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Psychometric evaluation of the Self-Report Habit Index for assessing habitual e-cigarette use behavior in high school adolescents

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HIGHLIGHTS

- The Self-Report Habit Index was examined for assessing habitual vaping behavior.
- Psychometric properties (e.g., latent structure, reliability, invariance) were strong.
- Habitual vaping behavior related to flavors vaped, vaping frequency, and dependence.
- Habitual vaping behavior incrementally related to outcomes beyond dependence.
- Habitual vaping behavior may precede adolescents developing e-cigarette dependence.

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ABSTRACT

Background: E-cigarettes are the most-used nicotine product among adolescents, but limited psychometrically-sound, e-cigarette-relevant measures exist for adolescents. We examined psychometric properties of the Self-Report Habit Index (SRHI) for assessing adolescents' habitual e-cigarette use.

Methods: During Fall 2022, 4855 students from eight Connecticut high schools completed an anonymous survey. The analytic sample comprised 491 students who reported past-month e-cigarette use and completed the SRHI (Age M=15.94, SD=1.24 years, 56 % female, 37.1 % Hispanic, 57.6 % White). We examined the SRHI's latent factor structure; internal reliability; measurement invariance and between-groups differences (e.g., nicotine vs. nicotine-free vaping); and associations with total e-cigarette flavors used in the past month, past-30-day vaping frequency, and e-cigarette dependence.

Results: The SRHI's 6-item, 1-factor structure was confirmed. Internal reliability was excellent. The SRHI was scalar invariant for all subgroups tested. Nicotine (vs. nicotine-free) and daily (vs. non-daily) e-cigarette use were associated with greater habitual e-cigarette use behavior. In adjusted models, habitual e-cigarette use was associated with using more e-cigarette flavors, vaping more frequently, and greater e-cigarette dependence. Habitual e-cigarette use incrementally accounted for variance in past-month flavors used and vaping frequency beyond dependence.

Conclusions: The SRHI evidenced solid psychometric properties for assessing habitual e-cigarette use behavior among high school students. Relationships between habitual use and frequency of use, e-cigarette flavors, and dependence might be expected as these constructs are associated with the three characterizing features of habitual behaviors: frequent repetition, cue-driven elicitation, and automaticity. Future prospective research can clarify the temporal ordering of habitual e-cigarette use and dependence in adolescents.

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1. Introduction

Compulsive behaviors, including maladaptive substance use, are thought to involve an imbalance of reduced or impaired goal-directed behavior (i.e., consequences are not considered before acting) coupled with increased habitual behavior (Vandaele and Janak, 2018; Voon et al., 2015). Habitual behaviors share three key features: frequent repetition, elicitation via environmental or situational contexts, and high automaticity (Orbell and Verplanken, 2015). Automaticity constitutes a lack of awareness, conscious intent, and control, paired with a high degree of mental efficiency (Bargh, 1994). Habitual behavior develops when a cue and resulting behavior become repetitively paired, increasing automaticity (Orbell and Verplanken, 2015). In short, it becomes easier to mindlessly engage in habitual behavior as automaticity increases. Habitual behaviors are difficult to control, and sometimes to self-identify, given the lack of awareness and intentionality that characterize them. However, understanding and accurately assessing maladaptive habitual behaviors are critical for cessation and replacement with adaptive responses (Stock, 2017).

Automaticity is a key feature of habitual behavior, but, perhaps unsurprisingly, it is also conceptualized as one facet of nicotine dependence alongside others like craving, loss of control, tolerance, and withdrawal (e.g., Piper et al., 2008). As noted, automaticity is linked to a cycle of repetitive use, but this cycle may need to continue for some time before other aspects of nicotine dependence like tolerance and withdrawal fully develop. In other words, automaticity (as it relates to habit) may precede nicotine dependence in individuals with less established use patterns, including adolescents, given that it may contribute to the frequent use that is associated with dependence over time (e.g., Morean et al., 2018). Thus, it is important to examine the extent to which habitual e-cigarette use behavior and e-cigarette dependence overlap or are distinct.

A six-item version of the original Self-Report Habit Index (SRHI; Verplanken and Orbell, 2003) has been shown to be psychometrically-sound for assessing habitual use of cannabis, alcohol, cigarettes, and e-cigarettes among adults (Morean et al., 2018b). However, the SRHI has not been validated for assessing habitual substance use behavior in adolescents. E-cigarettes remain the most popular nicotine product among adolescents (Park-Lee et al., 2022), and research suggests that adolescent e-cigarette use differs in important ways from adults' use. For instance, adults are more likely to use e-cigarettes for quitting cigarettes or as smoking substitutes, to have formerly smoked cigarettes, and to currently use both e-cigarettes and cigarettes (e.g., Gupta and Kalagher, 2021; Mayer et al., 2020; Thoonen and Jongenelis, 2024). In contrast, youth are more likely to use e-cigarettes due to curiosity, taste/flavors, for entertainment, and based on peer use (e.g., Gupta and Kalagher, 2021; Morean et al., 2018; Thoonen and Jongenelis, 2024). Given established differences in adolescent and adult e-cigarette use, it is important to separately evaluate the psychometric properties of the SRHI for assessing habitual e-cigarette use behaviors in high school adolescents.

Although the SRHI has never been evaluated for use with adolescents who vape, we expected to find evidence of a stable latent factor structure that is invariant across participant subgroups (e.g., sex, daily versus less frequent vaping) and is sensitive to detecting between groups differences. In addition, we expected to observe evidence of test-criterion validity through relationships with e-cigarette-relevant behaviors including flavor use, frequency of use, and dependence. Finally, we expected to observe evidence that habitual use is related to, yet distinct from, dependence. If the aforementioned psychometric properties were established, the current study would provide evidence for the utility of assessing habitual e-cigarette use behaviors in adolescents as it would prove to be a unique construct that can help inform our broader understanding of e-cigarette use in this population. In addition, findings would suggest that increasing awareness of habitual use may be an important and novel component for inclusion in prevention and intervention efforts aimed at adolescent vaping.

2. Material and methods

2.1. Participants and procedures

All procedures were performed in compliance with relevant laws and institutional guidelines, and the Yale University Institutional Review Board approved all procedures (#1207010580; 9/29/22). During Fall 2022, 4855 students from eight Connecticut high schools participated in a 20-minute, anonymous, school-wide, online survey. Schools informed parents/guardians about the survey two weeks prior to administration and provided instructions for opting children out (48 students were opted-out, and the remaining students were allowed to participate based on passive parental permission). We provided teachers with instructions for survey administration and our contact information for questions. Students were informed that their participation was voluntary. Choosing to complete the survey served as assent. Across schools, the average response rate was 87.6 %. The analytic sample comprised 491 students who endorsed past-month e-cigarette use and completed the SRHI (out of a total of 546 who endorsed past-month e-cigarette use). See Section 3.1 for participant demographics.

2.2. Measures

2.2.1. Demographics

Youth reported on biological sex (male, female), Hispanic ethnicity (no/yes), and race (select all that apply: American Indian/Alaska Native, Asian, Black, Native Hawaiian/Pacific Islander, "Other," White). Race was categorized as Black, White, or "Other" due to limited sample sizes in all groups other than Black and White.

2.2.2. Self-report habit index

Youth completed the 6-item version of the SRHI that demonstrated strong psychometric properties for assessing habitual e-cigarette use behavior in adults (Morean et al., 2018b). Table 1 contains all items and response options.

2.2.3. Other e-cigarette measures

Youth reported on past-30-day vaping frequency in number of days and on flavors vaped in the past 30 days (select all that apply: tobacco, menthol, mint, fruit, candy/dessert, vanilla, coffee, spice, alcoholic beverage, other beverage, other). We calculated the total number of

Table 1
Model fit and factor loadings of the single-factor Self Report Habit Index.

Self-Report Habit Index (ω = 0.94)		
Model Fit Indices		
RMSEA 0.068 (0.039–0.100)		
CFI 0.984		
TLI 0.965		
SRMR 0.018		
χ^2 (9) 68.94***		
Items		
Vaping is something…	Loading	Standard Error
I do automatically.	0.88	0.02
I do without having to consciously remember.	0.90	0.02
I do without thinking.	0.87	0.02
I start doing before I realize I'm doing it.	0.84	0.03
I would find hard NOT to do.	0.76	0.03
That is typically "me."	0.80	0.03

Note. RMSEA (Root Mean Square Error of Approximation), CFI (Bentler's Comparative Fit Index), TLI (Tucker Lewis Index), SRMR (Standardized Root Mean Square Residual). RMSEA is presented with its 95 % confidence interval in parentheses. ω (coefficient omega). Response options for the SRHI items were strongly disagree (0), disagree (1), neither disagree nor agree (2), agree (3), and strongly agree (4). *** $p < 0.001$. All items loaded at $p < 0.001$

flavors used based on findings showing that using more flavors is disproportionately associated with adolescent versus adult e-cigarette use (Morean et al., 2018a). We assessed past-month use of nicotine e-cigarettes (no, yes) and dependence via the PROMIS® short-form E-cigarette Nicotine Dependence scale (PROMIS® SF v1.0 - E-Cigarette Nicotine Dependence 4a; (Morean et al., 2019) which has been validated for use with adolescents (Morean et al., 2018c).

2.3. Data analytic plan

Power calculations were conducted using PASS 2022 to ensure the adequacy of the sample size for the planned analyses. Mplus 8.9 was used to examine item probability curves and item/test information curves as well as to evaluate the latent structure and measurement invariance of the SRHI. SPSS 29 was used to conduct remaining analyses.

2.3.1. Examining the suitability of the SRHI for use with adolescents

Given that the e-cigarette version of the SRHI had not previously been used with adolescents, we took several steps to examine its appropriateness for use with this population. First, we examined the reading level of the items. Second, an item-factor analysis (e.g., IRT 2PL model) was conducted in MPLUS, specifying weighted least square mean and variance adjusted estimation and theta (i.e., probit) parameterization, from which probability and information plots were generated. We used a modified graded response model (Samejima, 1969), which is appropriate for polytomous, Likert-type response options like those used in the SRHI.

2.3.2. Confirmatory factor analysis (CFA)

A CFA was run to test the proposed 1-factor latent structure of the SRHI. We used full-information maximum likelihood with robust standard errors to manage non-normal data distributions and to generate fit indices. Good model fit was defined as Root Mean Square Error of Approximation (RMSEA) < 0.07 (Steiger, 2007), Bentler's Comparative Fit Index (CFI) > 0.95 (Bentler, 1990), and Standardized Root Mean Square Residual (SRMR) < 0.08 (Hu and Bentler, 1999).

2.3.3. Internal reliability

Coefficient omega was calculated as an index of internal consistency.

2.3.4. Measurement invariance

Multigroup CFA was used to test invariance by sex (female/male), age (< 16 years versus 16 years and older), Race (Black, White, Other), Hispanic ethnicity (no/yes), use of nicotine e-cigarettes (no/yes), and daily e-cigarette use (30 days; no/yes). We examined three increasingly stringent levels of invariance that built on each other: configural (constraining latent factors and items per factor to equality), metric (additionally constraining factor loadings to equality), and scalar (additionally constraining item intercepts to equality). Configural invariance was met if the model fit with all items loading significantly, and metric invariance was met if further constraining factor loadings to equality did not significantly worsen the model fit by more than RMSEA $\geq$.015, CFI $\geq$.01, or SRMR $\geq$.03 (Chen, 2007). Scalar invariance was achieved if further constraining intercepts to equality did not significantly worsen the model fit observed for the metric model by CFI $\geq$.01 (Byrne, 1998; Chen, 2007).

2.3.5. Between-group differences

After establishing scalar measurement invariance, a requirement for examining between-groups differences (Chen, 2008; Steenkamp and Baumgartner, 1998), we ran independent-samples t-tests to examine differences in SRHI scores based on sex, age, Hispanic ethnicity, use of nicotine e-cigarettes, and daily e-cigarette use, and we ran an ANOVA to examine differences in SRHI scores based on race.

2.3.6. Concurrent Relationships

Three univariate general linear models (GLMs) were run to evaluate how SRHI scores related to the following continuous outcomes: the total number of e-cigarette flavors used in the past month, past-month vaping frequency, and e-cigarette dependence. Covariates included sex, age, Hispanic ethnicity, race, and nicotine e-cigarette use. For dependence, past-month vaping frequency also was included as a covariate to ensure that dependence was not just a proxy for frequency of use. Given that the distribution for frequency of past month use was bimodal with nodes at 1 (n = 84) and 30 days (n = 117; Supplemental Figure 1) and that bimodal distributions cannot be transformed to approximate normality, we also ran a logistic regression with the outcome of daily vaping (no/yes) and a multinomial logistic regression model with data-driven terciles as the categorical outcomes (i.e., 3 days or less, 4–20 days, and 20 days or more).

2.3.7. Habitual e-cigarette use behavior versus e-cigarette dependence

We first examined the relationship between habitual e-cigarette use behavior and dependence via correlation. Then, we examined rates of endorsement of habitual e-cigarette use behavior and e-cigarette dependence to help determine if habitual e-cigarette use behavior may be more prevalent in adolescents than e-cigarette dependence. Here, habitual e-cigarette use was dichotomized as no habitual use (SRHI = 0) versus any habitual use (SRHI > 0), and dependence was dichotomized as no dependence (PROMIS = 0) versus any dependence (PROMIS > 0).

Finally, we repeated the adjusted analyses described in Section 2.3.6 for past-month vaping frequency and total e-cigarette flavors used in the past month, respectively, with habitual e-cigarette use behavior and dependence simultaneously included in the models as independent variables. Here, we were hoping to identify if habitual use accounted for incremental variance in the outcomes above and beyond dependence.

3. Results

3.1. Sample characteristics

The sample was 15.94 (SD = 1.24) years old on average, 54.6 % female, 37.1 % Hispanic, 57.6 % White, 12.4 % Black, and 29.9 % from race other than Black or White. On average participants vaped on 13.17 (SD = 11.88) days in the past 30 days, with 23.8 % vaping daily. The majority (69.2 %) reported using e-cigarettes with nicotine (versus nicotine-free), and, on average, participants endorsed using 2.36 (SD = 1.82) flavors in the past month. The mean score for habitual use was 2.16 (SD = 1.17) and the mean score for dependence was 0.78 (SD = 1.11). See Supplemental Table 1 for a tabular depiction of participant demographics.

3.2. Power calculations

Calculations revealed that we were adequately powered to conduct the primary planned analyses (Supplemental Table 2).

3.3. Examining the suitability of the SRHI for use with adolescents

An examination of the Flesch-Kincaid Grade Level in Microsoft Word suggested that the SRHI items can be read by individuals with less than an 8th grade reading level (Grade Level: 7.7). Further, the entire sampling space (i.e., response scale) was used by participants (Supplemental Figure 2), although, as expected, some adolescents provided consistent responses across all six SRHI item when examined descriptively ("Strongly Disagree" [n = 146], "Disagree" [n = 20], "Agree" [n = 6], "Neither Disagree nor Agree [n = 17], "Strongly Agree [n = 24]). When examining item probability curves, the expected order of the responses (strongly disagree, disagree, neither disagree nor agree, agree, strongly agree) was maintained across all items, with each utilized as expected across the latent trait (i.e., theta). The probability curve for Item 6

("Vaping is something that is typically me.") suggested that the "Strongly Disagree" and "Strongly Agree" response options were primarily used by youth, although there was endorsement of other responses. An examination of the item information curves suggested some redundancy in the items, but the total information curve suggested that the adapted six items of the SHRI adequately captured variation in habitual e-cigarette use behavior across the latent trait space, especially among youth with average levels of habitual e-cigarette use (i.e., theta; Range: −1 to +1.5).

3.4. Confirmatory factor analysis and internal reliability

The single-factor structure was confirmed (Table 1), and internal reliability was excellent (ω = 0.94).

3.5. Measurement invariance

The SRHI was scalar invariant for each group tested (Supplemental Table 3).

3.6. Between-groups differences

Higher SRHI scores were observed for nicotine versus nicotine-free e-cigarette use and for daily versus less frequent vaping (Table 2).

3.7. Concurrent relationships

When all outcomes were treated as continuous, higher SHRI scores were associated with using more e-cigarette flavors in the past month (n_p^2 = 0.23), more frequent past-month vaping (n_p^2 = 0.30), and greater e-cigarette dependence (n_p^2 = 0.49), *p*-values < 0.001 (Table 3). For the models predicting total flavors used and past-month vaping frequency, significant demographic covariates included male sex and using nicotine e-cigarettes. Being older also was associated with more frequent vaping.

When past-month vaping was dichotomized into daily versus less frequent vaping, higher SRHI scores were associated with daily vaping (OR_{adj} = 3.56, p <.001; Supplemental Table 4) as were male sex, being older, and using nicotine e-cigarettes. Similarly, when considering data-driven terciles for vaping frequency, compared to vaping less often (i.e., on three days or less), higher SRHI scores were associated with more frequent vaping (i.e., vaping on 4–20 days [OR_{adj} = 1.48, p < 0.01] and on 21 days or more [OR_{adj} = 2.00, p < 0.01]) as was using nicotine e-cigarettes. Higher SRHI scores, male sex, being older, and using nicotine e-cigarettes (vs. no nicotine) were associated with vaping more often (i.e., on 21 days or more [OR_{adj} =2.93, p < 0.001] compared to 4–20 days; Supplemental Table 4).

Table 2
Between-groups differences in Self-Report Habit Index Scores.

Sex	Mean (SD)	t / F
Female (n = 268)	2.19 (1.17)	0.76
Male (n = 223)	2.11 (1.18)	
Age (< 16 years vs. 16 years and older		
< 16 years (n = 176)	2.11 (1.10)	-0.70
16 years and older (n = 315)	2.18 (1.21)	
Not Hispanic vs Hispanic		
Not Hispanic (n = 308)	2.13 (1.18)	-0.58
Hispanic (n = 182)	2.20 (1.17)	
Race		
Other (n = 147)	2.15 (1.13)	0.39
Black (n = 61)	2.04 (0.96)	
White (n = 283)	2.18 (1.24)	
Nicotine E-liquid Use		
No (n= 151)	1.78 (0.94)	-4.85***
Yes (n = 340)	**2.32 (1.23)**	
Daily versus Non-Daily Vaping		
Less Frequent (n = 374)	1.78 (0.86)	-15.18***
Daily (n = 117)	**3.34 (1.27)**	

Note. ***p <.001. *t* indicates the t-value for all between-subjects t-tests. F is the F-value for the one-way ANOVAs calculated for race.

Table 3
Relationships between the Self-Report Habit Index and e-cigarette flavors, frequency of past-month e-cigarette use, and e-cigarette dependence.

	Total Flavors Used in the Past Month					
	B	SE	t	95 % CI		np^2
Male (ref. Female)	0.63	0.18	3.51	0.28	0.99	0.03***
Age	0.08	0.07	1.16	-0.06	0.23	0.00
Hispanic (ref. Not)	-0.05	0.20	-0.24	-0.44	0.35	0.00
Race Other (ref. White)	0.07	0.22	0.31	-0.36	0.49	0.00
Race Black (ref. White)	-0.31	0.29	-1.07	-0.87	0.26	0.00
Nicotine E-cigarette Use (ref. not)	-0.84	0.20	-4.33	-1.23	-0.46	0.04***
Habitual Use	0.95	0.08	11.77	0.79	1.11	0.23***
	Frequency of Vaping in the Past Month (# of days)					
	B	SE	t	95 % CI		np^2
Male (ref. Female)	1.62	0.82	1.98	0.02	3.23	0.01*
Age	0.69	0.33	2.10	0.04	1.34	0.01*
Hispanic (ref. Not)	-0.97	0.91	-1.07	-2.76	0.82	0.00
Race Other (ref. White)	0.33	0.99	0.34	-1.61	2.28	0.00
Race Black (ref. White)	-2.01	1.29	-1.55	-4.55	0.54	0.01
Nicotine E-cigarette Use (ref. not)	-5.52	0.89	-6.24	-7.26	-3.78	0.08***
Habitual Use	5.33	0.37	14.39	4.60	6.06	0.30***
	E-cigarette Dependence					
	B	SE	t	95 % CI		np^2
Male (ref. Female)	0.08	0.05	1.51	-0.03	0.19	0.01
Age	0.03	0.02	1.35	-0.01	0.07	0.00
Hispanic (ref. Not)	-0.07	0.06	-1.16	-0.19	0.05	0.00
Race Other (ref. White)	0.01	0.07	0.08	-0.12	0.13	0.00
Race Black (ref. White)	-0.16	0.09	-1.91	-0.33	0.00	0.01
Nicotine E-cigarette Use (ref. not)	-0.08	0.06	-1.34	-0.20	0.04	0.00
Frequency of Vaping in the Past Month (# Days)	0.02	0.00	7.57	0.02	0.03	0.11***
Habitual Use	0.62	0.03	21.38	0.56	0.68	0.49***

Note. * p <.05 ** p <.01 *** p <.001. SE (Standard Error), 95 % CI (95 % Confidence Interval), n_p^2 (Partial Eta Squared). All outcome variables were treated as continuous.

3.8. Habitual e-cigarette use behavior versus e-cigarette dependence

Habitual e-cigarette use behavior and e-cigarette dependence correlated strongly (r = 0.79), suggesting 62.4 % overlap between the constructs. However, rates of endorsement differed by construct. 10.3 % (n = 15) of all adolescents who did not report any habitual use behavior (n = 146) endorsed some level of dependence. In contrast, 42.5 % (n = 97) of all adolescents who did not report any dependence (n = 228) endorsed some level of habitual use behavior (Table 4). In other words, 3.1 % (n = 15) of the total sample of adolescents who used e-cigarettes in the past month (N = 491) reported e-cigarette dependence only with no endorsement of habitual e-cigarette use behavior, while 19.8 % of the total sample (n= 97) reported habitual e-cigarette use behavior only with no endorsement of dependence (Table 4).

Finally, when including both constructs in the adjusted GLM models in which all variables were treated as continuous, habitual e-cigarette use behavior incrementally accounted for variance in the total number of e-cigarette flavors used in the past month (partial eta squared = 2 %) and in past-month vaping frequency (partial eta squared = 5 %; full results not depicted). In addition, habitual e-cigarette use behavior remained a significant predictor of daily vaping (OR = 1.68, p < 0.05) versus less frequent vaping and was associated with vaping on 4–20 days (OR = 1.48, p < 0.05) or on 21 days or more (OR = 2.00, p < 0.01) compared to vaping on 3 or fewer, as well as with vaping on 21 days or more (OR = 1.35, p < 0.05) compared to on 4–20 days (Supplemental Table 4). The significant demographic covariates generally mirrored those described in Section 3.6.

Table 4
Mean e-cigarette dependence scores by endorsement of varying mean levels of the Self-Report Habit Index and mean Self-Report Habit Index scores by endorsement of varying mean levels of e-cigarette dependence.

Mean Dependence	Mean Self-Report Habit Index Scores					
Scores	1	> 1 but < 2	≥ 2 but < 3	≥ 3 but < 4	≥ 4 but < 5	5
1	131 (89.7 %)	53 (58.9 %)	32 (24.8 %)	12 (16.2 %)	0 (0 %)	0 (0 %)
> 1	**15 (10.3 %)[a]**	37 (41.4 %)	97 (75.12 %)	62 (83.8 %)	25 (100 %)	25 (100 %)
≥ 2	2 (1.4 %)	9 (10.%)	46 (35.7 %)	52 (71.6 %)	23 (92.0 %)	25 (100 %)
≥ 3	0 (0 %)	1 (1.1 %)	10 (7.8 %)	23 (33.8 %)	19 (76.0 %)	24 (96.0 %)
≥ 4	0 (0 %)	0 (0 %)	1 (0.8 %)	5 (6.8 %)	11 (44.0 %)	23 (92.0 %)
5	0 (0 %)	0 (0 %)	1 (0.8 %)	3 (4.1 %)	2 (8.0 %)	16 (64.0 %)
# Participants/Group vs. Total Sample	146 (29.9 %)	90 (18.4 %)	129 (26.4 %)*	74 (15.1 %)*	25 (5.1 %)*	25 (5.1 %)*
Mean Self-Report	Mean Dependence Scores					
Habit Index Scores	1	> 1 but < 2	≥ 2 but < 3	≥ 3 but < 4	≥ 4 but < 5	5
1	131 (57.5 %)	13 (12.6 %)	2 (2.5 %)	0 (0 %)	0 (0 %)	0 (0 %)
> 1	**97 (42.5 %)[b]**	90 (87.4 %)	77 (97.5 %)	39 (100 %)	18 (100 %)	22 (100 %)
≥ 2	44 (19.3 %)	62 (60.2 %)	69 (87.3 %)	38 (97.4 %)	18 (100 %)	22 (100 %)
≥ 3	12 (5.3 %)	11 (10.7 %)	33 (41.2 %)	29 (74.4 %)	18 (100 %)	21 (95.5 %)
≥ 4	0 (0 %)	2 (1.9 %)	5 (6.3 %)	9 (23.1 %)	16 (88.9 %)	18 (81.8 %)
5	0 (0 %)	0 (0 %)	1 (1.3 %)	1 (2.6 %)	7 (38.9 %)	16 (72.7 %)
# Participants/Group vs. Total Sample	228 (46.6 %)*	103 (21.1 %)*	79 (16.2 %)	39 (8.0 %)	18 (3.7 %)	22 (4.5 %)

Note. A mean score of 1 equates to no endorsement of habitual use or dependence. Increasing scores correspond to increasing levels of each construct. Column totals do not add to 100 % because each cell is showing the percentage of participants who reach a certain threshold. For example, among those who did not endorse any habitual use (score of 1), 89.7 % did not endorse any dependence, 10.3 % endorsed some dependence (any mean score > 1), and 2 % endorsed dependence with a mean score of 2 or higher. The bolded cell with the superscript "a" indicates the percentage of participants who did not endorse any habitual use but who endorsed some level of dependence. The bolded cell with the superscript "b" indicates the percentage of participants who did not endorse any dependence but who endorsed some level of habitual use. The asterixis indicate numerically higher percentages when comparing the sample sizes of those with mean scores of a given value (i.e., 1, > 1 but < 2, ≥ 2 but < 3, ≥ 3 but < 4, ≥ 4 but < 5, 5) for habitual use versus dependence. For example, in the column for a mean score of 1 (indicating no use), 228 (46.6 %) for dependence is larger than 146 (29.9 %) for habitual use.

4. Discussion

This study provides support for using the 6-item, single-factor SRHI to assess habitual e-cigarette use behavior in high school students. The reading level (<8th grade), item probability curves, and item/test information curves provided evidence that adolescents understood the measure and were responding in ways that produced meaningful data. This provided a sound foundation supporting the primary psychometric analyses. Indeed, the SRHI had a stable latent factor structure, excellent internal consistency, and reached scalar invariance for all participant subgroups tested. Between-groups differences showed that adolescents who reported vaping nicotine (vs. nicotine-free) and daily vaping (vs. less frequent) endorsed more habitual use behavior, as might be expected. Nicotine e-cigarette use, in general, is associated with more frequent vaping and the development of dependence in adolescents (e.g., Morean et al., 2018). Further, the reinforcing nature of nicotine may impact habit development, given that habitual behavior develops when a cue and resulting behavior become increasingly paired through repetition (which nicotine facilitates and perpetuates via its reinforcing pharmacological effects; Kozlowski, 2021; Orbell and Verplanken, 2015). In addition, given that habitual behaviors are characterized by frequent repetition, consistent elicitation via environmental or situational cues, and high automaticity (Orbell and Verplanken, 2015), one might expect that individuals who vape daily would be more likely to develop habitual use behavior, and, conversely, that habitual use behaviors would translate to more frequent use. In short, our results suggest that e-cigarette use among adolescents likely reflects a cycle of habit.

In the adjusted models, habitual e-cigarette use behavior was associated with using more e-cigarette flavors, more frequent vaping (conceptualized in three different ways), and higher dependence scores even after accounting for significant effects of covariates including male sex, being older, and/or using nicotine e-cigarettes which have been shown to be associated with e-cigarette use in prior work (e.g., Kong et al., 2017; Perikleous et al., 2018; Vogel et al., 2018).

The significant effects of habitual e-cigarette use behavior might be expected based on prior work. Although we are not aware of any studies that specifically examine the relationship between total flavors used and habit or the related construct of dependence, flavors impact the overall appeal of e-cigarettes (King, 2020; Kong et al., 2015), using more flavors has been associated with disproportionately greater vaping frequency in adolescents compared to adults (Morean et al., 2018a), and relationships between flavor use and dependence have been observed (e.g., Li et al., 2024; Sargent et al., 2022). Thus, similar to nicotine, using multiple appealing flavors may increase the frequency and strength of repeated pairings between cues and vaping, leading to increased likelihood of habit development.

Mirroring the findings reported for between-groups differences, it also logically follows that more frequent vaping was related to habitual e-cigarette use behavior given the inextricable link between habitual use and behavioral frequency (Orbell and Verplanken, 2015). Of note, the strength of the relationship between habitual e-cigarette use behavior and vaping frequency (when treated as continuous) was nearly twice as large for adolescents ($n_p^2 = 0.30$) as was previously observed for adults ($n_p^2 = 0.17$) (Morean et al., 2018b). This may speak to the importance of habit (perhaps automaticity, in particular) to adolescent vaping, although this possibility requires additional investigation. Finally, the observed link between habitual use behavior and dependence is supported by prior research showing that habitual use is linked to more frequent use, which, in turn, is linked to dependence (e.g., Morean et al., 2018).

When more closely examining endorsement of habitual e-cigarette use behavior versus e-cigarette dependence, we found evidence that these are related constructs. Although causality/directionality could not be evaluated given the study design, findings speak to the possibility that habitual e-cigarette use behavior may be a precursor to developing e-cigarette dependence in adolescents. Most participants who endorsed habitual e-cigarette use behavior also endorsed dependence, but 19.8 % of the total sample endorsed habitual use and not dependence, while only 3.1 % endorsed dependence but not habitual use. Thus, it seems that habitual e-cigarette use behavior may be more commonly endorsed among adolescents, perhaps because they may not have firmly

established use patterns (although this was not assessed directly). Additional research is needed to assess the temporal sequencing between habitual e-cigarette use behavior and dependence. Finally, when examining incremental (cross-sectional) validity, habitual e-cigarette use behavior accounted for variance in the total number of flavors used in the past month and vaping frequency above and beyond dependence, speaking to the utility of assessing these constructs separately.

Of course, study limitations must be considered. First, we did not conduct qualitative research like cognitive interviews with adolescents prior to adapting the measure for use with e-cigarettes, so we cannot confirm that adolescents understood the measure's content as intended. However, the study team rated the vaping-specific SRHI items as appropriate for administration to high school students, supported in part by prior research showing that the SRHI has been used to assess other habitual behaviors in children and adolescents including diabetes management (e.g., Cummings et al., 2022), reading (e.g., Schmidt and Retelsdorf, 2016), fruit and vegetable consumption (e.g., Albani et al., 2018), and physical activity (e.g., Kremers and Burg, 2008; Kremers et al., 2008) among others. Concerns were also mitigated by the middle school reading level of the scale (7th grade) and the results indicating that adolescents utilized the full range of response options and that the items captured meaningful differences in habitual e-cigarette use behavior. Second, we utilized a convenience sample of high school students from Connecticut, which may limit generalizability. However, the SRHI evidenced comparably solid psychometric properties to those previously observed in adults (Morean et al., 2018b), helping to mitigate concerns. Third, we had insufficient sample sizes within racial groups other than Black and White to conduct more nuanced analyses, and the "other race" group was highly heterogenous; additional research in a more diverse sample is needed. Fourth, habitual e-cigarette use behavior may be influenced by characteristics not included in this report like impulsivity, which is elevated among adolescents and is known to contribute to e-cigarette use (Bold et al., 2017; Davis et al., 2022; Masaki et al., 2022).

In conclusion, study findings support using the Self-Report Habit Index to assess habitual e-cigarette use behavior in high school students. Moving forward, it will be important to further disentangle habitual e-cigarette use behavior from dependence in adolescents, for whom habitual use may precede the development of dependence. It also will be important to examine if similar or different correlates are associated with each construct (e.g., impulsivity with habitual e-cigarette use behavior; duration of regular e-cigarette use with dependence). Prevention efforts may benefit from raising awareness of habitual e-cigarette use behavior, especially if it is found to precede dependence, and information about habitual use behavior can be integrated into vaping cessation programs potentially through practices including mindfulness training.

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Author statement

Drs. Morean, Kong, Davis, Bold, and Krishnan-Sarin contributed to study conceptualization, data curation, investigation, development and implementation of study methodology, and reviewing the manuscript before submission. Dr. Morean led project administration, conducted the primary statistical analyses, and wrote the original draft of the manuscript. Dr. Talley conducted the item response analyses and provided interpretation of them. Dr. Krishnan-Sarin secured funding for the study. All authors approved of the final version of the manuscript for submission.

CRediT authorship contribution statement

Amelia Talley: Formal analysis, Writing – review & editing. **Krysten W Bold:** Writing – review & editing, Methodology, Conceptualization. **Suchitra Krishnan-Sarin:** Writing – review & editing, Methodology, Funding acquisition, Conceptualization. **Danielle R Davis:** Writing – review & editing, Methodology, Conceptualization. **Grace Kong:** Writing – review & editing, Methodology, Conceptualization. **Meghan E Morean:** Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.dadr.2024.100251.

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