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Capturing habitualness of drinking and smoking behavior in humans

Lara A. Ray[a,b,c,*], Han Du[a], Erica Grodin[a], Spencer Bujarski[a], Lindsay Meredith[a], Diana Ho[a], Steven Nieto[a], Kate Wassum[a,c]

[a] University of California Los Angeles, Department of Psychology, Los Angeles, CA, USA
[b] University of California, Los Angeles, Department of Psychiatry and Biobehavioral Sciences, Los Angeles, CA, USA
[c] University of California Los Angeles, Brain Research Institute, Los Angeles, CA, USA

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ABSTRACT

Background: Recent findings suggest that overreliance on habit may be common in individuals diagnosed with addiction. To advance our understanding of habit in clinical samples and from behavioral measures, this study examines the interrelations between self-reported habit index for smoking and drinking as well as behavioral measures of intraindividual variability in smoking and drinking.

Methods: Treatment-seeking heavy drinking smokers ($N = 416$) completed the Self-Report Habit Index (SRHI) adapted for both smoking and drinking. "Behavioral habitualness" was computed from the degree of intraindividual variability in patterns of smoking and drinking over the past month. Using the 28-day Timeline-Follow Back (TLFB) interview, we derived two measures of intraindividual variability: interclass correlation (ICC) and autocorrelation [AR(7) coefficients].

Results: Self-report measures of habit were robustly associated with clinical severity of drinking and smoking with higher habit scores indicating greater severity of drinking and smoking, respectively. ICC and AR(7) coefficients, the behavioral measure of "patterness" and putative habit, were not associated with SRHI scores. While ICC for smoking was associated with higher nicotine dependence scores, this pattern was not found for drinking ICC and alcohol problem severity.

Conclusions: These results support the construct validity of the self-report measures of habit for smoking and drinking, as well as an initial evaluation of behavioral measure of smoking "patterness" as a potential proxy for habit smoking. Because habit represents a complex phenotype with limited clinical translation, additional studies capturing a wider range of substance use severity and coupled with brain-based validation methods are warranted.

1. Introduction

The use of substances, such as alcohol and nicotine, is often thought to reflect a decision making process that that takes anticipated consequences into account to guide behavior towards desirable goals. This goal-directed behavioral control is, thus, flexible, allowing one to readily adapt when circumstances change. But it is also cognitively taxing. An alternative, and more efficient, approach to executing routine behaviors is habits. Habits allow common behaviors to be executed more automatically on the basis of their past success, without thought of their consequences, freeing attention to be focused elsewhere. In other words, habit-driven behaviors are executed more automatically without careful consideration of their consequences (Graybiel, 2008), and are marked by an absence of goal-directed behavior (Vandaele and Janak, 2018). Thus, habits are typically defined as insensitivity to manipulations of the outcome or action-outcome contingency. There has been a great deal of interest in understanding the brain's habit networks and its implications for a host of behavioral disorders, including addiction (Dolan and Dayan, 2013; Malvaez and Wassum, 2018; Smith and Graybiel, 2016; Vandaele and Janak, 2018). Specifically, an overreliance on habit learning strategies may be phenotypically expressed in individuals diagnosed with addiction (Sjoerds et al., 2013). In the context of addiction, overreliance on habit may account for the continued drug use despite a host of negative consequences.

Basic neuroscience has implicated homologous brain regions across species in neural circuits subserving goal-directed and habitual actions (Balleine and O'Doherty, 2010), with the putamen and dorsolateral striatum playing a large role in the habitual control of behavior (Malvaez and Wassum, 2018). Further, the notion that habits are particularly "hard to break" in addiction may be in part due to maladaptive

* Corresponding author at: University of California, Los Angeles, Psychology Department, 1285 Franz Hall, Box 951563, Los Angeles, CA, 90095-1563, USA.
E-mail address: lararay@psych.ucla.edu (L.A. Ray).

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alterations in goal-directed brain systems (i.e., higher order prefrontal regions) (Morris et al., 2018), such that the individual can no longer revert to goal-directed strategy the face of adverse consequences.

While habits may play a critical role in addiction, its role may not be uniformly salient across stages of the addiction cycle. In other words, while habits represent a possible strategy for acting, such strategy may become more prominent at higher levels of addiction severity. For instance, it has been postulated that compulsive alcohol use is characterized by a shift of cue processing from ventral to dorsal striatum (Vollstadt-Klein et al., 2010). This notion is consistent with the incentive-sensitization model of addiction, whereby compulsive alcohol use is under control of the dorsal striatum (Everitt and Robbins, 2005). The transition to habit-driven behavior may be seen as compatible with the allostatic model of addiction, whereby later stages of addiction are characterized by compulsivity (Koob, 2014; Koob and Volkow, 2010). Compulsive use is thought to reflect the use of a substance despite the negative consequences associated with such use, which can be considered habitual use or the result of poor goal-directed decision-making.

As the neuroscientific understanding of goals and habits in the brain has expanded significantly (Dolan and Dayan, 2013), the translation of these findings to clinical populations remains a high priority area. Habit learning, and its underlying neurocircuitry, has been recently interrogated in clinical samples using neuroimaging tools (Grodin et al., 2018; Park et al., 2010; Ray et al., 2014; Sebold et al., 2017; Sjoerds et al., 2013). Neuroimaging is well-suited to provide a mechanistic understanding of habit circuits in clinical populations. Additional work has examined the behavioral correlates of habit in substance using populations (Ersche et al., 2016; Luijten et al., 2019; Voon et al., 2015), indicating that this phenomenon can be studied using task-based behavioral assessments. Beyond tasks, a questionnaire has been recently developed to capture habit, reward-, and fear-related motivations to drink, and habitual alcohol use in this questionnaire was associated with the severity of alcohol dependence across various domains (Piquet-Pessoa et al., 2019).

Based on the neuroscientific literature thus far, gaining insights into habitual actions from clinical and behavioral observations has the potential to uncover “translatable” assessments that are cost-effective and clinically useful. To that end, the present study examines the construct of habit in a clinical sample of heavy drinkers who are also daily cigarette smokers. Given that the sample is characterized by co-users of alcohol and nicotine, we examine dimensions of habit for both smoking and for drinking. In this clinical study, the assessment of habit is conducted via self-report using the Habit Index Form (Verplanken and Orbell, 2003), adapted for both smoking and drinking behaviors. In addition, the present study seeks to capture habitualness from the degree of intraindividual variability in patterns of smoking and drinking over the past month. Using the standard clinical interview for daily smoking and drinking over the past 4 weeks, we derive two related measures of intraindividual variability, namely interclass correlation and autocorrelation. The scientific premise of this work is that individuals with self-reported habitual drinking/smoking may have highly consistent (or patterned) drinking/smoking reports in their clinical interview, whereas goal directed drinkers and smokers may have more variable (or less patterned) smoking and drinking reports. Specifically, this is based on the premise that habits are formed slowly when the behavior is performed successfully many times over in the same situation. In other words, habits require a lot of repetition and form when a behavior is repeated int eh same situation regularly. Thus, to the extend to which habits can be detected by high consistency (and low variance) in behavior, this study seeks to elucidate whether behavioral indicators of drinking and cigarette smoking are associated with self-reported habit for drinking and smoking.

To advance our understanding of habit in clinical samples and from behavioral measures, the present study examines the interrelations between self-reported habit index for smoking and drinking as well as behavioral measures of intraindividual variability in smoking and drinking over the course of four weeks. To examine and validate the utility of intraindividual variability in smoking and drinking behavior, this study examines clinical determinants of habit-driven drinking and smoking. The study hypothesis is that if intraindividual variability in smoking and drinking offers a useful, and clinically accessible, measure of habit-driven alcohol and nicotine use, it would be associated with self-reported habit strength. Further, we hypothesize that habit-driven alcohol and nicotine use would be indicative of disorder severity, consistent with the putative transition from impulsive to compulsive and habitual substance use at later stages of addiction. Exploratory analyses will consider the role of severity, age, and sex as possible moderators of the association between self-report and behavioral measures of habit.

2. Method

2.1. Participants and procedures

Treatment-seeking heavy drinking daily smokers ($N = 416$) were recruited between March 2016 and May 2019 from the Los Angeles community through fliers, metro, TV, radio, and online advertisements. Initial eligibility screening was conducted via online and telephone surveys and was followed by an in-person testing session. *Inclusion criteria* were: (a) treatment seeking for smoking cessation and desire for drinking reduction or quitting drinking; (b) age between 21 and 65; (c) smoking ≥ 5 cigarettes per day (not including e-cigarettes, cigars, or chewing tobacco); (d) consuming ≥ 14 drinks per week for men (≥ 7 drinks per week for women) OR reporting binge drinking (≥ 5 drinks in single episode for men and ≥ 4 for women) at least once per month. Participants were allowed to concurrently use e-cigarettes and other tobacco products so long as they reported smoking ≥ 5 cigarettes per day. *Exclusion criteria* were: (a) history of psychotic disorder or bipolar disorder; (b) medical conditions that would affect treatment participation such as uncontrolled hypertension, hepatitis, chronic liver disease, or seizure disorder; (c) test positive for drugs of abuse (except cannabis) on a urine toxicology test. After providing written informed consent, participants were breathalyzed, provided urine for toxicology screening, and completed a battery of self-report questionnaires and interviews. All participants were required to have a breath alcohol content (BrAC) of 0 mg%. This visit was the initial assessment of eligibility for the treatment study and data were collected prior to randomization to treatment, which took place at a separate study visit. All participants were told that if eligible for the treatment study, they would receive active treatment for smoking cessation and drinking reduction in the form of varenicline and that in addition to varenicline they may receive either naltrexone or matched placebo (NCT 02698215). All study procedures were approved by the Institutional Review Board at UCLA.

2.2. Measures

2.2.1. Drinking and smoking

The following measures of smoking and drinking behavior were administered: (a) the Structured Clinical Interview for DSM-5 adapted from (First et al., 2015) assessed for lifetime and current AUD; (b) the 28-day timeline follow-back (TLFB) assessed drinking and smoking quantity and frequency (Sobell et al., 1988); (c) the Alcohol Use Disorders Identification Test (AUDIT) (Allen et al., 1997) captured alcohol-related problems; (d) the Fagerstrom Test for Nicotine Dependence (FTND) assessed for nicotine dependence (Heatherton et al., 1991). Depressive symptomatology was assessed via the Beck Depression Inventory – II (BDI-II) (Beck et al., 1996).

2.2.2. Habit

To capture habitualness of smoking and drinking, the Self-Report Habit Index (SRHI) (Verplanken and Orbell, 2003) was adapted for

Table 1
Mean, Standard Deviation (SD), and Spearman Rank Order Correlations among Study Variables (N = 416).

Variable	Mean (SD)	Habit Score Drinking	Habit Score Smoking	ICC Drinking	ICC Smoking	AUDIT Score	FTND Score
Habit Score Drinking	3.35 (1.48)	1.0	0.33*	0.02	0.09	0.55*	0.11
Habit Score Smoking	4.78 (1.15)		1.0	0.05	0.06	0.12	0.34*
ICC Drinking	0.32 (0.34)			1.0	0.33*	0.04	0.05
ICC Smoking	0.35 (0.41)				1.0	0.01	0.17*
AUDIT Score	14.75 (8.49)					1.0	0.14
FTND Score	6.67 (2.24)						1.0

* Adjusted p-value of $p < .0033$.

smoking in one version and for drinking in another. The SRHI consists of 12 items accompanied by a 7-point response scale anchored by agree/disagree. The SRHI has been developed to be easily adapted for a host of behaviors (e.g., brush my teeth, read e-mail, smoke, etc.). Each behavior is presented as "Drinking alcohol is something…" followed by items such as "I do frequently," "I do automatically," and "I do without thinking." We averaged all 12 items to obtain a mean habit rating for smoking and one for drinking, with a range of 1–7, where higher scores indicate higher endorsement of habit. In this sample, the SRHI demonstrated high levels of internal consistency, as indicated by a Cronbach α (standardized) of 0.91 for the SRHI Drinking and 0.89 for the SRHI Smoking.

In addition to the self-report measures of habit (i.e., SRHI for drinking and for smoking), this study computed two measures of intraindividual variability for both smoking and drinking data over the past 28 days collected from the TLFB smoking and drinking interviews:

(a) *Interclass Correlation (ICC)*: Estimation of the ICC in our analysis indicates the percentage of total variation in the outcome (i.e., drinking or smoking) that is attributable to the day effect within a week (McGraw and Wong, 1996). Both day and week were treated as random. In this case, ICC measures the degree of absolute agreement of drinking or smoking behaviors among 4 weeks (McGraw and Wong, 1996). In other words, it estimates the homogeneity of behavior for 4 weeks. An ICC of 1 represents total agreement between drinking (or smoking) behavior over the 4-week period (i.e., completely patterned drinking or smoking behavior). Notably, the outcome in the TLFB is the number of drinks on a given day or the number of cigarettes on a given day, each modeled separately.

(b) *Autocorrelation AR(7) coefficients:* In this study, an AR(7) coefficients process is assumed to present the temporal dependence within 7 days (i.e., a week). More specifically, AR(7) coefficients process is an autoregressive model, in which the current value of the series can be explained as a function of values in the past 7 days. In the AR(7) coefficients, there are 7 autoregressive coefficients (ϕ_1 to ϕ_7). ϕ_i reflects the correlation between the values of two time points with an interval of i. For example, a larger ϕ_1 indicates a stronger correlation between two consecutive time points and a higher level of inertia. For each individual, we calculated the 7 autoregressive coefficients across 28 days. As with the ICC approach, the outcome used here is the number of drinks on a given day or the number of cigarettes on a given day, each modeled separately. Due to missing data and model fitting, all 7 coefficients could not be calculated for drinking and smoking in 68 and 130 participants, respectively.

(c) *Mean and variance composite:* In order to incorporate both intraindividual mean drinking/smoking and intraindividual variance in drinking/smoking, we used mean and variance indicators to form four groups: (a) high intraindividual mean and high intraindividual variance, (b) high intraindividual mean and low intraindividual variance, (c) low intraindividual mean and high intraindividual variance, and (d) low intraindividual mean and low intraindividual variance. This grouping was implemented for drinking and smoking separately. We then grouped the relationship between the groups and self-reported smoking and drinking habit index, respectively.

2.3. Data analysis

Due to the cross-sectional nature of the assessment, a series of Spearman rank order correlations (appropriate for non-normally distributed data) and General Linear Model (GLM; more specifically, one-factor ANOVA) tests were used to examine associations across our intraindividual variability measures, self-report habit measures, and measures of clinical severity of smoking and drinking. Age, gender, and smoking/drinking severity measures were tested as possible moderators of the relationship between intraindivdiual variability measures of habit and self-report habit scores. In order to account for multiple comparisons, a Bonferroni correction was implemented. Since Table 1 presents 15 correlations, the *p*-value of 0.05 was divided by 15 resulting in an adjusted critical p-value of $p < .0033$.

3. Results

Participants in this study were treatment seeking for smoking cessation and drinking reduction. The average age of the sample was 42.85 (SD = 12.36) and 34.13 % of the sample was female (N = 142 female and 274 male). The sample was ethnically diverse: White/Caucasian (N = 33, 7.8 %), Latino (N = 99, 23.8 %), Black/African American (N = 197, 47.4 %), Mixed (N = 39, 9.4 %), Native American (N = 4, 1 %), Asian (N = 9, 2.2 %), Pacific Islander (N = 7, 1.7 %), and a few participants did not wish to report their ethnic background (N = 28, 6.7 %). The average score on the AUDIT was 14.75 (SD = 8.49) and the average total number of standard drinks in the past 28 days was 110.8 (SD = 108.3), consistent with the heavy-drinking inclusion criteria. The average score on the FTND was 6.67 (SD = 2.24) and the average number of cigarettes per day in the past 28 days was 12.25 (SD = 7.61), indicating high levels of cigarette use and nicotine dependence in the sample.

3.1. Self-reported habit and intraindividual variability measures (ICC and AR(7) coefficients)

As seen in Table 1, the average ICC score for smoking (Mean ICC = 0.35) was slightly higher than for drinking (Mean ICC = 0.32). As shown in Fig. 1, there was a positive and significant association between the ICC for smoking and the ICC for drinking (r = 0.36, $p < .0001$). Likewise, the SRHI scores for smoking and drinking were significantly correlated in this sample (r = 0.31, $p < .0001$). As expected, given that ICC and AR(7) coefficients were both derived from the same raw data (i.e., smoking and drinking quantity on the TLFB), the two were strongly correlated for both smoking (t(1,286) = 15.30, $p < .0001$) and drinking (t(1,348) = 13.90, $p < .0001$).

Central to our research question, the relationship between our behavioral measure of habit (i.e., ICC for drinking) and the self-reported habit for drinking (SRHI) was not significant (r = 0.02, p = 0.67). The same pattern was found for the ICC for smoking and SRHI for smoking (r = 0.10, p = 0.052), albeit the relationship was stronger for smoking.

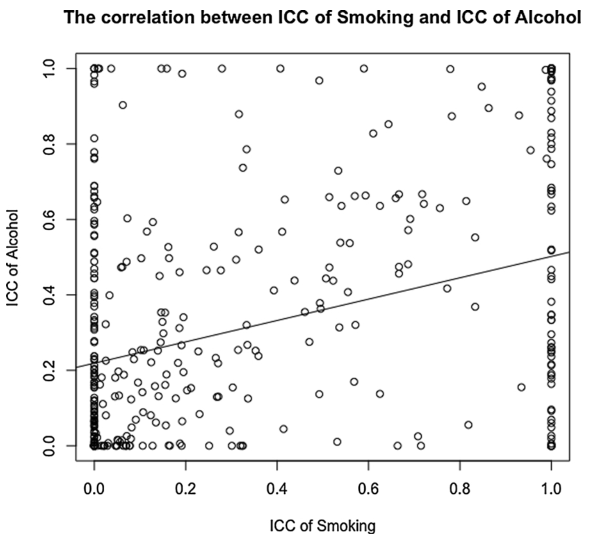

Fig. 1. Scatterplot (and regression line) for the association between the ICC for smoking and the ICC for drinking.

To test whether AR(7) coefficients were related to self-reported habit, the general linear model was used in which all 7 autoregressive coefficients were used to model self-report habit for drinking and smoking respectively. Results revealed no significant association between AR(7) coefficients for drinking and SRHI for drinking ($F(1,348) = 0.53$, $p = 0.47$). A similar pattern emerged for AR(7) coefficients and SRHI for smoking, ($F(1,286) = 2.77$, $p = 0.10$). In sum, both ICC and AR(7) coefficients analyses indicated that our behavioral measure of "patterness" and putative habit did not demonstrate significant associations with validated self-reports of habit, with at best only marginal effects for smoking associations but not for drinking.

3.2. Mean and variance grouping

For smoking behavior, participants were classified as follows: (1) high mean cigarettes and high variance (N = 43), high mean cigarettes and low variance (N = 112), low mean cigarettes and high variance (N = 210), and low mean cigarettes and low variance (N = 50). An ANOVA comparing the four groups on SRHI for smoking was significant ($F(3,414) = 5.11$, $p < .01$). Planned *t*-test comparisons showed that groups 1 and 2 systematically differed from groups 3 and 4 ($ps < .05$), whereas groups 1 and 2 did not differ ($p = .80$) nor did groups 3 and 4 ($p = .70$). These analyses suggest that mean cigarettes explains higher self-reported habit scores and that variance does not add to this prediction.

For drinking behavior, participants were classified as follows: (1) high mean cigarettes and high variance (N = 26), high mean cigarettes and low variance (N = 105), low mean cigarettes and high variance (N = 279), and low mean cigarettes and low variance (N = 5). We only retained the first 3 groups, since the last group had such a small cell size. An ANOVA comparing the three groups on SRHI for drinking was significant ($F(2,409) = 33.92$, $p < .0001$). Planned *t*-test comparisons showed that groups 1 and 2 systematically differed from group 3 ($ps < .001$), whereas groups 1 and 2 did not differ ($p = .22$). These analyses suggest that mean drinks explains higher self-reported habit scores and that variance does not add to this prediction.

3.3. Habit measures and clinical severity

As shown in Table 1, alcohol problems indexed by the AUDIT were strongly associated with SRHI for drinking ($r = 0.55$, $p < .0001$) whereas ICC for drinking was not related to AUDIT score ($r = 0.04$, $p = .38$). Analyses using AR(7) coefficients also showed no association to AUDIT score in this sample ($F(1,348) = 1.05$, $p = 0.31$). When both ICC and SRHI scores were entered into a multiple regression model to predict AUDIT score in the sample, we found that SRHI ($t(1,414) = 13.37$, $p < .0001$) remained a significant predictor of AUDIT score but ICC was not ($t(1,414) = 0.78$, $p = .44$).

For smoking, nicotine dependence severity indexed by the FTND was associated with the ICC measure ($r = 0.17$, $p < .001$). Likewise self-reported habit (SRHI) score for smoking was robustly and positively associated with FTND score ($r = 0.34$, $p < .0001$). The combined AR(7) coefficients autoregressive coefficients were not significantly associated with nicotine dependence severity on the FTND ($F(1,286) = 1.42$, $p = 0.24$), based on the results of a one-factor ANOVA. Interestingly, when both ICC for smoking and SRHI smoking scores were entered into a multiple regression model predicting nicotine dependence severity (i.e., FTND score), both SRHI ($t(1,413) = 6.27$, $p < .0001$) and ICC ($t(1,413) = 3.38$, $p < .001$) remained significant predictors.

Follow-up analyses using a median-split approach found that individuals at or above the AUDIT median of 14 (N = 213) reported significantly higher scores on self-reported habit index for drinking than those below the median on the AUDIT (N = 203) (mean SRHI 4.00 ($SD = 1.26$) versus 2.66 ($SD = 1.38$) ($t(414) = -10.42$, $p < .0001$)). Similar results were obtained using a median-split for the FTND, whereby individuals at or above the FTND median of 7 (N = 227) had higher smoking SRHI scores than those below the median (N = 186) (mean SRHI 5.07 ($SD = 1.06$) versus 4.44 ($SD = 1.16$) ($t(414) = -5.79$, $p < .0001$).

In sum, the self-report measures of habit were robustly and positively associated with clinical severity of drinking and smoking, such that higher habit scores predicted greater severity of drinking and smoking, respectively. Furthermore, smoking ICC was a significant predictor of nicotine dependence severity, alone as well as in models that control for the unique effects of self-reported habit (SRHI) on FTND score.

3.4. Exploratory analyses of moderators

Habit may become more clinically relevant at high levels of addiction severity, such that at high levels of alcohol problems, for example, behavioral and self-report measures of habit are more strongly related. To test this hypothesis we conducted a series of analyses in which we allowed the association between self-reported habit and behaviorally-derived measures of habit/pattern [i.e., ICC and AR(7) coefficients] to be moderated by clinical severity indicated by the FTND and AUDIT, respectively, using multiple regression. In models for drinking, we allowed self-reported habit drinking to be predicted by drinking ICC, AUDIT, and the ICC × AUDIT interaction. Results revealed that AUDIT remained a predictor of self-reported habit for drinking ($t = 11.01$, $p < .0001$), whereas drinking ICC ($t = 0.96$, $p = .34$) and ICC × AUDIT ($t = -1.16$, $p = .25$) were not significant predictors of self-reported habit. A separate multiple regression model for smoking indicated a very similar pattern, with self-reported habit for smoking was strongly predicted by FTND ($t = 17.22$, $p < .0001$), but not by smoking ICC ($t = -0.87$, $p = .38$) and ICC × FNTD interaction ($t = 1.16$, $p = .25$).

Lastly, gender and age were considered as both predictors and as possible moderators of the relationship between self-report habit and behavioral indicators of habit. Results revealed no main effect of age ($t = -0.88$, $p = .38$) or age × ICC ($t = 0.12$, $p = .91$) interaction predicting self-reported habit for drinking. The same was true for gender, with no main effect of gender ($F(1,414) = 0.00$, $p = .95$) or gender × ICC ($F(1,414) = 1.95$, $p = .16$). Separate models predicting self-reported smoking habit showed no significant age × ICC ($t = 0.45$, $p = .66$) interaction nor a gender × ICC ($F(1,413) = 1.55$, $p = .22$) interaction. An approach of selecting only very heavy drinkers to examine associations between intraindividual variables and self-report yielded similar results. Together, these exploratory analyses show that neither clinical severity, age, nor gender moderated the association between self-reported habit and habit captured via ICCs, for drinking and smoking, each tested separately.

4. Discussion

In light of the rich emerging literature on the basic neuroscience of habit (Graybiel, 2008; Smith and Graybiel, 2016) and its cognitive neuroscience applications (Voon et al., 2015), this report extends the study of habit by capturing self-reports and behaviorally-driven measures of habitualness for smoking and drinking in a clinical sample. To that end, self-report measures of habit as well as behaviorally-driven measures of intraindividual variance, reflecting consistency and regularity of drinking and smoking, were obtained in a large sample of heavy drinking smokers. Results from this study found support for the use of self-report measures, such as the SRHI, for the assessment of habit drinking and habit smoking, as scores on the SRHI were strongly associated with severity of drinking and smoking problems, respectively. This is consistent with a recent report developing a novel measure of to capture habit, reward-, and fear-related motivations to drink, whereby habitual alcohol use in this questionnaire was associated with the severity of alcohol dependence across various domains (Piquet-Pessoa et al., 2019). Notably, this association was found in a high-severity, mostly inpatient, Brazilian sample upon recent detoxification. Further, Piquet-Pessoa and colleagues (2019), note that the items used to capture habit were derived from the SHRI. Our findings are also consistent with a recent study using the SHRI to evaluate associations between the strength of habitual substance use and measures of frequency and quantity of substance use (Morean et al., 2018). This study found a positive association between habitual alcohol and cigarette use and frequency and quantity of alcohol and cigarettes consumed in the past month, respectively. And while Morean et al. (2018) recommended a 6-item version of the SRHI, our findings rely on the full 12-item scale instead.

Regarding the behaviorally-driven measures of habit, vis-à-vis, intraindividual variability measures [ICC and ARC(7) coefficients], empirical support for their utility was moderate in this study. In particular, the results for smoking habit provide some construct validity whereby ICCs were positively associated with nicotine dependence score and remained a significant predictor of nicotine dependence over and above the self-report smoking habit (SRHI) score. It is interesting that while correlated, the SRHI score and the ICC for smoking explained unique variance in nicotine dependence. And while the results were encouraging for smoking habit measures, they were less so for behaviorally-driven measures of habit for drinking. Contrary to smoking, drinking ICC was unrelated to measures of alcohol problem severity (i.e., AUDIT) and to total alcohol use in the past 28 days. It was also unrelated to the SRHI for drinking. Thus it is quite possible that a higher severity sample is required before behaviorally-driven measures of drinking can become informative. Further, this study focused heavily on whether drinking and smoking is patterned by day. Yet another consideration relevant to habit formation, is whether substance use is patterned by time of day, place, people present, affect, etc. Attention to context is consistent with the notion that habits tend to develop when something is done repeatedly in the same (or similar) situations such that those environments (and associated cues), come to control behavior (Malvaez and Wassum, 2018).

The premise of this study is that capturing behavioral measures of habit strength is needed in order to advance the translation of the construct of habit to clinical samples and applied settings. This is consistent with the recommendation of Morean and colleagues (2018) who recently reported on the SRHI for marijuana, alcohol, and cigarette use (Morean et al., 2018). A similar approach to capturing invariance in behavior has been implemented in mood disorder. For example, a study showed that emotional inertia (i.e., higher autocorrelations in ratings of emotion) was related to lower self-esteem and higher levels of depression (Kuppens et al., 2010). Whereas another report found that individuals with major depressive disorders had lower autocorrelations in cortisol over time compared with those in the control group (Peeters et al., 2004). In sum, behavioral markers are critical to corroborating and extending upon self-reports and task-based assessments of habit. In particular, behavioral markers that are clinically accessible can provide unique opportunities for translational science.

A number of factors should be considered in interpreting these findings and considering future directions. First, this is a sample for whom financial insecurity may impact their alcohol and smoking patterns (Kim et al., 2017). As such, variability in smoking and drinking may be determined by the availability of resources, beyond the control of the participants. Second, this is a treatment-seeking sample who is primarily interested in quitting smoking. Recent research has suggested that individuals alter their behavior in anticipation of receiving treatment (Witkiewitz et al., 2017), which may be a factor in this trial. Third, this study did not directly assess for goal-directedness of drinking and smoking behavior and as discussed herein, habit is often defined as an absence of evidence for goal-direct control. Therefore, our group and others would benefit from integrating assessments of goal-directed control when seeking to examine habit. Fourth, this study drew measures of behavioral "patterness" from the TLFB interview, which is vulnerable to recall biases (Dulin et al., 2017; Vinson et al., 2003). Those biases may be most prominent the further back in time individuals have to recall their behavior. As such, pursuing a similar approach to behaviorally-driven measures of habit using other data sources such as electronic diary and ecological momentary assessment, may prove useful in the future. These approaches may also provide a richer description of environmental factors that may come to control behavior, as proposed in the habit literature.

In sum, these results provide construct validity to the self-report measures of habit for smoking and drinking, as well an initial evaluation of behaviorally-derived measures of smoking "patterness" as a potential proxy for habit. More work is needed to develop the intraindividual variability measure of drinking. Conversely, this study cannot rule out the possibility that "patterness" captures aspects of the addiction spectrum, other than habit, such as severity or avoidance of withdrawal symptoms, which in turn differ for smoking and drinking. Because habit represents a complex phenotype with limited clinical translation thus far, additional studies capturing a wider range of substance use severity and coupled with brain-based (and task-based) validation methods are warranted.

Contributors

LR and SB were responsible for the study concept and design. DH and LM contributed to data acquisition and cleaning. LR, SB, and HD contributed to data analysis and interpretation of the findings. LR drafted the manuscript. All authors provided critical revision of the manuscript for important intellectual content. All authors critically reviewed content and approved final version for submission.

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Declaration of Competing Interest

No conflict declared.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.drugalcdep.2019.107738.

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