol use patterns. Lastly, participants downloaded a smartphone application generating surveys prompted at random intervals multiple times a day during ambulatory assessment. Procedures for contextual and alcohol use assessment were similar across the two samples, although ambulatory procedures employed for Sample 2 were extended and also intensified to increase density of drinking episodes captured in the final dataset (7 days of assessment for Sample 1, 14 days of assessment for Sample 2; 6 random prompts/day for Sample 1, 8 prompts/day for Sample 2).

Within ambulatory surveys, participants were asked to report on their mood, the number of drinks they had consumed since they last filled out the survey, and to provide a photograph of their surroundings. In providing photographs, participants were presented with the following prompt: “Take a picture of your environment right now. Take a picture of what you see.” Participants were instructed to take photographs that captured as much as possible of the current context, leaning back and zooming out where necessary (see Figure 1). For each picture taken, participants were invited to provide a “caption”—to briefly describe the scene and what they were doing. Participants attended two additional laboratory sessions, the first of which was scheduled at the study midpoint and functioned as an ambulatory “check in” visit involving compliance feedback and photograph review, and the second of which functioned as a “close-out” visit. In the case of both samples, procedures featured in-lab experimental tasks unrelated to the current ambulatory analysis (Fairbairn et al., 2018; Kang, 2022). Participants received compensation for attending laboratory visits and wearing the SCRAM monitor, and an additional

monetary bonus for responding to at least 70% of prompted surveys within 15 minutes of the prompt sounding.

Measures

Alcohol Consumption

Estimates of participants' drinking levels were obtained from alcohol biosensors, which provide indexes of Transdermal Alcohol Concentration (TAC) by assessing the quantity of alcohol diffused through the skin. SCRAM TAC readings were converted into estimated Blood Alcohol Content (eBAC) values using a machine learning model whose output has demonstrated strong correspondence with BAC levels in laboratory-based testing (Fairbairn et al., 2020; Fairbairn & Bosch, 2021). Context-linked alcohol consumption (operationalized as peak eBAC achieved in the time period following the capture of a given drinking context and prior to the time at which eBAC has returned to zero) was examined to determine the effect of drinking contexts on peak eBAC values achieved over the course of a drinking episode. Peak eBAC was selected as an outcome accounting for the lag between the time alcohol is ingested and the time it is circulated throughout the body via the blood (giving rise to intoxication), thus accounting for the time it takes for effects of the drinking linked with a specific context to manifest through physiologically based eBAC assessment. Self-reports of alcohol consumption derived from ambulatory surveys (e.g., "How many alcoholic drinks have you had since the last time you filled out a survey?") were used to validate eBAC values.

Drinking Context Characteristics

Photographs were assessed for contextual characteristics according to the SPAIS model. "Schedule"-related variables were operationalized as features linked with timing of the drinking context, "Physical" as characteristics of the venue or location, "Activity" as entertainment or task

simultaneous with drinking, “Interpersonal” as observable social dimensions of the drinking setting, and “Substance” as specific characteristics of available substances in the context, including alcohol and other drugs. Three “Schedule”-related context characteristics were coded including: a) day of the week; b) time of day; c) day of year. Four “Physical” context characteristics were coded including: a) physical setting; b) lighting levels; c) types of bottles on display; d) presence of alcohol advertisements. Four “Activity” context characteristics were coded including: a) dancing; b) drinking games; c) meal consumption; d) sports entertainment. Three “Interpersonal” context characteristics were coded including: a) total number of people; b) presenting gender of individuals; c) engagement in virtual social interactions (e.g., over Zoom). Lastly, five “Substance”-related contextual features were coded including: a) type of alcoholic beverage consumed; b) number of drinks actively being consumed by individuals; c) overall number of drinks (both empty and actively being consumed drinks); d) types of substance (cigarettes and vapes, cannabis and related products such as bongs and grinders, pill bottles, or a combination of the aforementioned categories); e) number of substances captured. A complete list of SPAIS dimension sub-facets and methods of measurement is provided in Table S2.

In coding photographs, we employed computer vision software. Photographs were processed using Amazon Rekognition (Amazon Web Services; AWS), a software that was chosen for its documented tools for detecting specific contextual elements (objects, people, and environments) relevant to the aims of this research (https://docs.aws.amazon.com/?nc2=h_ql_doc_do). In addition, to ensure Rekognition accuracy, a team of human coders reviewed and extracted all features by manually examining each photograph and corresponding captions. Finally, when Rekognition output failed to include information relevant to a subset of contextual characteristics, data provided by human coders

served as the primary measure (see Table S2). Regarding human coding, all drinking context variables were double-coded by at least two independent raters blind to one another's assessments (agreement between raters, κ=0.78). Disagreements were resolved by discussion. Computer vision software yielded an average agreement of 89% (κ=0.44) when compared with final ratings of the same photographs as designated by human coders.

Problem Drinking Severity

Participants in both studies completed the Short Inventory of Problems (SIP-2R; Miller et al., 1995). This 15-item Likert questionnaire assesses five major domains of alcohol-related harm including social, interpersonal, intrapersonal, physical, and impulse control (Kiluk et al., 2013; Miller et al., 1995). SIP represents a continuous alternative to categorical indexes such as SCID, and scores obtained from the SIP have been used clinically to determine the severity of a person's drinking (Feinn et al., 2003). Table S1 displays mean SIP-2R scores subdivided according to study sample.

Data Analytic Plan

Our analyses followed the pre-registered plan in all ways with the exception of the following deviations: 1.) we opted to use SIP-2R status as opposed to AUD status to better reflect the range of problem severity that may be experienced in relation to drinking as opposed to binary diagnostic status that may fail to capture this heterogeneity; 2.) multivariate models presented here focus on accounting for covariance within clusters of predictors judged as most conceptually similar and thus likely to capture overlapping variance in drinking behaviors (i.e., sub-facet level multivariate model; see below), in addition to offering a more stringent test of study hypotheses. Due to the number of variables and also issues with collinearity, a single model containing all SPAIS clusters simultaneously failed to converge and is thus not included

here (McClelland & Judd, 1993; Yoo et al., 2014); 3.) we assessed peak eBAC over the entire drinking session as opposed to limiting analyses to a single context due to concerns regarding redundancy in context measures, as well as lag times between participants visiting contexts and eBAC outputs. Note that results of bivariate analyses, described as Aim 1.1 in pre-registration materials, are presented in Table S3 but do not form the primary analyses reported below (primary analyses reflect Aim 1.2 from the pre-registration materials).

Data analysis focused on contexts in which alcohol was being consumed, operationalized as eBAC>0.00% at the time a photograph was taken. The total number of photographs collected was 6,259 (1,544 in Sample 1 and 4,715 in Sample 2), 1,422 of which were identified as photographs associated with a positive eBAC value at the time the photograph was taken.[2] Multilevel modeling was used to account for the clustering of observations within individuals. All predictors in the same SPAIS sub-facet were examined together in a single combined multivariable model, thus providing information on effects of each context characteristic independent of other factors likely to be highly related. For each model, all context-level characteristics were initially estimated as random at level 2, with the most complex model structure reaching convergence criteria represented in reported results; in situations where initial models failed to converge, random slopes reflecting context-level characteristics were removed individually until a model reaching convergence criteria was produced (Barr et al., 2013; Nezlek, 2012). To supplement primary multivariate models, we conducted additional bivariate models examining each variable independently as a predictor of peak eBAC to capture uncontrolled effects (full results in online supplement).

[2] Of note, 8 participants did not provide photographs of drinking contexts due to: 1) not drinking alcohol, 2) not taking context photos when out drinking, 3) experiencing photo-data upload issues.

Hierarchical generalized linear models assuming a binomial distribution and robust standard errors were employed to account for non-normally distributed eBAC residuals (Raudenbush & Bryk, 2002). Drinking problem severity scores were entered as a moderator at level 2 to determine the extent to which the relationship between drinking contexts and drinking outcomes differs according to alcohol problem severity. Study sample was added as a covariate in all models. For predictors featuring multiple discreet categories results omnibus F tests reflecting variance across all levels of the predictor are provided. To correct for the potential effects of alpha inflation due to multiple testing, the Benjamini–Hochberg approach was employed to control the false discovery rate (FDR), which was set at .05 (Benjamini & Hochberg, 1995).

Results

Overall Compliance, Picture Data, And Alcohol Consumption

Rates of compliance were high; with Sample 1 participants responding to an average of 93.1% of prompts (SD = 10.6) and Sample 2 participants responding to an average of 76.57% of prompts (SD = 18.08). All but 3 participants (94%) in Sample 1 and all participants (100%) in Sample 2 engaged in at least one drinking episode. On average, Sample 1 participants had at least one positive eBAC reading on 4.08 days (SD = 2.22) whereas participants in Study 2 had at least one positive eBAC reading on 8.18 days (SD = 3.81).

Daily self-reports of drinking corresponded closely with eBAC readings. The correlation between daily self-reports of the total number of drinks consumed and daily summed eBAC was moderate in magnitude for both studies: Sample 1, $r = 0.707$, $p < 0.0001$; Sample 2, $r = 0.510$, $p < 0.0001$. Furthermore, combining responses across both studies, the momentary drinking data revealed that when participants indicated that they were currently drinking, their eBAC was also

positive 75.21% of the time. When participants indicated that they were not drinking, their eBAC readings were zero 88.65% of the time.

Schedule Characteristics and Alcohol Consumption

Results of bivariate analyses, in which each Schedule characteristic is entered independently as a predictor of peak eBAC, are presented in Table S3. Regarding results of primary analyses, multivariable models including all Schedule variables entered together in a single model indicated significant effects of time of day, t (1319) = 2.43, p = 0.015, day of the week, t (1319) = 3.17, p = 0.002, and special occasion days, t (1319) = 4.5, $p < 0.0001$, on peak eBAC levels. Specifically, after accounting for the other covariates in the model, evening drinking (vs. day drinking) was associated with a 13% increase, weekend (vs. weekday) with a 16% increase, and celebratory drinking (vs. non-celebratory drinking) with a 48% increase in peak eBAC levels. Full results of multivariable models are presented in Table 3 and Figure 2.

Physical Characteristics and Alcohol Consumption

Results of bivariate analyses are presented in Table S3. Regarding results of primary analyses, multivariable models including all Physical variables entered together in a single model indicated a significant main effect for setting, F (6,248) = 9.78, $p < 0.0001$ and beverage container on display, F (3,163) = 6.80, p = 0.0002, in predicting peak eBAC levels (see Table 3 and Figure 2). No significant main effect was detected for lighting, F (3,163) = 0.99, p = 0.397 and alcohol advertisements, t (1309) = 1.79, p = 0.074. Examination of contrasts indicated that, after accounting for the other covariates in the model, drinking in all other settings was associated with a 20%-44% decrease in peak eBAC when compared to drinking in a bar or club (see Table 3 for contrasts). Further, compared to settings with only alcoholic bottles on display,

the presence of a mix of alcoholic and non-alcoholic bottles was associated with a 16% increase, and the absence of bottles with a 10% decrease, in peak eBAC.

Activities and Alcohol Consumption

Results of bivariate analyses are presented in Table S3. Regarding results of primary analyses, multivariable models including all Activity variables entered together in a single model indicated a significant effect for dancing, t (1318) = 4.16, $p < 0.0001$, drinking games, t (1318) = 3.95, $p < 0.0001$, and meal consumption, t (1318) = 3.11, $p = 0.002$, on peak eBAC (see Table 3 and Figure 2). Specifically, after accounting for the other covariates in the model, drinking in contexts in which dancing took place were associated with a 63% increase, playing drinking games with a 46% increase, and the presence of a meal with a 19% increase in peak eBAC levels. There was no significant effect of the availability of sport-related entertainment on alcohol consumption, t (1318) = 1.47, $p = 0.142$.

Interpersonal Characteristics and Alcohol Consumption

Results of bivariate analyses are presented in Table S3. Regarding results of primary analyses, multivariable models including all Interpersonal variables entered together in a single model indicated a significant main effect for presenting gender composition of group members, F (2,126) = 5.13, $p = 0.007$, and crowdedness, t (789) = 2.23, $p = 0.026$, on peak eBAC (see Table 3 and Figure 2). Specifically, examination of contrasts indicated that, after accounting for the other covariates in the model, drinking in mixed-gender groups was associated with a 14% increase in peak eBAC compared to all-male presenting groups. Further, each additional person present in a drinking context was linked with a 1% increase in peak eBAC. Virtual interaction was not significantly related to peak eBAC, t (789) = -1.23, $p = 0.218$.

Substance Characteristics and Alcohol Consumption

Results of bivariate analyses are presented in Table S3. Regarding results of primary analyses, multivariable models including all Substance variables entered together in a single model indicated no significant main effects for any of the substance predictors in predicting peak eBAC (see Table 3 and Figure 2). Specifically, the main effect of active drinks did not meet the threshold of for significance according to corrected alpha levels, t (64) = 2.33, p = 0.023 (adjusted p<.008; Benjamini & Hochberg, 1995). Similarly, none of alcohol type, F (4,10) = 0.59, p = 0.679, overall number of drinks, t (64) = -1.20, p = 0.233, substance type, F (3,6) = 2.15, p = 0.199, and overall number of substances, t (64) = 0.49, p = 0.628, were significantly related to peak eBAC.

Drinking Problem Severity, SPAIS Characteristics, and Alcohol Consumption

Follow-up analyses examining the moderating effect of problem drinking on the relationship between each of SPAIS characteristics predictors and alcohol consumption revealed no significant interactions between alcohol problem severity and any of Schedule, Physical, Activities, Interpersonal, and Substance characteristics in predicting peak eBAC levels. See Table S4 for full results.

Discussion

I am myself, plus my surroundings, and if I do not preserve the latter, I do not preserve myself.

—Ortega y Gasset, *Meditations on Quixote,* 1914

Behavior does not occur in a vacuum, but is rather inevitably intertwined with the contexts individuals inhabit. A growing body of work within addiction science has sought to isolate contextual features (Stanesby et al., 2019; Stevely, Holmes, & Meier, 2020), yet methodological and also taxonomical challenges endure. In the current study we examine a

novel multi-axial organizational framework for understanding contextual effects. Examining a sample of individuals comprising those with AUD as well as social drinkers, we employ objective assessment techniques for capturing both alcohol consumption and context, so circumventing challenges associated with common methods variance for self-reports while also permitting the assessment of unique effects of individual contextual features above-and-beyond related variables. Results indicated multi-faceted links between elements of drinking context and peak intoxication, with effects spanning across physical, interpersonal, activity/entertainment, and scheduling domains. Specifically, drinking in bars/clubs was associated with a 20-44%, special occasion drinking with a 48%, and drinking games with a 63% increase in peak eBAC levels. The direction of these effects was in line with our registered hypotheses. Also in line with hypotheses, in the social domain, the introduction of each new person into a drinking context was associated with a 1% increase in peak eBAC. Evening drinking, weekend drinking, drinking in establishments featuring alcohol bottles on display, as well as drinking combined with meal consumption and dancing were also linked with higher eBAC levels. Contrary to predictions, we found no significant increase in drinking linked with male-presenting groups, with mixed-gender groups being instead linked with increased consumption in the current study. Furthermore, and contrary to predictions, no significant unique effects of substance characteristic variables were observed. Finally, effects emerged as consistent across individuals with variable use patterns, with no differential effects of context across social and problem-level drinkers.

Results might carry a range of implications, including for the conceptual understanding of problem drinking, the methodological study of context, as well as within the realm of prevention and intervention. Rates of relapse to alcohol use among those in treatment for AUD

are high, with urges to use often emerging suddenly and in response to immediate environmental cues (Marlatt, 1996). Although some of these triggers are likely to be idiosyncratic and also readily identifiable by individual drinkers, yet others have emerged as common across drinkers and may further be difficult for individual users to consciously parse (Otten et al., 2014). This study's findings, though preliminary, indicate that the relationship between drinking contexts and drinking outcomes appears to stand irrespective of an individual's problem drinking severity. Thus, by identifying specific contextual features significantly linked with problematic use across drinkers, findings of this research reveal potentially modifiable change targets for alcohol use interventions, providing novel structural as well as individual-level points of intervention for addressing substance use behaviors that have often emerged as difficult to alter via other means.

In the conceptual domain, these findings point to a role for a variety of elements of context in shaping drinking behavior, so potentially elucidating key psychological mechanisms promoting drinking in real-world contexts. In the realm of attention/cognition, findings indicate that environments involving prominent alcohol cues (e.g., alcohol bottles on display) were linked with increased consumption, as were environments linked with distraction/activity simultaneous with drinking. In addition, contexts likely to spark social discomfort/anxiety were linked with increased alcohol intake (e.g., crowds), as were occasions likely to alter perception of negative consequences linked to drinking (e.g., special occasions/weekends). Thus, through offering a nuanced view of the more minute elements of everyday drinking context linked with risky intake, results of this study represent an advance in our understanding of risk and protective factors for the development and maintenance of AUD (Buckner & Heimberg, 2010; Kohen et al., 2023; Marlatt, 1996).

Finally, in addition to the conceptual contributions of this work, it is worth noting its implications in the domain of methodology. Everyday contexts can be extraordinarily complex, featuring multiple discreet yet interrelated elements (Blake et al., 2020). Relying on participants to report accurately on contextual features can give rise to response fatigue and subjective bias, potential confounds that can be exacerbated with the introduction of cognitive disruptions imposed by intoxicating substances (Weissenborn & Duka, 2003). This study offers initial proof of concept for the use of photographs and computer vision technology as a means of capturing context, potentially indicating that, in research as in other domains, a picture can sometimes be worth a thousand words. Furthermore, the transdermal alcohol sensors used in this research provide a continuous estimate of BAC levels in real time, circumventing challenges linked with both self-reports and other methods for assessing drinking (Wang et al., 2019). In sum, through this research we offer a new paradigm and framework for the exploration of context in addiction science.

Limitations of this research should be noted. First, measures in this study were designed to capture the theorized temporal ordering of effects, with eBAC outcomes defined as peak intoxication level reached subsequent to the relevant assessment of context. Nonetheless, in the absence of laboratory assessment or assigned ambulatory contexts, this study is capable of modeling only associations and causality cannot be inferred. Second, as the first test of SPAIS, the current study focuses specifically on contextual factors with SPAIS sub-facets, examining individual-level characteristics only as these related to problem drinking status. However, an exploration of interactions between individual, sociodemographic, and contextual features represents an important direction of future research (e.g., see Caumiant et al., 2023), as does an examination of interactions between

contextual dimensions both within and between SPAIS sub-facets. Related, given that the pooled sample was primarily of college drinking age, generalizability of the present research is limited outside of this age group, and future research should aim to replicate study findings across the lifespan. Third, photos employed in the current study provide one view/perspective of context—i.e., features in the participants' immediate sight line. Note that participants in the current study received instruction to capture as much of the context as possible in photos, and photographic feature coding was supplemented with human coding of participant-provided text/captions. Nonetheless, the absence of a given contextual feature from a photograph does not clearly indicate that the feature was not present within the context; in other words, while our use of photographic measures of environment may provide information regarding the *presence* of a given contextual feature, the omission of a feature from a given photograph does not necessarily document its *absence.*

Finally, we selected transdermal biosensors for use in the current research as a passive measurement modality unlikely to suffer from specific psychological and distraction-related artifacts linked with self-reports—artifacts judged as a potentially problematic confound here given our focus on context. Nonetheless, as with any measurement modality for assessing drinking, BAC readings derived from transdermal alcohol sensors are not precise and are vulnerable to sources of noise (Leffingwell et al., 2013; Luczak & Rosen, 2014). For instance, transdermal sensors may produce variable readings in response to a variety of individual difference factors (e.g. skin thickness, perspiration rate, etc.), as well as environmental characteristics (e.g. physical movement, environmental alcohol, etc.). Although well-validated to detect drinking outcomes across a diverse range of real-world drinking contexts (Fairbairn et al., 2019, 2020; Fairbairn & Kang, 2019; Leffingwell et al.,

2013; Yu et al., 2022), future researchers may wish to develop strategies for identifying external influences on transdermal outputs and accounting for such artifacts in statistical models.

In sum, this research points to the importance of considering characteristics of not only the drinkers themselves, but of timing, physical space, activity, and companionship within drinking contexts for predicting intoxication levels. Implications of this work span across methodological and conceptual domains, providing proof of concept for the use of novel technology for the examination of real-world drinking contexts. Findings may also inform prevention and intervention programs aimed at stemming problematic use, shedding light on factors driving alcohol consumption and thus potential mechanisms of risk and maintenance for AUD.

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Table 1

Select references consulted in developing SPAIS framework

Dimension	Variable	Select References	Contextual Conclusions
Schedule	Time of day	Mustonen et al. (2016)	Night corr. drinking
		Reed et al. (2013)	Night corr. drinking
	Day of week	Hoeppner et al. (2012)	Weekend corr. drinking
		Patrick et al. (2016)	Weekend corr. drinking
		Tremblay et al. (2010)	Weekend corr. drinking
	Day of year (e.g., holiday)	Glindemann et al. (2007)	Holiday corr. drinking
		Mäkelä et al. (2005)	Holiday corr. drinking
Physical	Lighting	Wilkinson (2017)	Darkness corr. drinking
		Carlini et al. (2014)	Mixed findings
		Buvik & Rossow (2015)	Darkness corr. drinking
	Alcohol advertisement	Courtney et al. (2018)	Advertisement corr. drinking
		Kuo et al. (2003)	Advertisement corr. drinking
		Stockwell et al. (1993)	Advertisement corr. drinking
	Drinks on display	Puac-Polanco et al. (2020)	Drinks on display corr. drinking
	Setting	Clapp et al. (2003)	Setting(s) corr. drinking
		Kypri et al. (2010),	Setting(s) corr. drinking
		Rodriguez et al. (2016)	Setting(s) corr. drinking
Activity/entertainment	Drinking games	Bhullar et al. (2012)	Games corr. drinking
		Ehret et al. (2012)	Games corr. drinking
		Zamboanga et al. (2014)	Games corr. drinking
		Borsari (2004)	Games corr. drinking
	Dancing or dance floor	Carlini et al. (2014)	Dance floor(s) corr. drinking
		Clapp et al. (2009)	Dancing corr. drinking
		Hughes et al. (2012)	Dance floor corr. drinking
	Meal consumption	Hughes et al. (2012)	Food corr. drinking
	Sports entertainment	Pennay et al. (2021)	Sports corr. drinking
Interpersonal/social	Group Size	Lindman (1982)	Social group corr. drinking
		O'Donnell et al. (2019)	Social group corr. drinking
		Reed et al, (2013)	Social group corr. drinking
		(Cullum et al., 2012)	Social group corr. drinking
		Lewis et al. (2011)	Social group corr. drinking
	Virtual	Ariss et al. (2023)	In-person corr. drinking

	Presenting Gender	Taberno et al. (2019)	Male group corr. drinking
		Sykes et al. (1993)	Male group corr. drinking
Substance/drink	Alcohol type	Dietze et al. (2017)	Variety corr. drinking
		Naimi et al. (2007)	Beer corr. drinking
	Active drinks	Clapp & Shillington (2001)	Active drinks corr. drinking
	Overall drinks	Labhart et al. (2017)	Longer duration corr. drinking
	Substance number	Lipperman- Kreda (2018)	Increased #substances corr. drinking
	Substance type	Clapp et al. (2006)	Illicit drugs corr. drinking

Note. "corr." = correlated with

Table 2

Descriptive characteristics of the samples

	Sample 1 (n=48)	Sample 2 (n=60)
Gender		
n(%) Male	24 (50 %)	31 (51.67 %)
n(%) Female	24 (50 %)	29 (48.33 %)
Race		
n(%) White	27 (56.25 %)	39 (65.0 %)
n(%) African American	6 (12.5 %)	5 (8.33 %)
n(%) Asian	8 (16.67 %)	13 (21.67 %)
n(%) Pacific Islander	1 (2.08 %)	1 (1.67 %)
n(%) American Indian or Alaska Native	--	1 (1.67 %)
n(%) Multi-racial	--	1 (1.66 %)
n(%) Other	3 (6.25 %)	--
Ethnicity		
n(%) Hispanic	3 (6.25 %)	12 (20.0 %)
n(%) Not Hispanic	--	48 (80.0 %)
Age		
mean (sd)	22.56 (1.99)	22.62 (2.88)
SIP-2R scores		
mean (sd)	2.21(2.16)	7.72(6.99)

Table 3

Multivariate models examining associations between SPAIS predictors and alcohol consumption.

Predictor of eBAC	*b*	*t*-value	*p*-value	95%CI	Odds
Schedule					
Evening	0.12	2.43	0.0154	[0.02, 0.22]	1.13
Weekend	0.15	3.17	0.0015	[0.06, 0.24]	1.16
Special occasion	0.39	4.50	<0.0001	[0.22, 0.56]	1.48
Study sample	0.15	2.21	0.030	[0.02, 0.29]	1.17
Physical					
Setting					
Private residence	-0.45	-6.75	<0.0001	[-0.59, -0.32]	0.64
Restaurant	-0.23	-2.59	0.0100	[-0.41, -0.06]	0.79
Outdoor	-0.22	-2.48	0.0137	[-0.39, -0.05]	0.80
Car	-0.33	-3.52	0.0005	[-0.53, -0.15]	0.72
Work	-0.58	-5.08	<0.0001	[-0.80, -0.35]	0.56
Other	-0.28	-3.46	0.0006	[-0.45, -0.12]	0.76
Lighting					
Dark	0.02	0.35	0.7251	[-0.11, 0.15]	1.02
Colored neon lights	0.12	1.53	0.1284	[-0.03, 0.25]	1.13
Light	0.05	1.19	0.2435	[-0.03, 0.13]	1.05
Beverage containers					
No bottles	-0.10	-1.98	0.0495	[-0.21, -0.0002]	0.90
Non-alcoholic	-0.12	-1.78	0.0772	[-0.26, 0.01]	0.89
Mix	0.15	2.15	0.0328	[0.01, 0.28]	1.16
Alcohol Signs	0.11	1.79	0.0737	[-0.01, 0.23]	1.12
Study sample	0.17	2.58	0.0115	[0.04, 0.29]	1.18
Activities					
Meal	0.17	3.11	0.0019	[0.06, 0.28]	1.19
Sports entertainment	0.12	1.47	0.1418	[-0.04, 0.28]	1.13
Dancing	0.49	4.16	<0.0001	[0.26, 0.72]	1.63
Drinking games	0.38	3.95	0.0001	[0.19, 0.57]	1.46
Study sample	0.17	2.77	0.0067	[0.05, 0.30]	1.19
Interpersonal					
Total number of people	0.01	2.23	0.0257	[0.001, 0.02]	1.01
Gender composition					
Female	-0.02	-0.45	0.6506	[-0.12, 0.08]	0.98

Mixed Gender	0.13	2.73	0.0073	[0.04, 0.22]	1.14
Virtual Interaction	-0.34	-1.23	0.2175	[-0.88, 0.20]	0.71
Study sample	0.28	3.47	0.0008	[0.09, 0.33]	1.09
Substance					
Substance Type					
Cigarettes and vapes	0.07	0.46	0.663	[-0.29, 0.42]	1.07
Pill bottles	-0.61	-1.89	0.107	[-1.40, 0.18]	0.54
Combination of substances	0.22	1.17	0.288	[-0.25, 0.69]	1.25
Alcohol type					
Wine	0.14	0.42	0.685	[-0.60, 0.87]	1.15
Beer	-0.17	-0.99	0.344	[-0.56,0.22]	0.84
Spirit	-0.32	-0.75	0.469	[-1.28,0.63]	0.73
Combination of alcohol	0.04	0.26	0.801	[-0.27,0.34]	1.04
Number of active drinks	0.12	2.33	0.023	[0.02, 0.23]	1.13
Overall number of drinks	-0.02	-1.20	0.233	[-0.04, 0.01]	0.98
Number of substances	0.01	0.49	0.628	[-0.03, 0.05]	1.01
Study sample	0.19	0.78	0.443	[-0.31, 0.69]	1.21

Note. All categorical variables were entered as dummy codes. The reference category for setting was "bar," the reference category for lighting was "dim," the reference category for beverage containers on display was "alcoholic bottles," the reference for alcohol signs was "no alcohol signs", the reference category for gender was "all-male," the reference category for type of interaction was "in-person", the reference category for time of day was "daytime," the reference category for day of week was "weekday," the reference category for day of year was "non-special occasion day", the reference category for meal was "no meal," the reference category for sports entertainment was " no sports entertainment," the reference category for drinking games was "no drinking games," and the reference category for dancing was “no dancing”, the reference category for alcohol type was “mixed drinks”, the reference category for substance type was “cannabis products”. Study sample was included as a covariate and represents the relative increase in the AUD sample compared to the non-AUD sample.

Figure 1

Example measures assessed through computer vision (solid-line boxes) and human raters (dotted-line boxes) within Sample 2 photographs. Participants whose photos are displayed above provided consent for dissemination and faces are obscured to further protect privacy of those depicted.

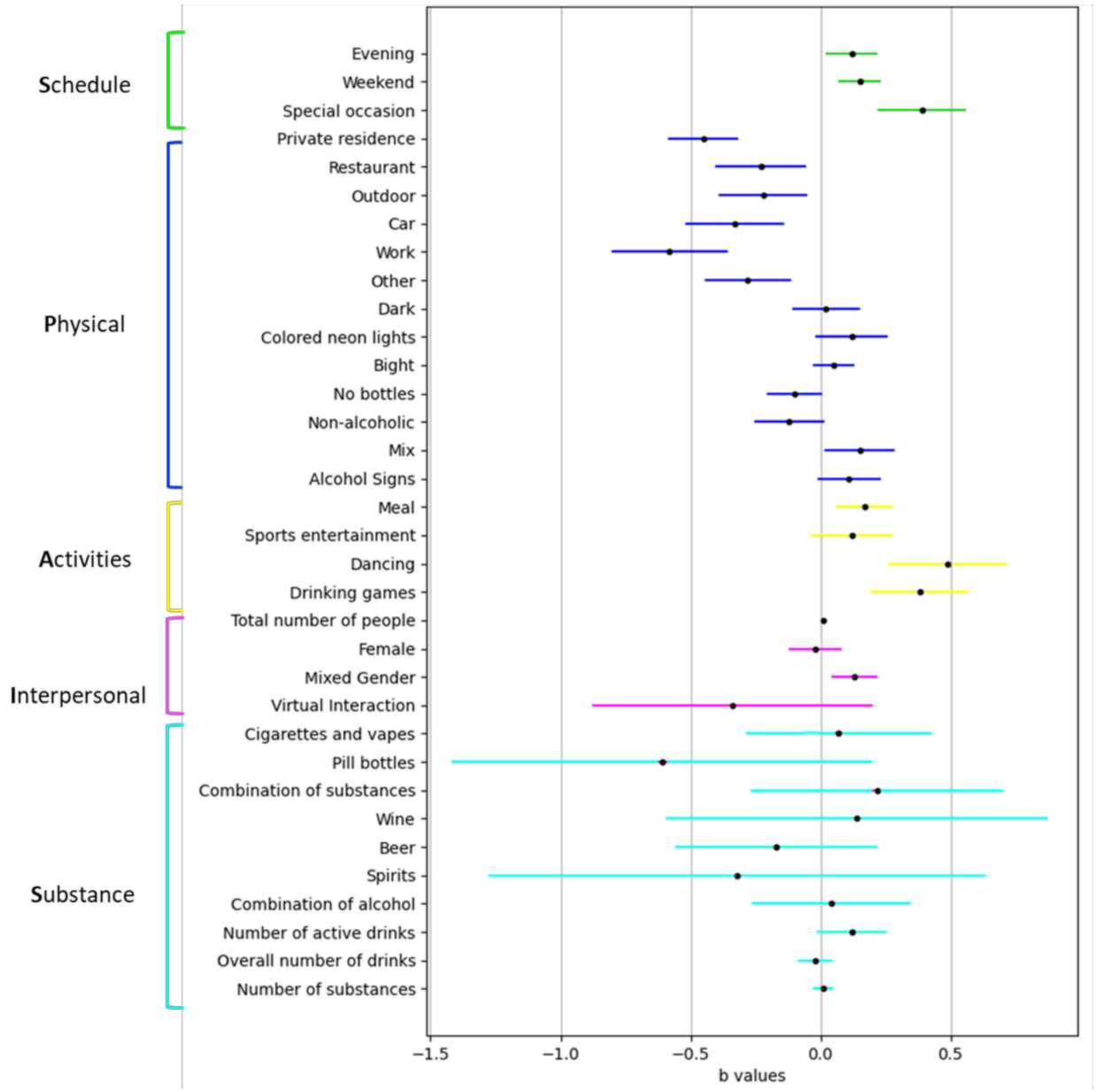

Figure 2
Plot of SPAIS predictor effects and corresponding confidence levels.