Published in final edited form as:

Drug Alcohol Depend. 2018 May 01; 186: 207–214. doi:10.1016/j.drugalcdep.2018.01.014.

The Self-Report Habit Index: Assessing habitual marijuana, alcohol, e-cigarette, and cigarette use

Meghan Morean^{a,b}, Kelly S. DeMartini^c, Dawn Foster^b, Julie Patock-Peckham^d, Kathleen A. Garrison^e, Philip R. Corlett^b, John H. Krystal^b, Suchitra Krishan-Sarin^b, and Stephanie S. O'Malley^b

^aOberlin College, Department of Psychology, 120 W. Lorain St., Oberlin, OH 44074

^bYale School of Medicine, Department of Psychiatry, CMHC, 34 Park Street, New Haven, CT 06519

^cYale School of Medicine, Department of Psychiatry, 1 Long Wharf Drive, Box 18, New Haven, CT 06511

^dArizona State University, Department of Psychology, 950 S. McAllister Ave, Tempe, AZ 85287

^eYale School of Medicine, Department of Psychiatry, 1 Church Street #730, New Haven, CT 06511

Abstract

Correspondence: Meghan Morean, Department of Psychology, Oberlin College, 120 W. Lorain St., Oberlin, OH 44074, USA, Meghan.Morean@oberlin.edu or Meghan.Morean@yale.edu.

Conflict of Interest

The authors report no conflicts of interest relevant to the development of the habit scale.

Role of Funding Source

This work was supported in part by National Institute on Alcohol Abuse and Alcoholism (P50AA12870; K01AA024160-01A1), the Yale Center for Clinical Investigation (UL1 RR024139), the U.S. Department of Veterans Affairs (National Center for PTSD), National Institutes of Health (NIH)/National Institute on Drug Abuse (NIDA; K12DA00167), NIDA and the FDA Center for Tobacco Products (P50DA036151), and the Burton Family Foundation's (FP11815). The content is solely the responsibility of the authors and does not necessarily represent the official views of the funding agencies.

Contributors

Dr. Morean contributed to the conceptualization of the study assessing cigarette and e-cigarette use and the development of the associated surveys, ran statistical analyses, and wrote the initial draft of the methods, results, and discussion sections. Dr. DeMartini contributed to the conceptualization of the alcohol studies, wrote the initial draft of the introduction of the manuscript, and provided input on the final manuscript. Dr. Foster contributed to the conceptualization of the current study, the planned analyses, and to data collection. Dr. Foster also provided input on the final manuscript. Dr. Patock-Peckham contributed to the two studies collected at Arizona State University by developing the survey with her collaborators and handling IRB applications. Dr. Patock-Peckham trained the research assistants who coded and cleaned the data, assisted with compiling measures, edited this work in poster form, and contributed to the writing and editing of the final manuscript. Dr. Garrison contributed to the planning and data collection associated with the study assessing habitual alcohol and cigarette use and provided input on the final manuscript. Dr. Corlett made significant contributions to revising the introduction and conclusion sections of the revised manuscript. Dr. Krystal provided some financial support, contributed to discussions related to the role of habit in addiction, and provided input on drafts of the manuscript. Dr. Krishnan-Sarin contributed to the conceptualization of the studies conducted at Yale, data collection, and analysis planning and provided input on the final manuscript. Dr. O'Malley contributed to the conceptualization of all studies, the analytic plan, and reviewed multiple drafts of the manuscript. All authors approved of the final manuscript for submission.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Background—Substance use is partially driven by habitual processes that occur automatically in response to environmental cues and may be central to users' identities. This study was designed to validate the Self-Report Habit Index (SRHI) for assessing habitual marijuana, alcohol, cigarette, and e-cigarette use.

Methods—We examined the SRHI's psychometrics in separate samples of adult marijuana ($N=189;170$), alcohol ($N=100;133$), cigarette ($N=58;371$), and e-cigarette ($N=239$) users.

Results—A 6-item, single-factor solution evidenced good fit across substances (CFI marijuana/alcohol/cigarettes/e-cigarettes = .996/.997/.996/.994, RMSEA = .046/.047/.067/.068, SRMR = .017/.017/.010/.015) and internal consistency ($\alpha=0.88/0.94/0.95/0.91$). The SRHI was scalar invariant for sex and race. However, independent-samples t-tests indicated only that women endorsed stronger habitual e-cigarette use and that men endorsed stronger habitual marijuana use. The SRHI also was scalar invariant by product type in dual-users (cigarettes/e-cigarettes [$N=371$]; alcohol/cigarettes [$n=58$]), although differences in habit strength only were observed for cigarettes versus e-cigarettes, with dual-users reporting stronger habitual cigarette use. Finally, the SRHI predicted frequency of marijuana, alcohol, cigarette, and e-cigarette use (η_p^2 [marijuana/alcohol/cigarettes/e-cigarettes] = 0.37/0.48/0.31/0.17) and quantity of alcohol and cigarette use (η_p^2 = 0.43/0.33).

Conclusions—The SRHI is a psychometrically sound measure of adults' habitual substance use. The SRHI detected mean differences by sex and substance type and predicted the frequency of using each substance. Future research should determine if the SRHI is appropriate for use with other substances or age groups (e.g., adolescents), how it relates to task-based, behavioral measures of habit strength, and the degree to which habit predicts the development or maintenance of addiction.

Keywords

marijuana; cannabis; alcohol; cigarettes; electronic cigarettes; e-cigarettes; vaping; habit; habitual use

1. Introduction

The degree of compulsivity with which users repeatedly engage in behavior that they know may result in negative consequences is key component of substance use disorders. One hypothesis for compulsivity focuses on the two parallel systems of instrumental behavioral control: goal-directed and habitual behaviors (Dolan and Dayan, 2013; Everitt et al., 2001; Voon et al., 2015). Goal-directed behaviors reflect information about the consequences of a behavioral choice, which is tethered to desired outcomes (e.g., in rodents: Adams and Dickinson, 1981; and humans: de Wit et al., 2009). In contrast, habitual control reflects actions that are elicited irrespective of their consequences. Typical behavioral repertoires entail flexible weighting between goal-directed and habitual systems according to context and task demands. Pathological behavior, including substance use disorders in humans, may result when the habit system becomes too dominant and behavior becomes inflexibly evoked by environmental cues without consideration of consequences (Voon et al., 2015). Substance abusers often show impaired goal-directed responding, and thus demonstrate habitual or model-free control (alcohol: McKim et al., 2017; Sebold et al., 2014; Sjoerds et al., 2013;

cocaine: Ersche et al., 2012; methamphetamine: Voon et al., 2015). For instance, although Voon and colleagues (2015) found no difference in control between *abstinent* alcohol abusers and matched healthy volunteers, the same group found a bias toward habitual control (and away from goal-directedness) in binge drinkers using an identical task (Doñamayo et al., 2017). We suggest, as do Voon and colleagues, that those who are able to achieve abstinence can marshal sufficient top-down control over their behavior to inhibit their propensity to drink. Indeed, clinical interventions for substance-use disorders developed thus far focus primarily on restoring goal-directed behavioral control, boosting executive control or changing outcome value (Stock, 2017). However, more recently, there has been an increase in research designed to better understand and assess the habitual system and to develop a more complete understanding of how users make choices across a variety of substances (Aarts and Dijksterhuis, 2000; Verplanken and Aarts, 1999; Wood et al., 2002; Wood and Neal, 2007). If the habit system is hyper-engaged among individuals with substance use disorders, there may be a therapeutic window through which maladaptive habits could be replaced with more adaptive responses (Stock, 2017).

To better incorporate the habitual nature of decision making into models of and interventions for substance use disorders, it is necessary to understand how habit itself is defined and how habits are acquired and maintained. While different definitions of habit have been proposed, three components appear to be central: habitual behaviors are frequently repeated, have a high degree of automaticity, and are cued in stable situational contexts (Orbell and Verplanken, 2010). Consensus has emerged that habits are acquired through incremental strengthening of the association between a situation (cue) and an action (Lally et al., 2010). In other words, behavioral repetition performed in a consistent context progressively increases the automaticity with which the behavior is performed in that particular situation (Verplanken, 2006; Wood and Neal, 2007). Bargh (1994) determined that “automaticity” is present if a behavior displays efficiency, lack of awareness, unintentionality, and uncontrollability. Taking into account automaticity and frequency, habit behaviors have a history of repetition, are characterized by a lack of awareness and conscious intent, are mentally efficient, can be difficult to control, and may become a defining feature of one’s identity (Verplanken et al., 2007; Verplanken and Holland, 2002).

Verplanken and Orbell (2003) developed the most commonly used instrument for assessing habit: The Self-Report Habit Index (SRHI). To complete the SRHI, participants are asked whether a target behavior occurs frequently; requires conscious awareness, thought, and effort; is difficult to control; and is self-descriptive. This assessment has been used to study a variety of health habits, including, but not limited to, smoking (Orbell and Verplanken, 2010), habitual negative self-talk (Verplanken et al., 2007), and eating behaviors and body image (de Bruijn et al., 2007; Verplanken and Tangelder, 2011). However, it can be argued that these studies are premature, given that a complete evaluation of the psychometric properties of the SRHI has not been conducted. Existing studies largely have focused on test-retest reliability and evaluating relationships between the SRHI and the frequency of engaging in different behaviors. However, the most fundamental level of psychometric evaluation generally is absent; the latent factor structure of the SRHI has not been established using factor analytic techniques, so it is unclear whether the 12 SRHI items truly represent a single factor structure (as is indicated by the scoring instructions) for any of the

behaviors it has been used to assess. Additionally, recent research has questioned the conceptual basis for including all 12 items in the measure. There is evidence that engaging in habitual behavior is distinct from simply engaging in a behavior frequently, as truly habitual behaviors are activated automatically (Ouellette and Wood, 1998; Gardner et al., 2012). As such, the effects of habit may be better attributed to automaticity (Gardner, 2012), suggesting that removing the frequency items from the SRHI would permit a truer estimate of habit (Gardner et al., 2012). In light of the extant conceptual disagreements, a full psychometric analysis of all the items included in the SRHI is warranted.

Further, although mean-level comparisons are commonplace in studies utilizing the SRHI, the statistical support for making such comparisons has not been demonstrated. To date, no one has evaluated the measurement invariance of the SRHI, which would demonstrate whether the latent structure of the measure is comparable for groups of interest (e.g., men vs. women). In the absence of established scalar measurement invariance for groups of interest (e.g., sex, different habitual behaviors), mean-level comparisons are not interpretable because it is unclear the extent to which group-level differences (or the absence thereof) reflect true differences based on group membership or are reflective of measurement error (e.g., discrepancies in factor structure or item bias; Steenkamp and Baumgartner, 1998; Vandenberg and Lance, 2000).

Thus, in the current study we evaluated the psychometric properties of the SRHI for assessing habitual marijuana, alcohol, cigarette, and e-cigarette use, respectively. We first conducted factor analyses to establish the latent structure of the SRHI for assessing habitual substance use. Next, we evaluated the internal consistency of the SRHI for each substance. We then conducted measurement invariance analyses to determine whether habitual use of each substance could be compared meaningfully by sex and/or race. Measurement invariance analyses also were conducted within subsamples of dual-users of cigarettes and e-cigarettes and dual-users of alcohol and cigarettes, respectively, to determine whether habitual use of these products could be compared meaningfully. For all groups in which scalar invariance was established, we conducted mean-level comparisons of SRHI scores. Finally, we examined test-criterion relationships between SRHI scores and the frequency of marijuana, alcohol, cigarette, and e-cigarette use, respectively. Test-criterion relationships between the SRHI and indices of the quantity of alcohol and cigarette use (the only substances for which quantity data were available) also were examined. The SRHI would be considered a reliable and valid measure of habitual substance use only if a confirmable latent factor structure could be identified and there was evidence of internal consistency, scalar measurement invariance, and test-criterion relationships with each substance use outcome of interest.

2. Materials and method

Data for the current analyses were drawn from four separate studies in which SHRI data were collected. Of note, the specific datasets used in the current analyses have not been published on previously. We first describe the measures that were common across all studies and subsequently present the unique methods associated with each study.

2.1 Demographics

All participants reported on sex, age, and race.

2.2 The SRHI (Verplanken and Orbell, 2003)

All participants completed the SRHI for the substances indicated in study descriptions below. As noted, the original SRHI is a 12-item measure designed to assess characteristics of habitual behavior including automaticity (e.g., “marijuana is something I use automatically”), frequency of engagement in the behavior (e.g., “marijuana is something I use frequently”), and the link between the behavior and self-identity (e.g., “Using marijuana is something that feels typically ‘me’”). Note that within each study, the generic stem (i.e., “xxxx” is something...) was adapted for the specific substance (e.g., marijuana is something...). Response options for each item ranged from (strongly disagree) to (strongly agree). The 12-item SRHI was included in three of the four studies (see study descriptions below). Based on the results of exploratory and confirmatory factor analysis (described below), a 6-item version of the SRHI was included in the fourth study.

2.3 Study 1: SRHI marijuana

2.3.1 Participants—448 college students completed a survey in 2015, and 473 unique students completed a second version of the survey in 2016. Past-month marijuana users who completed the marijuana SRHI were included in the current analyses (2015 Study: $n = 189$ [55.0% male; 59.8% White; mean age = 19.12 (1.80) years]; 2016 Study: $n = 170$ [66.9% male; 64.1% White; mean age = 19.78 (2.42) years]).

2.3.2 Procedures—The Arizona State University Institutional Review Board approved the study. Introductory Psychology students who were ages 18 and older and native English speakers were recruited through Sona Systems technology, an online subject pool management site. Participation was voluntary and anonymous. Surveys were administered in classrooms, and students returned completed surveys to an anonymous drop box (i.e., sealed box with a slit in it). Participants earned one hour of course credit for participating.

2.3.3 Measures—In addition to the 12-item SRHI for marijuana, participants reported on their marijuana and cigarette smoking frequency, with response options including “never used marijuana/cigarettes, former user, less than once a month, monthly, 2–3 times a month, once a week, 2–3 times a week, 4–5 times a week, and daily or nearly daily.” As noted, for the purposes of the current analyses, only individuals who endorsed using marijuana at least monthly were included. Individuals who reported smoking cigarettes at least once a month were coded as “current smokers.”

2.4 Study 2: SRHI alcohol and SRHI cigarettes

2.4.1 Participants—100 adults completed an anonymous online survey in 2017 (50% male, 75% White, mean age = 25.04 [1.69] years). A subsample of 58 participants also reported smoking cigarettes and completed the cigarette SRHI (53.4% male, 70.7% White, mean age 25.00 [1.77] years).

2.4.2 Procedures—The Yale School of Medicine Institutional Review Board approved the study. Participants were recruited through Amazon Mechanical Turk (i.e., Mturk), an online data collection platform that has been shown to provide reliable survey data (Mason and Suri, 2014). To be eligible, participants had to be Mturk “Master Workers” who had completed at least 5,000 previous MTurk jobs (demonstrating platform familiarity) with an approval rating of at least 95% (demonstrating high quality work); be between the ages of 18–25 years; be native English speakers; reside in the U.S.; and endorse at least one past-month binge drinking episode (≥ 4 drinks females; ≥ 5 drinks males). Participants were compensated a \$7 for completing sections of the survey relevant to the current study.

2.4.3 Measures—In addition to the 12-item SRHI alcohol and SRHI cigarette, participants reported on their past-month alcohol use and cigarette smoking frequency (i.e., “During the past 30 days, on how many days did you drink one or more alcoholic beverages?; smoke part or all of a cigarette?”; response options: 0–30). Participants who reported past-month cigarette smoking were categorized as “current smokers.” All participants also reported on the number of drinks typically consumed per drinking day (i.e., “On the days that you drank during the past 30 days, how many drinks did you usually have each day? Count as a drink a can or bottle of beer; a wine cooler or a glass of wine, champagne, or sherry; a shot of liquor or a mixed drink or cocktail;” response options: 1–30), and current smokers reported on the number of cigarettes typically smoked per day (i.e., “On the days you smoked cigarettes during the past 30 days, how many cigarettes did you smoke per day, on average?”; response options: < 1, 1, 2–5, 6–15, 16–25, 26–35, >35).

2.5 Study 3: SRHI alcohol

2.5.1 Participants and procedures—133 adult alcohol users completed surveys between 2011 and 2015 (52% male, 62% White, mean age (27.80 [8.09] years).

2.5.2 Procedures—The Yale School of Medicine Institutional Review Board approved the study. Data were collected as part of the baseline assessment battery that was common across studies that were completed through the NIAAA-funded Yale Center for the Translational Neuroscience of Alcoholism (CTNA). The CTNA studies enrolled a range of low-risk and high-risk drinkers (based on family history of alcohol dependence and current drinking patterns) to participate in imaging and/or laboratory-based alcohol studies. The overall goals of the CTNA studies were to utilize state-of-the-art clinical and molecular neuroscience methodologies to test mechanistic hypotheses and translate those into pharmacotherapies for alcohol dependence.

2.5.3. Measures—In addition to the 12-item SHRI alcohol, alcohol use was assessed with the Timeline FollowBack interview (Sobell and Sobell, 1992), which utilizes a calendar-based methodology with prompts to help participants recall each day of drinking in the past 30 days. For the current analyses, we calculated drinking frequency (i.e., the total number drinking days in the past month; range 0–30 days) and the total number of drinks consumed in the past month. As an index of high-risk drinking, we also calculated a variable that reflected whether the amount of alcohol an individual typically consumed on a drinking day

qualified as a binge drinking episode (i.e., 4 or more drinks for women, 5 or more drinks for men).

2.6 Study 4: SRHI cigarette and SRHI e-cigarette

2.6.1 Participants—239 exclusive e-cigarette users (47.7% male, 84.5% White, mean age 37.45 [13.39] years) and 371 dual-users of cigarettes and e-cigarettes (49.3% male, 85.2% White, mean age 37.88 [13.01] years) completed an anonymous, 20-minute, online survey in Summer 2017.

2.6.2 Procedures—The Yale School of Medicine Institutional Review Board approved the study. Participants were recruited through Qualtrics Online Sample, which is a secure market research service offered through Qualtrics, Inc (website) that invites potential participants to complete study eligibility questionnaires. Eligible participants completed a formal consent form prior to study participation. Compensation was based on the terms of individual participant's agreements with Qualtrics (up to \$7).

2.6.3 Measures—In addition to the 12-item SRHI for cigarettes and e-cigarettes, participants reported on their e-cigarette and cigarette use. Weekly e-cigarette use was determined using the following questions: “On average, how often do you use electronic cigarettes (also known as vaping)?” (“never, 1–2 times per year, or 3–11 times per year, once a month, 2–3 times a month, once a week or more”) and “During the past 30 days, on how many days did you use an e-cigarette?” (response of 4 days). Individuals who responded 1 to the following question: “During the past 30 days, on how many days did you smoke a cigarette?” were characterized as “current smokers.” Current smokers also reported on the average number of cigarettes smoked per day (i.e., “On average, how many cigarettes do you smoke per day?;” response options: 0, 1–4, 5–9, 10–14, 15–19, 20–29, 30 or more). Finally, participants reported whether they “usually use eliquids that contain nicotine” (“yes/no”).

2.7 Data analytic plan

2.7.1 Descriptive statistics—We first ran descriptive statistics on the central study variables.

2.7.2 Latent structure—Studies 1–3 (measuring SRHI marijuana, alcohol, and alcohol/cigarettes) were completed prior to Study 4 (SRHI cigarette/e-cigarette), and each contained the original, 12-item SRHI. Therefore, confirmatory factor analyses (CFA) were run on the SRHI data from these studies to determine whether the proposed 12-item, single-factor latent structure fit the data. Because the 12-item, single-factor structure did not fit our data (see “Latent Structure” in “Results”), exploratory factor analyses (EFA) were run to determine a plausible factor structure(s) for the SRHI. EFA was run on data from Study 1 (marijuana data from 2015, n=189) and Study 2 (alcohol, n=100; cigarette, n=58). These samples were chosen for EFA because each had a “companion” dataset (for the same substance), within which plausible latent structures identified via EFA could be evaluated using a confirmatory framework (i.e., Study 1 [marijuana data from 2016, n=170], Study 3 [alcohol data, n=133], and Study 4 [cigarette data, n=371]). The best fitting model (i.e., a 6-item, single-factor structure; see “Results”) was subsequently fit to the e-cigarette data from

the Study 4 (n=239). For all models, the following criteria were used to define adequate fit: Bentler's Comparative Fit Index (CFI) ≥ 0.90 , Root Mean Square Error of Approximation (RMSEA) < 0.08 , and standardized root-mean-square residual (SRMR) < 0.08 (Hu and Bentler, 1999). Note that all remaining analyses were conducted only within the companion datasets and the e-cigarette data from Study 4.

2.7.3 Internal consistency—Cronbach's alpha was examined as an index of internal consistency.

2.7.4 Measurement invariance (MI)—Multigroup CFA was used to evaluate MI of the 6-item SRHI versions to determine whether the latent structures were supported within two subgroups of interest: sex and race. MI also was evaluated within the sample of 371 dual-users of cigarettes and e-cigarettes (Study 4) and the sample of 58 dual-users of alcohol and cigarettes (Study 2) who had completed the SRHI for both products. These analyses would determine whether habitual cigarette/e-cigarette use or habitual alcohol/cigarette use could be compared meaningfully.

Three levels of invariance had to be met for mean-level comparisons to be interpretable: configural invariance (i.e., the basic latent structure and number of items loading on the factor are constrained to equality across groups), metric invariance (i.e., the magnitude of the item factors loadings are constrained to equality across groups), and scalar invariance (i.e., the magnitude of the item factor loadings and their intercepts are constrained to equality across groups; Chen, 2008, Steenkamp and Baumgartner, 1998, Widaman and Reise, 1997). Configural invariance was established if all items loaded significantly onto their designated factor(s) and the model fit the data (i.e., CFI > 0.90 , RMSEA $< .08$, SRMR $< .08$). Metric invariance was established if the change in fit indices from the configurally invariant model did not exceed these parameters: RMSEA $\leq .015$, CFI $\geq .01$, or SRMR $\leq .030$. Scalar invariance was established if change in fit indices from the metrically invariant model did not exceed CFI $\geq .010$, plus a change in SRMR $\leq .010$ or RMSEA $\leq .015$ (Chen, 2007).

2.7.5 Mean-level differences—Independent-samples t-tests were run to examine potential mean-level differences in SRHI scores by sex and race. An independent-samples t-test was also run to evaluate whether habit strength was stronger among drinkers whose average daily alcohol consumption met criteria for a binge drinking episode. Paired-samples t-tests were run to examine potential differences in habitual cigarette/e-cigarette use and alcohol/cigarette use among dual-users. Bivariate correlations were also run to examine the magnitude of the relationships between habitual product use in dual-users.

2.7.6 Test-criterion relationships—First, unadjusted bivariate correlations were examined to evaluate the relationship between SRHI scores and the frequency of marijuana, alcohol, cigarette, and e-cigarette use, respectively. Data on quantity of use were available for alcohol and cigarettes, so correlations also were run between SRHI scores and drinks per drinking day and cigarettes smoked per day, respectively. Univariate general linear models (GLM) then were run to evaluate relationships between SRHI scores and substance use frequency and quantity (as available) after accounting for the following model covariates:

age, sex, race, current smoking status (in the model predicting marijuana use), and nicotine e-liquid use (in the models predicting cigarette/e-cigarette use).

3. Results

3.1 Descriptive statistics

The distributions of all continuous variables approximated normality and all cell sizes were sufficient for the categorical variables (see Table 1 for participant demographics).

3.2 Latent structure

The 12-item, single factor SRHI structure did not fit the data for marijuana, alcohol, or cigarettes (CFI [marijuana (Study 1); alcohol (Study 2); cigarettes (Study 2); alcohol (Study 3)] = 0.824; 0.861; 0.880; 0.856; RMSEA = 0.149; 0.177; 0.146; 0.168; SRMR = 0.067; 0.68; .047; 0.054). Exploratory factor analytic models suggested that a 6-item, single-factor structure likely would produce the best fit within a confirmatory framework. The identified latent structure comprised four items that previously were identified as being especially important to assessing habit automaticity: “Using [marijuana/alcohol/cigarettes] is something...I do automatically, I do without having to consciously remember, I do without thinking, I start doing before I realize I’m doing it” (Gardner et al., 2012) and two additional items: “Using [marijuana/alcohol/cigarettes] is something...I would find hard not to do; that is typically “me.” When the 6-item structure was fit to the companion datasets and the data for e-cigarettes, each model evidenced good fit (Table 2) and all items loaded significantly onto the latent factor (Table 3).

3.3 Internal consistency

Cronbach’s alpha values indicated that each 6-item SRHI version was internally consistent (marijuana $\alpha = 0.88$, alcohol $\alpha = 0.94$, e-cigarettes $\alpha = 0.91$, cigarettes $\alpha = 0.95$).

3.4 Measurement invariance

The SRHI scores were scalar measurement invariant by sex and race for all substances (Table 2). SRHI scores also were scalar invariant for habitual e-cigarette/cigarette use and habitual alcohol/cigarette use within the respective samples of dual-users (Table 4).

3.5 Mean-level differences

Independent samples *t*-tests indicated that men reported stronger habitual marijuana use compared to women and that women reported stronger habitual e-cigarette use than did men (Table 5). Further, as expected, binge drinkers reported stronger habitual alcohol use than non-binge drinkers (Cohen’s $d = 1.06$, $p < .001$). No other significant between-groups differences were noted. Paired samples *t*-tests indicated that dual cigarette and e-cigarette reported minimally stronger habitual cigarette use compared to e-cigarette use (Cohen’s $d = 0.11$, $p < .05$). Habitual alcohol and cigarette use did not differ significantly among dual-users of these products.

3.6 Correlations between product use among dual-users

The correlations between cigarette and e-cigarette SRHI scores ($r = 0.23$, $p < .001$) and alcohol and cigarette SRHI scores ($r = 0.21$, $p = .121$) were modest, suggesting that minimal variance in habitual use of these products is shared.

3.7 Test-criterion relationships

Correlations indicated that habit strength was significantly associated with increased frequency of using marijuana ($r = 0.61$), alcohol ($r = 0.75$), cigarettes ($r = 0.54$), and e-cigarettes ($r = 0.46$) as well as consuming more total drinks in the past month ($r = 0.70$) and smoking more cigarettes per day ($r = 0.57$), all p -values $< .001$ (Table 6). After accounting for demographic covariates, habit strength remained significantly associated with increased frequency of using marijuana ($\eta_p^2 = .37$), alcohol ($\eta_p^2 = .48$), cigarettes ($\eta_p^2 = .32$), and e-cigarettes ($\eta_p^2 = .17$) and with consuming more total drinks in the past month ($\eta_p^2 = .43$) and smoking more cigarettes per day ($\eta_p^2 = .33$), all p -values $< .001$; Table 6).

4. Discussion

The current study provides evidence for the reliability and validity of SRHI scores for assessing habitual marijuana, alcohol, cigarette, and e-cigarette use in adult users. A 6-item, single-factor latent structure was supported for each substance and universally evidenced internal consistency. The 6-item SRHI comprised four items related to automaticity (Gardner et al., 2012), one item reflecting difficulty controlling use, and one item related to identity. Of note, no items related to frequency of use were retained, which is consistent with prior research highlighting the distinction between habit and behavioral frequency (Gardner et al., 2012). SRHI scores were scalar measurement invariant for sex, race, and for habitual e-cigarette/cigarette use and alcohol/cigarette use (within the subsamples of dual-users). Between-groups differences were observed only for sex such that women reported stronger habitual e-cigarette use and men reported stronger habitual cannabis use. Although there was no difference in strength of habitual drinking and smoking among dual-users of these substances, dual cigarette/e-cigarette users reported significantly weaker habitual e-cigarette use than cigarette use. While the effect size was modest, this finding may be linked to prior research demonstrating that dual-users are less dependent on e-cigarettes than cigarettes overall (e.g., Liu et al., 2017). Also of interest is that the small magnitudes of the correlations between habitual cigarette and e-cigarette use and between habitual drinking and smoking, respectively, suggested that habit is a unique construct and that individuals can discern between their habitual use of two products. Further, these findings support the notion that habitual behaviors are substance-specific and relatively independent of one another, rather than representing a general propensity that dominates the learning process. Importantly, habit strength accounted for significant variance in the frequency of using each product (range 17–43%), the average number of drinks consumed per drinking day (43%), and the average number of cigarettes smoked per day (33%) above and beyond demographic covariates.

The study findings should be considered alongside several limitations. First, self-report data are limited by participants' willingness or ability to respond accurately. Second, the

generalizability of the findings may be limited by certain characteristics of the samples (e.g., online data recruitment versus in-person study participation), and future research is needed to evaluate the utility of the SRHI in other age groups (e.g., adolescents) and with other substances. Additional research also should examine patterns of habitual substance use among individuals who are poly-substance users (e.g., compare habit strength for alcohol, marijuana, and smoking in users of all three substances). Further, the SRHI was originally developed to assess general habitual behavior rather than habitual substance use, which may be linked to physical addiction. Therefore, it is possible that the six SRHI items retained in the current study do not cover all aspects of habitual substance use. In addition, all participants included in the current analyses reported using each respective substance at least monthly. However, the inclusion criteria varied across parent studies (e.g., at least weekly e-cigarette use versus at least one binge drinking episode in the past month); this resulted in different substance use frequencies being used as a threshold for defining current substance use in the present study. Future research is needed to evaluate the extent to which habit is associated with substance use in samples that represent the full continuum of use (e.g., infrequent to daily use). Further, although the SRHI evidences strong psychometric properties as a self-report measure of habitual substance use, future laboratory-based research is needed to evaluate the extent to which self-reported habit aligns with task-based, cognitive-neuroscience-driven, behavioral indices of habitual behavior (e.g., Sebold et al., 2014, Sjoerds et al., 2013; Voon et al., 2015). These studies will be key to establishing the link between the self-reported construct of habit and more formal and objective computational measures. Should there be good accord between these habit assays, we believe that the SRHI will be a practical tool for tracking habit formation and resolution with recovery in substance use disorder. Furthermore, studies that combine subjective and objective measures of habit also will be critical in addressing a final important limitation of the present study. We cannot rule out the possibility that subjects were giving what they deemed to be socially desirable responses or using habit as a convenient post-hoc rationalization for their behavior, which they can appreciate is undesirable, but in which they nevertheless engage. Demonstrating a strong relationship between objective and subjective measures of habit would help rule out these alternative explanations, since objective habit measures are less susceptible to socially desirable responding and apparent demand characteristics.

Despite its limitations, the current study demonstrates that the SRHI provides a solid foundation for studying habitual substance use across a wide range of substances (i.e., marijuana, alcohol, e-cigarettes, and cigarette use). The SRHI evidenced a confirmable latent factor structure, internal consistency, measurement invariance; could discern mean-level differences in habitual substance use by sex and product type; and accounted for variance in substance use. Future research is needed to evaluate the utility of the SHRI for assessing habitual use of other substances (e.g., cocaine, opiates) and to determine whether habit strength predicts the development or maintenance of addiction.

Acknowledgments

The authors wish to thank all participants who contributed to this work.

References

- Aarts H, Dijksterhuis A. Habits as knowledge structures: Automaticity in goal-directed behavior. *J Pers Soc Psychol.* 2000; 78:53–63. [PubMed: 10653505]
- Adams CD, Dickinson A. Instrumental responding following reinforcer devaluation. *J Exp Psychol.* 1981; 33 B:77–98.
- Ajzen I. Residual effects of past on later behavior: Habituation and reasoned action perspectives. *Pers Soc Psychol Rev.* 2002; 6:107–122.
- Bargh, JA. The Four Horsemen of automaticity: awareness, efficiency, intention, and control in social cognition. In: Wyer, RS., jr, Srull, TK., editors. *Handbook of Social Cognition.* Psychology Press; New York: 1994. p. 1–40.
- Chen FF. Sensitivity of goodness of fit indexes to lack of measurement invariance. *Struct Equ Modeling.* 2007; 14:464–504.
- Chen FF. What happens if we compare chopsticks with forks? The impact of making inappropriate comparisons in cross-cultural research. *J Pers Soc Psychol.* 2008; 95:1005–1018. [PubMed: 18954190]
- De Bruijn GJ, Kremers SP, De Vet E, De Nooijer J, Van Mechelen W, Brug J. Does habit strength moderate the intention–behaviour relationship in the Theory of Planned Behaviour? The case of fruit consumption. *Psychol Health.* 2007; 22:899–916.
- de Wit S, Corlett PR, Aitken MR, Dickinson A, Fletcher PC. Differential engagement of the ventromedial prefrontal cortex by goal-directed and habitual behavior toward food pictures in humans. *J Neurosci.* 2009; 29:11330–11338. [PubMed: 19741139]
- Dolan RJ, Dayan P. Goals and habits in the brain. *Neuron.* 2013; 80:312–325. [PubMed: 24139036]
- Doñamayor N, Strelchuk D, Baek K, Banca P, Voon V. The involuntary nature of binge drinking: Goal directedness and awareness of intention. *Addict Biol.* 2017; doi: 10.1111/adb.12505
- Ersche KD, Jones PS, Williams GB, Turton AJ, Robbins TW, Bullmore ET. Abnormal brain structure implicated in stimulant drug addiction. *Science.* 2012; 335:601–604. [PubMed: 22301321]
- Everitt BJ, Dickinson A, Robbins TW. The neuropsychological basis of addictive behaviour. *Brain Res Rev.* 2011; 36:129–138.
- Gardner B. Habit as automaticity, not frequency. *Euro Health Psychol.* 2012; 14:32–36.
- Gardner B, Abraham C, Lally P, de Bruijn GJ. Towards parsimony in habit measurement: Testing the convergent and predictive validity of an automaticity subscale of the Self-Report Habit Index. *Int J Behav Nutr Phys Act.* 2012; 9:102. [PubMed: 22935297]
- Hu L, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Struct Equ Modeling.* 1999; 6:1–55.
- Lally P, Van Jaarsveld CH, Potts HW, Wardle J. How are habits formed? Modelling habit formation in the real world. *Eur J Soc Psychol.* 2010; 40:998–1009.
- Liu G, Wasserman E, Kong L, Foulds J. A comparison of nicotine dependence among exclusive E-cigarette and cigarette users in the PATH study. *Prev Med.* 2017; 104:86–91. [PubMed: 28389330]
- Mason W, Suri S. Conducting behavioral research on Amazon’s Mechanical Turk. *Behav Res Methods.* 2012; 44:1–23. [PubMed: 21717266]
- McKim TH, Shnitko TA, Robinson DL, Boettiger CA. Translational research on habit and alcohol. *Curr Addict Rep.* 2016; 3:37–49. [PubMed: 26925365]
- Orbell S, Verplanken B. The automatic component of habit in health behavior: Habit as cue-contingent automaticity. *Health Psychol.* 2010; 29:374–383. [PubMed: 20658824]
- Ouellette JA, Wood W. Habit and intention in everyday life: The multiple processes by which past behavior predicts future behavior. *Psychol Bull.* 1998; 124:54–74.
- Sebold M, Deserno L, Nebe S, Schad DJ, Garbusow M, Hägele C, Keller J, Jünger E, Kathmann N, Smolka M, Rapp MA. Model-based and model-free decisions in alcohol dependence. *Neuropsychobiol.* 2014; 70:122–131.
- Sheeran P. Intention—behavior relations: A conceptual and empirical review. *Eur Rev Soc Psychol.* 2002; 12:1–36.

- Sjoerds Z, de Wit S, van den Brink W, Robbins TW, Beekman AT, Penninx BW, Veltman DJ. Behavioral and neuroimaging evidence for overreliance on habit learning in alcohol-dependent patients. *Transl Psychiatry*. 2013; 3:e337. [PubMed: 24346135]
- Steenkamp JEM, Baumgartner H. Assessing measurement invariance in cross-national consumer research. *J Cons Res*. 1998; 25:78–90.
- Stock AK. Barking up the wrong tree: Why and how we may need to revise alcohol addiction therapy. *Front Psychol*. 2017; 8:884. [PubMed: 28611718]
- Vandenberg RJ, Lance CE. A review and synthesis of the measurement invariance literature: Suggestions, practices, and recommendations for organizational research. *Organ Res Method*. 2000; 3:4–70.
- Verplanken B. Beyond frequency: Habit as mental construct. *Br J Soc Psychol*. 2006; 45:639–656. [PubMed: 16984725]
- Verplanken B, Aarts H. Habit, attitude, and planned behavior: Is habit an empty construct or an interesting case of goal-directed automaticity? *Eur Rev Soc Psychol*. 1999; 10:101–34.
- Verplanken B, Friberg O, Wang CE, Trafimow D, Woolf K. Mental habits: Metacognitive reflection on negative self-thinking. *J Pers Soc Psychol*. 2007; 92:526–541. [PubMed: 17352607]
- Verplanken B, Holland RW. Motivated decision making: Effects of activation and self-centrality of values on choices and behavior. *J Pers Soc Psychol*. 2002; 82:434–447. [PubMed: 11902626]
- Verplanken B, Orbell S. Reflections on past behavior: A self-report index of habit strength. *J Apply Soc Psychol*. 2003; 33:1313–1330.
- Verplanken B, Tangedler Y. No body is perfect: The significance of habitual negative thinking about appearance for body dissatisfaction, eating disorder propensity, self-esteem and snacking. *Psychol Health*. 2011; 26:685–701. [PubMed: 21347977]
- Voon V, Derbyshire K, Rück C, Irvine MA, Worbe Y, Enander J, Schreiber LR, Gillan C, Fineberg NA, Sahakian BJ, Robbins TW. Disorders of compulsivity: a common bias towards learning habits. *Mol Psychiatry*. 2015; 20:345–352. [PubMed: 24840709]
- Widaman, KF., Reise, SP. Exploring the measurement invariance of psychological instruments: Applications in the substance use domain. In: West, SG., editor. *The science of prevention: Methodological advances from alcohol and substance abuse research*. American Psychological Association; Washington, DC: 1997. p. 281-324.
- Wood W, Neal DT. A new look at habits and the habit-goal interface. *Psychol Rev*. 2007; 114:843–863. [PubMed: 17907866]
- Wood W, Quinn JM, Kashy DA. Habits in everyday life: thought, emotion, and action. *J Pers Soc Psychol*. 2002; 83:1281–1297. [PubMed: 12500811]

Highlights

- Substance use is driven in part by habitual behavior
- Measures assessing habitual substance use are lacking
- New measure can assess habitual alcohol, marijuana, e-cigarette, and cigarette use
- Self-reported habit was associated with the frequency of using each substance

Table 1

Demographics

Variables	Study1		Study2		Study 3		Study 4	
	Marijuana (2015) (n=189)	Marijuana (2016) (n=170)	Alcohol (n=100)	Cigarettes (n = 58)	Alcohol (n=133)	E-cigarettes Only (n = 239)	Cigarettes	Dual Users (n = 371)
	% or <i>M</i> (SD)	% or <i>M</i> (SD)	% or <i>M</i> (SD)	% or <i>M</i> (SD)	% or <i>M</i> (SD)	% or <i>M</i> (SD)	% or <i>M</i> (SD)	% or <i>M</i> (SD)
Male	55.0%	66.9%	50.0%	54.3%	52.0%	47.7%	49.3%	49.3%
White	59.8%	64.1%	75.0%	70.7%	62.0%	84.5%	85.2%	85.2%
Age	19.1 (1.8)	19.8 (2.4)	25.0 (1.7)	25.0 (1.8)	27.8 (8.1)	37.5 (13.4)	37.9 (13.0)	37.9 (13.0)
#days/past 30	11.1 (9.8)	14.1(10.3)	12.2 (8.7)	12.7 (10.8)	12.2 (10.4)	25.9 (7.4)	20.3 (10.9)	22.1 (8.9)
Total drinks/past 30			48.79 (58.81)		70.53 (86.08)			
Binge Drinking	--	--	36.0%	--	37.6%	--	--	--
Cigarettes/day	--	--	--	11.91 (9.59)	--	--	7.74 (6.92)	--
SRHI (Mean)	2.1 (0.9)	2.3(1.0)	3.5 (1.8)	3.0 (1.9)	2.5 (1.7)	3.2 (1.0)	3.5 (1.1)	3.4 (1.0)

Note. The response scales for the number of cigarettes smoked per day originally were presented to participants in ranges (e.g., 5–9). To facilitate interpretation of the data within the table, the ranges were converted to means (e.g., 5–9 cigarettes per day was recoded as 7 cigarettes per day). However, the original scaling of the variables was used, for all other data analyses.

Table 2

CFA and MI analyses

Self-Report Habit Index (6-Item)												
	Marijuana (n = 170)			Alcohol (n = 133)			Cigarettes (n = 371)			E-Cigarettes (n = 239)		
	RMSEA	CFI	SRMR	RMSEA	CFI	SRMR	RMSEA	CFI	SRMR	RMSEA	CFI	SRMR
Confirmatory Model	.046	.996	.017	.047	.997	.017	.067	.996	.010	.068	.994	.015
Level of Invariance												
Sex												
Configural	.068	.992	.021	.050	.997	.015	.065	.997	.012	.068	.994	.013
Metric	.051	.994	.037	.058	.995	.070	.051	.997	.028	.063	.993	.035
Scalar	.062	.987	.045	.011	.999	.072	.045	.997	.025	.058	.992	.041
Race												
Configural	.044	.997	.025	.072	.994	.022	.080	.990	.027	.057	.996	.011
Metric	.038	.999	.037	.077	.991	.069	.053	.992	.051	.039	.997	.019
Scalar	.028	.997	.050	.076	.996	.065	.038	.995	.059	.029	.998	.017

Note. Abbreviations are RMSEA (Root Mean Square Error of Approximation), CFI (Bentler's Comparative Fit Index), SRMR (Standardized Root Square Mean Residual). Scalar invariance was achieved for each subgroup tested.

Table 3

Factor Loadings and alpha

	<u>Marijuana (n=170)</u>	<u>Alcohol (n = 133)</u>	<u>Cigarettes (n = 371)</u>	<u>E-Cigarettes (n = 239)</u>
	Internal Consistency (Cronbach's α)			
	0.88	0.94	0.95	0.91
SRHI Items	Standardized Item Factor Loadings			
<i>I do automatically.</i>	0.74	0.87	0.92	0.90
<i>I do without having to consciously remember.</i>	0.82	0.92	0.90	0.79
<i>I do without thinking.</i>	0.81	0.91	0.91	0.88
<i>I start doing before I realize I'm doing it.</i>	0.63	0.76	0.87	0.79
<i>I would find hard not to do.</i>	0.54	0.81	0.81	0.68
<i>That is typically "me."</i>	0.72	0.77	0.83	0.64

Table 4

MI (substance)

Level of Invariance	E-cigarette vs Cigarette (n = 371)			Alcohol vs Cigarette (n = 58)		
	RMSEA	CFI	SRMR	RMSEA	CFI	SRMR
Configural	.010	.999	.008	.049	.996	.057
Metric	.028	.995	.034	.049	.995	.059
Scalar	.058	.986	.046	.055	.993	.067

Note. Abbreviations are RMSEA (Root Mean Square Error of Approximation), CFI (Bentler's Comparative Fit Index), SRMR (Standardized Root Square Mean Residual). Scalar invariance was achieved in each case.

Table 5

T-tests

Independent Samples t-Tests			
SRHI Scores by Sex			
Substances	Female	Male	<i>t</i>
Marijuana	2.03 (0.86)	2.33 (0.94)	-3.12 **
Alcohol	3.54 (1.77)	3.51 (1.80)	0.08
E-Cigarettes	3.44 (1.00)	2.94 (0.95)	3.98 ***
Cigarettes	3.61 (1.15)	3.49 (1.12)	1.03
SRHI Scores by Race			
Substances	Non-White	White	<i>t</i>
Marijuana	2.20 (0.93)	2.22 (0.91)	-0.19
Alcohol	3.53 (1.81)	3.53 (1.78)	0.02
E-Cigarettes	3.01 (1.05)	3.23 (0.99)	-1.21
Cigarettes	3.41 (1.07)	3.58 (1.15)	-0.95
Paired Samples t-Test			
Habitual E-cigarette Use vs. Cigarette Use (Dual E-cigarette/Cigarette Users)			
Pairings	E-Cigarettes	Cigarettes	<i>t</i>
SRHI	3.40 (1.00)	3.55 (1.13)	-2.11 *
	Alcohol	Cigarettes	<i>t</i>
	3.90 (1.68)	3.80 (2.02)	0.34

Note.

*
 $p < .05$ **
 $p < .010$ ***
 $p < .001$

All values are presented as mean (standard deviation).

Table 6

Final GLM

Bivariate Correlations										
Variables	Frequency of Use					Quantity of Use				
	Marijuana (n = 170)	Alcohol (n = 133)	Cigarettes (n = 371)	E-Cigarettes (n = 239)		Alcohol (n = 133)	Cigarettes (n = 071)			
SRHI	0.61***	0.75***	0.54***	0.46***		0.70***	0.57***			
Univariate General Linear Models										
Variables	F	η_p^2	F	η_p^2	F	η_p^2	F	η_p^2	F	η_p^2
Sex	0.12	0.00	2.03	0.02	2.29	0.01	3.07	0.01	7.56	0.06**
Age	0.59	0.00	10.62	0.08***	12.93	0.04***	9.03	0.04**	0.44	0.00
Race	0.61	0.00	0.10	0.00	3.04	0.01	1.52	0.01	2.31	0.02
Nicotine E-liquid Use	--	--	--	--	0.23	0.00	29.72	0.12***	--	--
SRHI	95.11	0.37***	117.9	0.48***	162.19	0.32***	47.85	0.17***	96.43	0.43***
									171.06	0.33***

Note. -- denotes that a variable was not included in a model; reference groups are males, non-white individuals, and non-smokers; Models predicting frequency of use: adjusted R^2 (Marijuana) = 0.37; adjusted R^2 (Alcohol) = 0.58; adjusted R^2 (Cigarettes) = 0.35; adjusted R^2 (E-Cigarettes) = 0.33; models predicting quantity of use: adjusted R^2 (Alcohol) = 0.52; adjusted R^2 (Cigarettes) = 0.35

* $p < .05$ ** $p < .01$ *** $p < .001$