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An integrated dual process model in predicting e-cigarette use in undergraduate students

Daniel J. Phipps[1,2] | **Natasha J. Nott**[2] | **Kyra Hamilton**[1,2,3]

[1]Sport and Exercise Sciences, University of Jyväskylä, Jyväskylä, Finland

[2]School of Applied Psychology, Griffith University, Brisbane, Australia

[3]Health Sciences Research Institute, University of California, Merced, Merced, California, USA

Correspondence
Daniel J. Phipps, Sport and Exercise Sciences, University of Jyväskylä, Keskussairaalantie 4, 40600 Jyväskylä, Finland.
Email: daniel.j.phipps@jyu.fi

Abstract

The use of e-cigarette or vape devices is a growing concern on an international scale, given the devices' addictive nature and questions regarding their short- and long-term health impacts. Their use is especially an issue in young people, many of whom have little or no previous nicotine use experience. This study tested an integrated dual process model in 363 young Australian undergraduates where prospectively measured e-cigarette use was predicted by the psychological constructs of the theory of planned behavior, supplemented with risk perception, e-cigarette dependence, habit, and implicit attitude. Intention to use an e-cigarette was predicted by affective attitude, subjective norm, and e-cigarette dependance, but not instrumental attitude, perceived behavioral control, or risk perception. E-cigarette use was predicted by e-cigarette dependance, intention, habit, implicit attitude, and previous nicotine use, although perceived behavioral control did not directly predict behavior nor moderate the intention–behavior relationship. Current findings provide evidence for important psychological predictors of e-cigarette use, signposting potential intervention targets. Specifically, interventions may benefit from using strategies that tap affective or normative

beliefs alongside automatic constructs and dependence, while focusing less on beliefs about the health impacts of e-cigarettes or control over using.

KEYWORDS

e-cigarettes, habit, implicit attitude, risk perception, theory of planned behavior, vaping

INTRODUCTION

Governments and public health organizations have long placed efforts into reducing tobacco use. However, although tobacco use has fallen (World Health Organization, 2019), nicotine usage rates are starting to increase through the rapid worldwide adoption of e-cigarette and vape devices (Wakefield et al., 2023). That is, devices that deliver aerosolized and often flavored nicotine to the lungs by heating a propylene glycol solution. Such devices are often championed as a healthier alternative to traditional tobacco smoking or as a potentially efficacious pathway to quitting nicotine use overall. However, there is also concern that although e-cigarettes may be useful for harm minimization for seasoned smokers, they are also being used in increasing numbers by young people (Morean, Krishnan-Sarin, & O'Malley, 2018; Wakefield et al., 2023), with 49% of Australians aged 18–24 reporting at least some e-cigarette use (Australian Institute of Health and Welfare, 2024). Importantly, for these young people, many who use e-cigarettes also report little or no previous experience using traditional cigarettes (Hammond et al., 2020). Evidence suggests that such devices are addictive and, despite being significantly less harmful than traditional cigarettes, are still associated with health consequences such as respiratory illness, poor oral health, and increased susceptibility to pulmonary infection (Almeida-da-Silva et al., 2021; Groner, 2022). Furthermore, although the recency of e-cigarettes precludes studies on their long-term effects, using e-cigarettes has been associated with markers for long-term chronic pulmonary and cardiovascular illnesses (Tsai et al., 2020). Although these health effects are less severe than those associated with traditional smoking, their potential presence, in combination with the notable popularity of e-cigarettes in younger populations (Wakefield et al., 2023), has sparked widespread concerns among experts and calls from the world health organization to stem the rising uptake of e-cigarettes (World Health Organization, 2022).

A key step toward reducing the use of e-cigarette devices is the investigation of the drivers and beliefs underlying their usage to allow for evidence-based, targeted behavior change strategies (Hagger et al., 2020). A well-used model that has been employed to understand and explain people's health behavior is the theory of planned behavior (Ajzen, 1991). The theory posits that intention is the most proximal predictor of behavior. Intention, in turn, is formed based on people's attitude, defined as their perceptions of the positive or negative consequences of engaging in a behavior, whether affective or feeling based, or instrumental and utility based; subjective norm, defined as perceptions of what important others might think of them engaging in a behavior and the value placed on gaining that approval; and perceived behavioral control, defined as beliefs about whether a behavior is under volitional control and within their ability to enact. Also, as research has tended to reveal the main effects of perceived behavioral control on behavior, most applications of the theory of planned behavior have treated perceived

behavioral control also as a direct predictor of behavior alongside intention, partially representing a proxy for the effects of actual behavioral control on behavior (Ajzen, 1991). However, it should be noted that perceived behavioral control was conceptualized not only as a determinant of behavior but also as a moderator of the intention–behavior relation. This is because the greater an individual's perceived control over the behavior, the more likely they are to expend effort into carrying out their intention, although this proposed moderating effect of perceived behavioral control is rarely tested (Hagger et al., 2022). To date, the theory of planned behavior has strong evidence in predicting a modest portion of variance in health behaviors (Hagger & Hamilton, 2024; McEachan et al., 2011). There is also some preliminary evidence for the utility of the theory in predicting e-cigarette usage (Hershberger et al., 2018; Scheinfeld et al., 2019; Wang et al., 2022). Such studies have showed attitude, subjective norm, and perceived behavioral control as all being associated with e-cigarette intentions and usage in regression modeling in university study populations in China and the USA, indicating the validity of the theory of planned behavior as a model for understanding e-cigarette usage.

Yet, despite the success of the theory of planned behavior in predicting intention and behavior with its parsimony of constructs, the model still faces criticism given it accounts for only a modest portion of variance in both intention and behavior (McEachan et al., 2011), including in cases where the theory of planned behavior has been applied to the prediction of e-cigarette usage (Scheinfeld et al., 2019; Wang et al., 2022). These findings have led researchers to suggest that the model may not represent a complete set of behavioral determinants and contributed to the rise of integrated models of behavior (Hagger & Hamilton, 2020; Phipps et al., 2020). Of growing interest has been the testing of models that expand on the theory of planned behavior, integrating constructs from other theories with the goal of increasing the models' effectiveness in predicting both intention and behavior (Hagger & Hamilton, 2020).

One construct that has been used to supplement the theory of planned behavior in predicting intention is *risk perception*, an individual's beliefs about the perceived severity of the potential negative consequences stemming from a behavior, and how susceptible they are to these negative consequences. Previous evidence supports the role of risk perception in predicting people's intention for a variety of health behaviors (Brewer et al., 2007), including e-cigarette use (Popova et al., 2018). In the context of e-cigarette use, investigating the risk perception construct warrants attention given the evidence that many, in particular, young people and those with previous experience using nicotine, view e-cigarettes as low risk (Wackowski & Delnevo, 2016), despite the advice of health professionals (Tsai et al., 2020). Thus, it is plausible that endorsement of e-cigarettes as low risk may be an important driver of behavioral intentions beyond the theory of planned behavior, although this effect remains relatively untested to date.

Beyond the prediction of intentions, theorists have also argued that intentional processes themselves are insufficient in predicting behavior (Hagger, 2020; Ouellette & Wood, 1998). Such a proposition is evidenced by the modest correlation between intention and behavior (McEachan et al., 2011) and findings that intervention programs often produce a larger change in beliefs and intentions than in behavior itself (Rhodes & Dickau, 2012). These findings have contributed to criticisms of social cognition theories, like the theory of planned behavior, for their assumption that behavior occurs volitionally. That is, that behavior is enacted as the result of considered decision-making, where individuals consider their beliefs (i.e. attitude, subjective norm, perceived behavioral control, and risk perceptions), form an intention, and then act. In contrast, contemporary dual process theories, like the reflective impulsive model (Strack & Deutsch, 2004) or associative–propositional evaluation model (Gawronski & Bodenhausen, 2006), argue that although behavior may be enacted volitionally in some

circumstances, many day-to-day, frequently occurring behaviors are likely enacted instead through highly efficient, automatic processes, requiring little or no conscious deliberation (Strack & Deutsch, 2004). Thus, these automatic constructs should affect behavior independently and regardless of intention, represented in modeling as direct effects on behavior not mediated via intention or similar constructs. Importantly, in the context of e-cigarette use, such automatic processes are likely to be of particular relevance for behaviors that are potentially addictive (Stacy & Wiers, 2010), theoretically represented in the impulse or urge to use a substance triggered by environmental cues or emotional states (West & Hardy, 2007).

Although there are several potential representations of such automatic pathways in dual process theory, two prominent constructs representing the automatic drivers of behavior are implicit attitude and habit. Implicit attitude, defined as the automatically activated affective response triggered by encountering behavior-relevant stimuli (Greenwald & Banaji, 1995), has regularly been shown to predict a small but statistically significant portion of variance in health behavior (Greenwald et al., 2009; Phipps et al., 2024). Importantly, although the effects of implicit attitude are often small, these effects persist beyond those accounted for by social cognition constructs like attitude and intention when included simultaneously in regression models (Perugini, 2005; Phipps et al., 2021; Phipps, Rhodes, et al., 2022). That is, the automatically activated affective response may trigger approach/avoid tendencies or behavioral schema automatically upon encountering a behavior-relevant stimulus, regardless of one's intentions.

Habit has also shown promise as a representation of automatic behavioral correlates. Habit is often viewed as the extent to which a behavior is experienced as automatic or enacted without conscious input (Verplanken & Orbell, 2003). That is, where behavior occurs frequently in the presence of stable cues (Gardner & Lally, 2018; Lally et al., 2010; Phipps et al., 2022), these cues may become linked to behavioral scripts in associative memory. As these cues become linked to behavioral scripts, encountering such cues in the future may in turn be sufficient to activate a behavioral response with little conscious processing, regardless of one's intentions or goals (Phipps et al., 2024; Verplanken & Orbell, 2003). Similar to implicit attitude, habit has shown independent effects not mediated via intention when regressed on health behavior alongside intentional processes, particularly in simple, rapidly enacted behaviors (Hagger et al., 2023).

In the context of e-cigarette use, evidence testing dual process models is scarce (Morean, DeMartini, et al., 2018). However, from a theoretical perspective, dual process theories generally hypothesize automatic drivers of behavior are of particular relevance for behaviors that are simple and likely result in a short-term hedonistic benefit (Strack & Deutsch, 2004). That is, automatic tendencies are often in favor of the more immediately pleasing option, rather than behaviors that an individual considers healthy or important (Brand & Ekkekakis, 2018). Thus, as e-cigarette use is a simple behavior that likely for many users delivers near-instant pleasurable outcomes in the form of flavor and nicotine, it is theoretically plausible that such automatic drivers may be important in the prediction of their usage. However, in the absence of empirical evidence, such a consideration is speculative.

Also, as with any nicotine use, it is important to consider the potential role of nicotine dependance on both intention and behavior, given the highly addictive nature of nicotine. Similar to the smoking of traditional tobacco, feelings of dependance have been shown to be associated with both an increased frequency of e-cigarette use (Morean, Krishnan-Sarin, & O'Malley, 2018) and with intentions to continue using e-cigarettes (Huh et al., 2023). From PRIME theory (West & Hardy, 2007), perceived dependance on nicotine may fuel future usage through pathways aligning with both the reasoned and automatic systems in dual process

models. Perceived dependance may affect e-cigarette use via a reasoned, volitional pathway, as users plan ahead to use e-cigarettes to satisfy their addiction or avoid withdrawal, with effects represented as an indirect effect of nicotine dependence on e-cigarette use via intentions. Alternatively, independently of intention, those dependent on nicotine may be driven to use e-cigarettes even when they do not plan or intend on doing so because of impulse-driven processes, such as cravings. Therefore, it seems warranted to consider the role of dependance when investigating the drivers of e-cigarette intentions and usage.

The current study

The current study aims to assess the predictors of e-cigarette use in young university students. Specifically, we aim to predict e-cigarette use using an integrated dual process model in which the theory of planned behavior is supplemented with e-cigarette dependence, risk perception, implicit attitude, and habit. It was hypothesized that e-cigarette use would be predicted by intention, nicotine dependence, perceived behavioral control, habit, and implicit attitude and that perceived behavioral control would moderate the intention–behavior relationship, such that those reporting higher levels of perceived behavioral control would be more likely to act in line with their intentions to use or not use an e-cigarette. Further, affective attitude, instrumental attitude, subjective norm, risk perception, perceived behavioral control, and nicotine dependence were hypothesized to predict intention to use an e-cigarette and thus indirectly predict e-cigarette use through intention. Finally, it was predicted that those with experience using other forms of nicotine would be more likely to be e-cigarette users. A conceptual model of our hypotheses is presented in Figure 1.

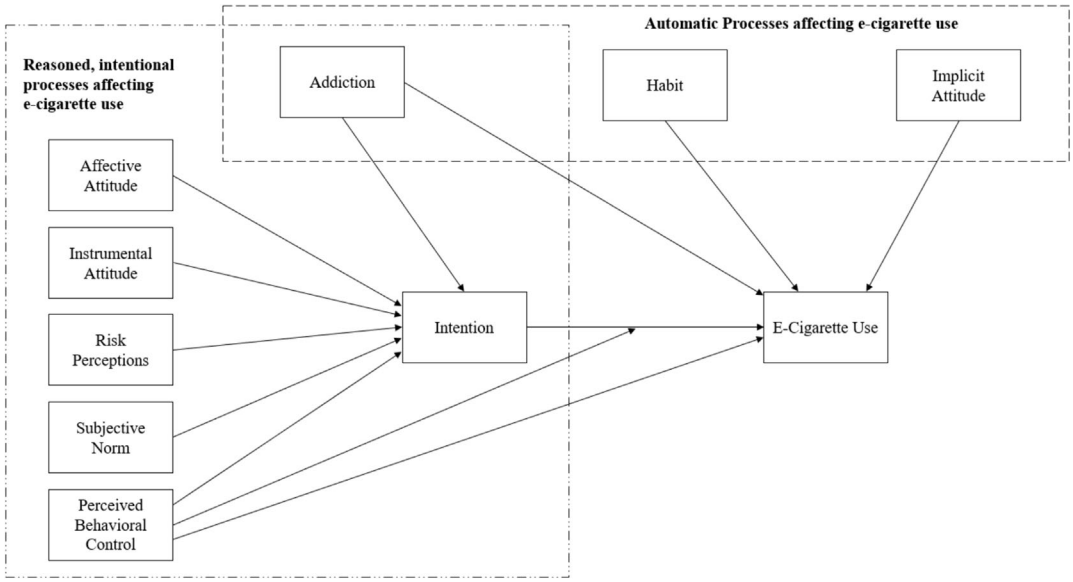

FIGURE 1 A conceptual dual process model for the prediction of e-cigarette use in undergraduate students.

METHODS

Participants and procedure

Participants were recruited from the first-year undergraduate participant pool at a major Australian university via an advertisement on the university course credit website from October 2022 to May 2023.[1] After informed consent, participants were required to complete an implicit measure, followed by a self-reported survey. Two weeks later, participants were re-contacted via email to provide a follow-up measure of behavior. At baseline, a total of 474 participants completed measures. However, 14 participants were flagged for exclusion based upon failing to correctly answer an attention check item ("Please select 'Disagree' to show you are paying attention"), and five participants were flagged for exclusion based upon implicit measure scoring criteria (e.g. excessive errors), leaving a valid sample of 455 participants (M age = 23.59, SD age = 8.53, 93 male, 348 female, 14 non-binary or preferred to not say). However, 92 participants did not complete the prospective measure of behavior 2 weeks later, resulting in a final sample of 363 (see Table 1 for descriptive statistics and demographic information). Those excluded because of non-completion of the follow-up behavioral measure were significantly younger than the final sample ($t[453] = 3.58$, $p < .001$, $d = .41$) but did not differ from the final sample in terms of gender ($\chi^2[3] = 6.21$, $p = .106$) or study variable scores at baseline ($F[9, 445] = 0.67$, $p = .733$).

Measures

All self-report items are available in Appendix A. Theory of planned behavior items are created in line with theory guidelines (Ajzen, 2006).

Attitude

Attitude was assessed in its affective and instrumental components with three and two items, respectively. All items shared the common stem "For me, using an e-cigarette or vape in the next two weeks would be ...", scored on a 7-point semantic differential scale (e.g. [1] Boring to [7] Fun and [1] Foolish to [7] Wise) (Ajzen, 2006).

Subjective norm

Subjective norm was assessed using three items (e.g. "Most people who are important to me would approve of me using an e-cigarette/vape"), each scored on a 7-point Likert scale anchored [1] Strongly Disagree to [7] Agree (Ajzen, 2006).

Perceived behavioral control

Perceived behavioral control was assessed using two items (e.g. "It is mostly up to me whether I use an e-cigarette/vape"), each scored on a 7-point Likert scale anchored [1] Strongly Disagree to [7] Agree (Ajzen, 2006).

TABLE 1 Demographic information for the final sample.

Variable	Statistic
Age	24.30 (9.06)
Gender	
Male	71
Female	283
Non-binary	9
Race	
Caucasian/White	294
Black	9
Asian (South-East Asia/South Asia)	38
Middle Eastern	2
Latino	6
Mauri & Pacific Islanders	14
Employment	
Student only	84
Part-time employed	246
Full time employed	33
Current regular smoker	
Yes	14
No	349
Ever used an e-cigarette before	
Yes	234
No	129
Ever used any other nicotine use before	
Yes	215
No	148

Intention

Intention to use an e-cigarette in the next 2 weeks was assessed using three items (e.g. "I intend to use an e-cigarette/vape"), each scored on a 7-point Likert scale anchored [1] Strongly Disagree to [7] Agree (Ajzen, 2006).

Risk perception

Perceptions around the health risks associated with e-cigarettes were assessed using two items (e.g. "In your opinion, is using e-cigarettes risky for one's health?") (Vogel et al., 2021), each scored on a 4-point Likert scale anchored [1] Not at all to [4] Yes.

Habit

Participants' habitual e-cigarette use was assessed using the self-reported behavioral automaticity scale (Gardner et al., 2012; Verplanken & Orbell, 2003). The scale consists of four items (e.g. "Using an e-cigarette or vape is something I do without thinking"), each scored on a 7-point Likert scale anchored [1] Strongly Disagree to [7] Agree.

Implicit attitude

Implicit attitude toward e-cigarettes was assessed using a single target implicit association test (Karpinski & Steinman, 2006), a reaction time-based task where participants must rapidly sort stimulus items as they appear on screen. The ST-IAT stimuli consisted of six images of e-cigarettes and vapes as target stimuli, and five positive words ("Good," "Tasty," "Enjoyable," "Nice," and "Fun") and five negative words ("Bad," "Nasty," "Dull," "Awful," and "Boring") as evaluative stimuli. The ST-IAT infers participants' implicit attitudes toward e-cigarettes by comparing reaction times when e-cigarette images share a response key with positive words as compared with when e-cigarette images share a response key with negative words. The ST-IAT was created and scored using the iatgen package (Carpenter et al., 2017), with scoring following the standardized *D* score procedure (Greenwald et al., 2003).

Other nicotine use

Participants were asked whether they had previous experience using nicotine in the forms of cigarettes, cigars, cigarillos, snus, or shisha. Those who indicated yes to any of the former were recorded as previous nicotine users.

Dependence

Participants perceived dependance on e-cigarettes was assessed using the e-cigarette dependance scale (Morean et al., 2019), which consists of four items (e.g. "When I haven't been able to vape for a few hours, the craving gets intolerable."), each scored on a 7-point Likert scale anchored [1] Strongly Disagree to [7] Agree.

Behavior

E-cigarette use was assessed using a single item drawn from previous research (Morean et al., 2017): How often have you used an e-cigarette or vape device?, with responses provided on an 11-point scale anchored [1] Never to [11] Every day.

Data analysis

Data were analyzed as a path model with the lavaan package in R using a robust maximum likelihood estimator (Rosseel, 2012). Interaction terms in the model were orthogonally residual centered. Model fit was assessed using the χ^2 (acceptable if $p > .05$), comparative fit index (CFI; acceptable if >.90), Tucker–Lewis index (TLI; acceptable if >.90), and the root mean square error of approximation (RMSEA; acceptable if <.08) statistics. As all items were forced responses, no missing data were present in the final sample. Using g*power 3.1, allowing for small–medium effect sizes ($f^2 = .10$) and $\alpha = .05$, a minimum sample of 190 was required to achieve a power of .90.

RESULTS

Reliability statistics, descriptives, and bivariate correlations between all constructs are presented in Table 2. The model showed a good fit to data ($\chi^2[8] = 17.34$, $p = .027$, CFI = .984, TLI = .958, RMSEA = .057), predicting 72% of the variance in intention and 71% of the variance in e-cigarette usage (see Figure 2). Detailed parameter estimates with their associated confidence intervals and standardized effects are presented in Table 3. E-cigarette use was predicted by intention, implicit attitude, habit, e-cigarette dependence, and previous nicotine experience. However, there was no direct effect of perceived behavioral control on e-cigarette use, nor did perceived behavioral control moderate the intention–behavior relationship. Intention to use an e-cigarette was predicted by affective attitude, subjective norm, and e-cigarette dependence, whereas the effects of instrumental attitude, risk perception, and perceived behavioral control on intention were not significantly different from zero. By extension, we found non-zero indirect effects of affective attitude, subjective norms, and e-cigarette dependance on e-cigarette use via intention. However, no indirect effects of instrumental attitude, risk perceptions, or perceived behavioral control on e-cigarette use via intentions were observed.[2]

DISCUSSION

The current study aimed to assess the correlates of e-cigarette use based on an integrated dual process model. Findings showed some support for the hypothesized model, with affective attitude, subjective norm, and dependence demonstrating significant effects on intention, whereas behavior was predicted by intention, habit, implicit attitude, and dependence.

Affective attitude predicted intentions, whereas instrumental attitudes did not, partially in line with previous research where attitude has shown significant associations with e-cigarette use (Scheinfeld et al., 2019; Wang et al., 2022). The lack of effect for instrumental attitude is not consistent with reasoned action theories like the theory of planned behavior (Ajzen, 1991), but it is not wholly incongruent with previous research in health behavior. Specifically, affective attitude has consistently shown stronger associations with intention than instrumental attitude (McEachan et al., 2016), with instrumental attitude often displaying weak or even null effects on health behavior intentions in modeling. This may be explained as a function of the primal emotive drive system favoring hedonistically pleasing outcomes (Williams, 2019), in this case, likely pleasant flavors and the effects of nicotine, while also downplaying long-term effects (Story et al., 2014), such as the potential poor health outcomes of e-cigarette usage. It is also

TABLE 2 Bivariate correlations and descriptive statistics for model constructs in predicting e-cigarette use in Australian undergraduate students.

	1	2	3	4	5	6	7	8	9	10
1. E-cigarette dependence										
2. Affective attitude	.619***									
3. Instrumental attitude	.371***	.629***								
4. Risk perception	−.113*	−.159**	−.375***							
5. Subjective norm	.342***	.361***	.280***	−.140**						
6. Perceived behavioral control	−.235***	−.178***	−.134*	0.101	−.182***					
7. Intention	.708***	.789***	.536***	−.159**	.424***	−.219***				
8. Habit	.885***	.613***	.370***	−.117*	.372***	−.229***	.708***			
9. Implicit attitude	.156**	.254***	.211***	−.152**	.112*	.033	.200***	.154**		
10. Behavior	.784***	.656***	.367***	−0.078	.354***	−.185***	.735***	.783***	.233***	
Mean	1.95	2.69	1.69	3.60	2.24	6.21	2.49	2.01	−0.05	3.71
Standard deviation	1.60	1.94	1.16	0.55	1.26	1.16	2.02	1.70	0.34	3.72
Possible range	1–7	1–7	1–7	1–4	1–7	1–7	1–7	1–7	−2-2	1–11
Reliability	.92	.95	.86	.82	.75	.67	.98	.98	.80	-

*$p < .050$, **$p < .010$, and ***$p < .001$.

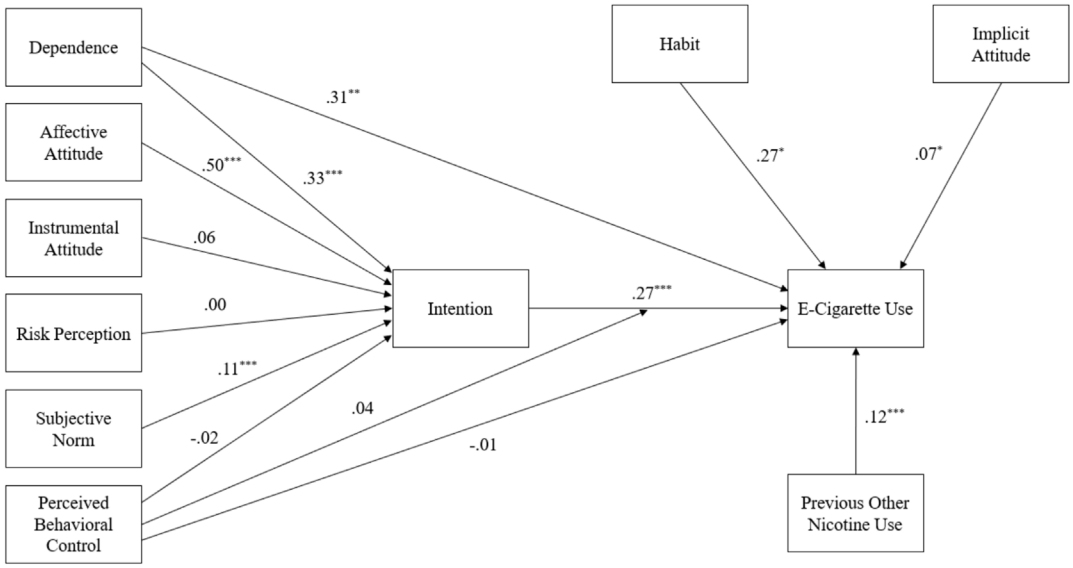

FIGURE 2 The path model predicting e-cigarette use in Australian undergraduate students. *Note*: *$p < .050$, **$p < .010$, ***$p < .001$.

important to consider that this effect may be particularly prominent in younger samples like university students, as sensation seeking and impulsivity remain relatively high in younger adults (i.e. those under 25 years) compared with older adults (Steinberg et al., 2008).

The significant effect of subjective norm on intention is consistent with reasoned action theories (Ajzen, 1991) and previous research in both traditional cigarette and e-cigarette use (Donaldson et al., 2021; Scheinfeld et al., 2019; Topa & Moriano, 2010). In the current sample population of young university students, this may be of particular relevance given the increasing prevalence of pro-e-cigarette use marketing and social media content targeted at younger audiences (Struik et al., 2020; Sun et al., 2023), the exposure to which is associated with positive normative beliefs around e-cigarettes (Brown & Allison, 2021; Phua, 2019). Further, the effect of normative groups may also be of importance regarding the initiation of e-cigarette use, as evidence indicates that many young people are introduced to e-cigarettes by borrowing or trying devices purchased by their peers (Baker et al., 2019). Thus, although subjective norm had only a small effect on intention, it may still represent a key target for preventative intervention strategies. For example, the effect of subjective norm may be of particular importance to the initiation of e-cigarette use, whereas other processes such as affect and nicotine dependance encourage continued use. However, this can only be speculated based on current group-level data, necessitating additional longitudinal research investigating the potential differentiation of the factors predicting e-cigarette uptake and continued usage.

In contrast to our expectations, perceived behavioral control did not significantly predict intention or behavior, nor did it moderate the intention–behavior relationship. Such a finding is in contrast to both theory and previous meta-analytic evidence supporting the role of perceived behavioral control on health behavior (Hagger et al., 2022; McEachan et al., 2011), but partially consistent with previous e-cigarette research where perceived behavioral control had weaker effects on e-cigarette use intentions than attitude or subjective norm (Scheinfeld et al., 2019; Wang et al., 2022). It is possible that these differences in the effects of perceived behavioral control may be due to differences in the cultural setting and time of data collection

TABLE 3 Parameter estimates for the path model predicting e-cigarette use in Australian undergraduate students.

	B	*SE*	*LLCI*	*ULCI*	*p*	*β*
Direct effects						
Dependence → intention	0.42***	0.07	0.28	0.56	<.001	.33
Affective attitude → intention	0.52***	0.06	0.40	0.64	<.001	.50
Instrumental attitude → intention	0.11	0.09	−0.07	0.29	.213	.06
Risk perception → intention	0.00	0.11	−0.22	0.22	.995	.00
Subjective norm → intention	0.17***	0.05	0.07	0.28	.002	.11
PBC → intention	−0.04	0.04	−0.12	0.04	.335	−.02
Dependence → behavior	0.72***	0.26	0.21	1.23	.006	.31
Intention → behavior	0.50***	0.11	0.28	0.72	<.001	.27
Implicit attitude → behavior	0.26*	0.12	0.03	0.49	.028	.07
Habit → behavior	0.59***	0.23	0.13	1.04	.012	.27
PBC → behavior	−0.03	0.08	−0.19	0.14	.753	−.01
PBC by intention → behavior	0.09	0.07	−0.04	0.22	.184	.04
Previous other nicotine use → behavior	0.88***	0.22	0.44	1.31	<.001	.12
Indirect and total effects						
Affective attitude → intention → behavior	0.26***	0.07	0.13	0.39	<.001	.14
Instrumental attitude → intention → behavior	0.06	0.05	−0.04	0.15	.227	.02
Risk perception → intention → behavior	0.00	0.06	−0.11	0.11	.995	.00
Subjective norm → intention → behavior	0.09**	0.03	0.03	0.15	.005	.03
PBC → intention → behavior	−0.02	0.02	−0.06	0.02	.352	−.01
PBC (total) → behavior	−0.05	0.08	−0.21	0.12	.578	−.01
Dependence → intention → behavior	0.21***	0.06	0.09	0.33	.001	.09
Dependence (total) → behavior	0.93***	0.26	0.43	1.44	<.001	.40

Note: PBC refers to perceived behavioral control. LLCI refers to the lower limit of the 95% confidence interval. ULCI refers to the upper limit of the 95% confidence interval.
*$p < .050$, **$p < .010$, and ***$p < .001$.

of the cited research as compared with the current study. For example, one potential explanation of the lack of effect of perceived behavioral control on e-cigarette use may be that, although the purchase of e-cigarette devices was subject to legal restrictions at the time of data collection in Queensland Australia, they were still widely available for purchase in store and online, with little effort required to purchase (Queensland Family & Child Commission, 2023). Thus, it may be that in the current sample, perceived behavioral control had little effect on e-cigarette use simply because participants likely had easy access to e-cigarette devices should they wish to use or purchase one. This speculation requires additional research, particularly as legislation evolves to further restrict the sale and recreational use of e-cigarette devices.

Also, in contrast to hypotheses, we observed no significant effect of risk perception on intention. This runs in contrast to previous evidence correlating risk perception with e-cigarette use behavior (Popova et al., 2018). However, as previous research did not include the effects of the theory of planned behavior alongside risk perception, this result may likely be explained as

variance in e-cigarette use accounted for by risk perception is better explained by the social cognition constructs already featured in the theory of planned behavior. Paired with the high mean endorsement of e-cigarettes as risky in the current sample, this finding may partially allay concerns by experts that the marketing of e-cigarettes as "less harmful" than traditional tobacco may be driving uptake (World Health Organization, 2022). It is also an important finding regarding current intervention programs, given many such programs focus primarily on providing information on the potential detrimental health effects of e-cigarette use (Kelder et al., 2020). However, as risk perception was assessed as the overall risk of e-cigarette use, rather than its comparative risk to traditional smoking, future research is likely needed in this regard to compare whether perceptions of e-cigarette use as less risky, as compared with high risk overall, contribute to their use.

Consistent with dual process theories and theories of addiction (Stacy & Wiers, 2010; Strack & Deutsch, 2004; West & Hardy, 2007), both implicit attitude and habit directly predicted e-cigarette use, whereas the effects of nicotine dependence were only partially mediated by intention. Regarding nicotine dependance, this partially mediated effect is in line with previous research and addiction theories such as PRIME (West & Hardy, 2007), as those dependent on nicotine may use e-cigarettes because of both intentional processes (e.g. planning on using an e-cigarette to avoid withdrawal) and as the result of cravings or urges occurring independently of intention (Huh et al., 2023; Morean, Krishnan-Sarin, & O'Malley, 2018). Further, we observed that implicit attitude and habit had significant effects on e-cigarette use beyond the effects accounted for by intention. Although novel in the field of e-cigarette research, these findings are consistent with dual process theory (Brand & Ekkekakis, 2018; Hagger, 2020; Strack & Deutsch, 2004). Specifically, it would be expected from theory that e-cigarette use as a rapidly enacted, simple, and hedonistically pleasing behavior would be particularly likely to fall under the control of automatic, highly efficient processes (Brand & Ekkekakis, 2018; Hagger et al., 2023; Hamilton et al., 2023; Strack & Deutsch, 2004). This is of particular importance from a practical perspective, as current evidence suggests that even strategies that are effective in changing the intentional, considered drivers of e-cigarette use may not result in the desired changes in behavior for those for whom using an e-cigarette has become an automatic or addiction-driven process. Thus, future intervention strategies may seek to address constructs like implicit attitude and habits alongside consciously held beliefs to maximize their effectiveness, for example, by analyzing and disrupting the environmental and internal cues that prompt automatic or impulsive e-cigarette use.

Strengths, limitations, and future directions

The current study had numerous strengths, including the focus on an increasing and potentially problematic health behavior, the testing of a novel dual process model, and the use of a prospective design. However, there are also several key issues that should be considered when interpreting results. First, it is important to note that implicit attitude and habit were inferred from reaction time-based tasks and meta-cognition, respectively. Thus, although the measures employed have evidence in favor of their validity (Gardner et al., 2012; Greenwald et al., 2009), they nonetheless represent inferences of automatic constructs rather than direct measures, and responses stemming from these measures should be considered with this caveat in mind. Further, it should be noted that all belief-based constructs were assessed using brief self-reported scales based on theory guidelines. Although commonly used, it remains plausible that response bias or poor recall may influence results on these measures. Similarly, behavior was measured

using a single-item self-reported measure of current e-cigarette use frequency drawn from previous research (Morean, Krishnan-Sarin, & O'Malley, 2018), which may not perfectly reflect e-cigarette use in the time lag of the study as is recommended in social cognition research (Ajzen, 2012). Future research may seek to investigate the drivers of e-cigarette use adopting more time-sensitive techniques, including more elaborated self-reported surveys or using person-orientated techniques such as N-of-1 or ecological momentary assessment to probe potential variation in specific instances of e-cigarette use. As the current study employed a prospective correlational design, which does not allow for assertions of directionality, these more intensive longitudinal studies would also allow for more detailed tests of the order of effects and causality, improving upon the utility of the current findings.

The sample for the current study consisted of predominantly young university students. Although the high usage rates of e-cigarettes in this population make them a valuable target for research (Struik et al., 2020; Sun et al., 2023), it is nonetheless a concern that findings in this sample may not generalize to other risk groups, such as adolescents or the general public. Further, first-year university students represent a relatively homogenous population. Additional research in more diverse populations may have value in investigating how demographic factors influence e-cigarette use and whether the effects of social-structural variables (e.g. age, gender, ethnicity, and location) can be mediated through social cognition factors and habit, as would be expected by theory (Ajzen, 1991) and empirical evidence (Hagger & Hamilton, 2021). Further, the current study assessed only quantitative data and did not include an analysis of participants' potential goals for using an e-cigarette. Thus, it is an important consideration that although only a small portion of the current sample identified as regular smokers, these participants may hold positive attitudes toward e-cigarettes and use them more frequently as a method of reducing their dependence on smoked cigarettes. Although the use of e-cigarettes to quit smoking appears less common in younger users (Bold et al., 2016; Pepper et al., 2014), future research may still seek to consider the potential differences in those using e-cigarettes as a method of harm reduction, rather than for joy or due to an independent addiction, as well as how strategies to reduce problematic e-cigarette use may interact with those using e-cigarettes as a legitimate method of improving their health outcomes.

Similarly, as we assessed intention to use e-cigarettes and not the situations or contexts in which this occurred, it is possible for some participants that although they did not intend or plan to use an e-cigarette, they were willing to do so if the opportunity arose. This is a common issue flagged in social cognition research for health risk behaviors that are non-intentional, but volitional (Gibbons et al., 2020; Phipps & Hamilton, 2024; Zimmermann & Sieverding, 2010), and may point to the importance of willingness rather than intention as a mediator of beliefs on behavior in this context or using models specifically designed to address such behaviors, like the prototype willingness model (Gibbons et al., 2003, 2020). Finally, for future research, it is important to consider the target behavior in the current study was the use of e-cigarettes, a relatively simple behavior in and of itself. However, future research may also seek to consider the more nuanced elements of the behavior, for example, the determinants of acquiring an e-cigarette, particularly as e-cigarette control mechanisms in many jurisdictions focus on increasing the difficulty of acquiring an e-cigarette (e.g. outright bans, restrictions on desirable flavors, and prescription requirements). Thus, the acquisition of e-cigarettes may be a notably more involved and difficult process as compared with using an e-cigarette when one is readily available, with potentially different determinants. Also, the current study focused on nicotine-based e-cigarettes. However, it is also a possibility that e-cigarettes can contain other active substances, like cannabis. Although this is uncommon in Australia (D'Mello et al., 2023), it should

nevertheless be a consideration for future research, particularly if replicating these findings where the use of cannabis e-cigarettes is more common.

Conclusions

The aim of the current study was to assess the predictors of e-cigarette use by adopting an integrated dual process model. Findings suggest that the use of e-cigarettes is determined by both intentional, deliberative and automatic, rapid reactions. From a theoretical standpoint, these results add to the increasing body of evidence in favor of dual process models of health behavior, where automatic processes such as implicit attitude and habit may contribute to explaining behavior beyond considered intentions. From a practical perspective, the significant effects of affective attitude and subjective norm on intention, and of implicit attitude and habit on behavior, indicate that e-cigarette use is likely a highly affect and norm-driven behavior, rather than under the influence of beliefs regarding the utility or risks of usage. Thus, current findings suggest that programs aiming to discourage e-cigarette use may be most efficacious when focusing on affective and normative beliefs, rather than on providing information on the dangers of e-cigarette use behavior. However, the strong effect of nicotine dependance suggests that any strategy for reducing e-cigarette use would likely need to account for addiction effects alongside behavior change techniques.

CONFLICT OF INTEREST STATEMENT

No conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available on the OSF platform: https://osf.io/3gxw5/.

ETHICS STATEMENT

This study was approved by the Griffith University Human Research Ethics Committee (#GU2022/697).

ORCID

Daniel J. Phipps https://orcid.org/0000-0002-0217-0578
Kyra Hamilton https://orcid.org/0000-0001-9975-685X

ENDNOTES

[1] All participants were included regardless of previous nicotine use. However, for completeness, we also present an alternative analysis with only nicotine users in the Supporting Information.

[2] Given the high correlations between e-cigarette dependence and habit, a model without the habit construct is also included in the Supporting Information. However, the exclusion of habit made minimal impact on the effects of other model parameters.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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APPENDIX: SURVEY MEASURES

Dependence (Morean et al., 2019)	
I find myself reaching for my e-cigarette without thinking about it.	[1] Strongly Disagree to [7] Strongly Agree
I drop everything to go out and buy e-cigarettes or vape.	[1] Strongly Disagree to [7] Strongly Agree
I vape more before going into a situation where vaping is not allowed.	[1] Strongly Disagree to [7] Strongly Agree
When I haven't been able to vape for a few hours, the craving gets intolerable.	[1] Strongly Disagree to [7] Strongly Agree
Habit (Gardner et al., 2012)	
Using an e-cigarette or vape is something I do automatically	[1] Strongly Disagree to [7] Strongly Agree
Using an e-cigarette or vape is something I do without having to consciously remember	[1] Strongly Disagree to [7] Strongly Agree
Using an e-cigarette or vape is something I do without thinking	[1] Strongly Disagree to [7] Strongly Agree
Using an e-cigarette or vape is something I start to do before I realise I'm doing it	[1] Strongly Disagree to [7] Strongly Agree
Affective Attitude (Ajzen, 2006)	
For me, using an e-cigarette or vape in the next two weeks would be ...	[1] Unpleasant to [7] Pleasant
	[1] Displeasing to [7] Enjoyable
	[1] Boring to [7] Fun
Instrumental Attitude (Ajzen, 2006)	
For me, using an e-cigarette or vape in the next two weeks would be ...	[1] Harmful to [7] Beneficial
	[1] Foolish to [7] Wise
Risk Perception (Vogel et al., 2021)	
How much do you think people harm themselves when they use e-cigarettes?	[1] No Harm to [4] A lot of harm
In your opinion, is using e-cigarettes risky for one's health?	[1] Not at all [4] Yes
How risky are e-cigarettes?	[1] Not at all to [4] Very
Subjective Norm (Ajzen, 2006)	
Most people who are important to me would approve of me using an e-cigarette/vape	[1] Strongly Disagree to [7] Strongly Agree
Most people whose opinions I value think that I should use an e-cigarette/vape	[1] Strongly Disagree to [7] Strongly Agree
Most people who are important to me use an e-cigarette/vape	[1] Strongly Disagree to [7] Strongly Agree

Perceived Behavioral Control (Ajzen, 2006)	
It is mostly up to me whether I use an e-cigarette/vape	[1] Strongly Disagree to [7] Strongly Agree
I have complete control over whether I use an e-cigarette/vape	[1] Strongly Disagree to [7] Strongly Agree
Intention (Ajzen, 2006)	
I intend to use an e-cigarette/vape	[1] Strongly Disagree to [7] Strongly Agree
I expect I will use an e-cigarette/vape	[1] Strongly Disagree to [7] Strongly Agree
It is likely that I will use an e-cigarette/vape	[1] Strongly Disagree to [7] Strongly Agree
Behavior (Morean et al., 2017)	
How often have you used use an e-cigarette or vape device?	[1] Never to [7] Every Day