



Parent, peer, and executive function relationships to early adolescent e-cigarette use: A substance use pathway?



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HIGHLIGHTS

- Lifetime e-cigarette use was almost twice the use of cigarettes in early adolescents.
- Executive function (EF) deficits related to e-cigarette, cigarette, and alcohol use.
- EF deficits were more important than demographic, peer, or parent influences on use.
- Suggests adolescent drug use prevention programs should include EF skills training.

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ABSTRACT

Introduction: Little is known about influences on e-cigarette use among early adolescents. This study examined influences that have been previously found to be associated with gateway drug use in adolescents: demographic (age, gender, ethnicity, free lunch), social contextual influences of parents and peers, and executive function deficits (EF).

Methods: A cross-sectional survey was administered to 410 7th grade students from two diverse school districts in Southern California (M age; = 12.4 years, 48.3% female, 34.9% on free lunch (low socioeconomic status), 45.1% White, 25.4% Hispanic/Latino, 14.9% Mixed/bi-racial.) Logistic regression analyses examined influences of demographic, parent e-cigarette ownership and peer use, and EF on lifetime e-cigarette, and gateway drug use (cigarette and/or alcohol use).

Results: Lifetime use prevalence was 11.0% for e-cigarettes, 6.8% for cigarettes, and 38.1% for alcohol. Free lunch and age were marginally related to e-cigarette use ($p < .10$). Parent e-cigarette ownership was associated with use of all substances, while peer use was associated with gateway drug use ($p's < .05-.001$). EF deficits were associated with use of all substances five times more likely than others to use e-cigarettes and over twice as likely to use gateway drugs.

Conclusions: E-cigarette and gateway drug use may have common underlying risk factors in early adolescence, including parent and peer modeling of substance use, as well as EF deficits. Future research is needed to examine longitudinal relationships of demographics, parent and peer modeling, and EF deficits to e-cigarette use in larger samples, trajectories of e-cigarette use compared to use of other substances, and the potential of EF skills training programs to prevent e-cigarette use.

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1. Introduction

E-cigarettes allow users to inhale nicotine vapor, imitating the act of smoking a conventional cigarette (Centers for Disease Control and

Prevention (CDC), 2013; McMillen, Maduka, & Winickoff, 2012). They include disposable e-cigarettes as well as refillable vape pens and tanks, and vary in flavor as well as substances used to produce the aerosol effect (CDC, 2013; Pepper & Brewer, 2013). Perhaps the most concerning aspect of e-cigarettes is their growing popularity and use among adolescents in the U.S. (Camenga et al., 2014; CDC, 2013), while cigarette use has declined (Eaton et al., 2012; Johnston, O'Malley, Bachman, & Schulenberg, 2013; U.S. Department of Health and Human Services, 2012). From 2011 to 2012, a national survey showed that the proportion of adolescents (grades 6–12) who had

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tried e-cigarettes increased from 3.1 to 6.8% (CDC, 2013). Studies of college students and young adults showed similar patterns (e.g., Choi & Forster, 2014; Sutfin, McCoy, Hoepfner, & Wolfson, 2013). Willingness to try e-cigarettes has also increased (Pepper et al., 2013).

Transition from elementary school to middle school (ages 11–12 or grades 6–7) may be a particularly vulnerable period for experimentation with e-cigarettes, and thus an important target for prevention efforts, for several reasons. First, experimentation with cigarettes and alcohol, often referred to as “gateway” drugs for their temporal relationship to use of other substances, increases rapidly during this period (Eaton et al., 2012; Pentz & Riggs, 2013; Riggs, Chou, Li, & Pentz, 2007), and at least 11% of early adolescents are willing to try electronic nicotine delivery systems (ENDS) such as e-cigarettes (Pepper et al., 2013). Second, early adolescence is a period of increased novelty seeking and changing social contexts of parent and peer influence, all of which are associated with increased experimentation with substances (Crawford, Pentz, Chou, Li, & Dwyer, 2003; Liao, Huang, Huh, Pentz, & Chou, 2013; Pentz & Riggs, 2013). Parents influence adolescent drug use through modeling their own use as well as having substances available in the home, e.g., alcohol (Liao et al., 2013). At the same time, in attempting to establish autonomy from parents, adolescents become more vulnerable to peer influences in the form of pressure to try something new as well as representing an increasing social norm for use (Lakon & Valente, 2012; Liao et al., 2013). Third, early adolescence is marked by rapid changes in the brain, with increased synaptic pruning and neuronal myelination which enable more efficient neural signaling and pre-frontal cortical control (Reyna & Farley, 2006). These changes aid the development of executive function (EF), neurocognitive processes which help to regulate emotions, inhibit impulsive behaviors such as experimentation with drugs, and promote positive decision-making, planning, and goal-directed behaviors as alternatives to drug use (Chambers, Taylor, & Potenza, 2003; Pentz & Riggs, 2013; Reyna & Farley, 2006). In early adolescents, problems or deficits in EF have been found to increase risk for cigarette and alcohol use, as well as other potentially addictive behaviors such as excessive videogaming and dysregulated eating (Pentz, Spruijt-Metz, Chou, & Riggs, 2011; Pentz & Riggs, 2013; Riggs, Spruijt-Metz, Chou, & Pentz, 2012). The reverse also appears to occur. Nicotine exposure during early adolescence may increase EF problems by interfering with the maturation of neural connectivity to inhibit impulsive limbic signals (Dwyer, McQuown, & Leslie, 2009; Kandel & Kandel, 2014). Couple this adverse effect with research showing that adolescents exhibit heightened sensitivity to the rewarding properties of nicotine compared to adults (Dwyer et al., 2009), and the need to evaluate the risk relationship between EF and e-cigarette use in early adolescents becomes even more compelling.

Early adolescence, then, may represent a particularly vulnerable period for e-cigarette use onset. However, relatively little is known about risk factors for e-cigarette use in this age group. Because conventional cigarette smoking is associated with e-cigarette use (Goniewicz & Zielinska-Danch, 2012; Grana, Popova & Ling, 2014; Lee, Grana, & Glantz, 2014), one way to improve our understanding of predictors of e-cigarette use in early adolescents is to examine risk factors that have been consistently found for cigarette use as a gateway drug in this age group. These include demographic characteristics, social contextual variables representing parent and peer influences, and EF deficits.

Among demographic characteristics, being older, female, Hispanic, and low socioeconomic status have been associated with early cigarette use (Chen & Jacobson, 2012; U.S. Department of Health and Human Services, 2012). Being older, male, and low socioeconomic status have been related to greater awareness of and willingness to try e-cigarettes (Cho, Shin, & Moon, 2011; Choi & Forster, 2014; Dutra & Glantz, 2014; Goniewicz & Zielinska-Danch, 2012; Grana, Popova, et al., 2014; Kinnunen et al., 2014; Lee et al., 2014). Being male, non-Hispanic White, and report of peer influence have been related to lifetime e-cigarette use (Cho et al., 2011; Dutra & Glantz, 2014). E-cigarette studies have been limited either by low proportions of

adolescents who have actually tried e-cigarettes, or by evaluation of single demographic characteristics for their relationship to e-cigarette use.

Among social contextual variables, both parents and peers have been shown to influence early adolescent cigarette use, as well as alcohol use (Henry, Kobus, & Schoeny, 2011; Lakon & Valente, 2012; Liao et al., 2013; Pentz & Riggs, 2013). While parent influence encompasses many domains, including lack of rules or communication about drug use and genetic risk, one of the strongest is parent modeling of drug use behavior, either directly or inferred through having substances available in the home (Pentz & Riggs, 2013). Similarly, peer influence encompasses several domains, including actual peer use as a modeling influence, perceived peer social norms for use, and peer pressure to try substances (Liao et al., 2013). Although most research has used self-report surveys to measure estimated peer use or norms, one of the most direct ways to measure peer influence is through social network survey methods, which capture actual peer use as measured by peers themselves (Valente, 2010). Neither parent nor peer influences have been measured for their relationship to adolescent e-cigarette use.

In addition to specific demographic characteristics, parent, and peer influences, executive function (EF) deficits have also been found to predict cigarette and alcohol use in early adolescents (Pentz & Riggs, 2013; Pentz et al., 2011; Riggs et al., 2012). In contrast, training early adolescents in EF skills has shown longitudinal effects on preventing cigarette and alcohol use and on reducing externalizing (impulsive) behavior as a mediator of health risk behavior (Pentz & Riggs, 2013). EF is typically measured in either a controlled setting with an experimenter structuring a set of tasks using immediate task performance as an indicator of EF, or as a rating of competence in everyday problem-solving situations (McAuley, Chen, Goos, Schachar, & Crosbie, 2010; Toplak, West, & Stanovich, 2013).

This study examined the simultaneous influences of variables that have been shown to predict gateway drug (cigarette and/or alcohol) use in previous studies, but which have not been systematically evaluated as risk factors for e-cigarette use (Chapman & Wu, 2014). The influences included demographic characteristics, parent and peer modeling, and EF. To address ecological validity, the study included social network assessment and a rating of EF in everyday situations. The study was conducted on an ethnically diverse sample of 7th grade students as part of a larger study on EF skills training for prevention of multiple health risk behaviors.

2. Methods

2.1. Background and study design

This study, conducted in 2013, was part of a large randomized controlled trial (RCT) of child obesity, tobacco and alcohol use prevention, Pathways to Health (Pentz & Riggs, 2013; Sakuma, Riggs, & Pentz, 2012). Participants were drawn from schools that participated in a cross-sectional pilot study for this project, but did not participate in intervention or the RCT.

2.2. Participants

Participants were 7th grade students attending two large, ethnically diverse public middle schools in two different counties in Southern California. All 7th grade students in the schools were invited to participate if they provided written parental consent and student assent. No student incentives were provided. All procedures were approved by the University of Southern California IRB.

2.3. Procedure

Research staff explained the survey and answered students' questions. They defined e-cigarette products as including disposable and rechargeable e-cigarettes, vape pens, and tanks, which can vary in flavor,

look, and nicotine level. The survey included sample pictures of these products. The 199-item survey was administered in one class period of 45 minutes and items were worded for fourth-grade reading comprehension.

2.4. Measures

2.4.1. Demographic factors

These included age, gender, socioeconomic status measured as being on a free lunch program at school (no = 0, 1 = yes), and race/ethnicity including the following response options: White, African American/Black, Hispanic/Latino, Asian, Bi-racial/Mixed and Other. Race/ethnicity was re-coded to 1 = White, other groups = 0.

2.4.2. Lifetime e-cigarette use

The item measuring lifetime e-cigarette use was adapted from the Population Assessment of Tobacco and Health (PATH) study (National Institutes of Health (NIH), 2014): “How many cartridges or disposable e-cigarettes have you used in your entire life?” Responses ranged from 0 = none, 1 = 1 or more puffs (but never a whole one) to 7 (= at least 100 or more). To generate lifetime use rates, this item was re-coded to 0 (no use) or 1 (any use).

2.4.3. Lifetime gateway drug use (cigarettes, alcohol)

Lifetime gateway drug use items were drawn from national surveys (YRBS; Eaton et al., 2012; Monitoring the Future Survey, Johnston, O'Malley, Bachman, & Schulenberg, 2013) on tobacco and alcohol use: “Have you ever smoked a cigarette in your whole life?” and “Have you ever tried alcohol in your whole life (beer, wine, liquor that is not for religious purposes)?” For cigarette use, response options ranged from 1 (“No, not even a puff”) to 4 (“Yes, one cigarette or more”). Alcohol use response choices ranged from 1 (“No, not even a sip”) to 3 (“Yes, more than a sip”). To generate lifetime gateway drug use prevalence, responses were dichotomized to 0 (no use) or 1 (any tobacco/alcohol use).

2.4.4. Parent and peer contextual factors for e-cigarette use

Two items were used to assess contexts for e-cigarette use. Parent e-cigarette ownership was assessed with the PATH (National Institutes of Health (NIH), 2014) question, “Do any of your parents or guardians own an e-cigarette?” Response options were 0 = no, 1 = yes. This question represented both a modeling influence as well as availability. The influence of actual peer use of e-cigarettes was obtained from a set of social network questions. Students were asked to nominate up to 7 of their closest friends within the school (e.g., Please think of your seven best friends in your school) (Valente, 2010). Nominated friend names were then linked with participant ID numbers for consented students. If a nominated student did not participate in the study, that individual was excluded from analyses. Peer use was calculated as the number of included nominees who self-reported use divided by the total number of included nominees. This provided a measure of the respondent's closest friends who reported their own use, rather than the respondent's perception of his/her friends' use.

2.4.5. Executive function (EF)

A total EF score was calculated as the sum of index items from four scales from the Behavioral Inventory of Executive Function, Self-Report (Guy, Isquith, & Gioia, 2004; Riggs et al., 2012), including emotional control, inhibitory control, working memory, and planning (40 items, alpha = .93). The BRIEF was designed to be an ecologically valid measure of competence in everyday problem solving situations for 5–18 year olds, which was the focus of this study (Guy et al., 2004; Toplak et al., 2013). The summed score of EF from the BRIEF has been used previously in the Pathways to Health trial (Pentz & Riggs, 2013). Item response choices ranged from 1 = Never, 2 = Sometimes, 3 = Often. Higher scores represented more EF problems.

Table 1
Demographics and prevalence rates of lifetime Use (n = 410).

	All (n = 410)	E-cigarette user (n = 45)	Gateway drug (cigarette/alcohol) user (n = 160)
Age (mean, SD)	12.5 (0.5)	12.6 (0.5)	12.5 (0.5)
Gender (% female)	48.3	44.4	53.8
Receive free lunch (%)	34.9	55.6	41.9
Race/Ethnicity			
% White	45.1	28.9	37.5
% Hispanic	25.4	26.7	28.1
% Mixed/Bi-Racial	14.9	24.4	20.0
% Others ^a	14.6	20.0	14.4
Lifetime Use			
% Cigarette	6.8	42.2	17.5
% E-cigarette	11.0	100.0	23.1
% Alcohol	38.1	80.0	97.5
Contextual Factors			
% Parent Ownership	14.9	28.9	26.9
Peer E-cig Use (mean, SD)	0.2 (0.2)	0.3 (0.3)	0.2 (0.3)
Executive Function (Mean, SD)	1.5 (0.3)	1.7 (0.3)	1.6 (0.3)

^a Others include African American (1.7%), Asian (4.4%), Others (4.6%) and missing (3.9%).

2.5. Data analysis

Analyses included descriptive analyses of sample characteristics and logistic regression analyses to examine the associations between the following variables and lifetime e-cigarette, and cigarette/alcohol use: (1) demographic characteristics; (2) social contexts (i.e., e-cigarette parent ownership and e-cigarette peer use) and (3) EF. Regression estimates were converted to odds ratios and 95% confidence intervals.

3. Results

3.1. Sample characteristics

Of the entire 496 7th grade population, 82.7% provided parental consent and self-assent for participation in the study; 11.7% did not return consent forms, and 5.6% were parental declines. The resulting analysis sample of 410 had a mean age of 12.4 years (SD = .5); 48.3% were female, and 34.9% reported receiving free/reduced lunch. Students were 45.1% White, 1.7% African American/Black, 25.4% Hispanic/Latino(a), 4.4% Asian, 14.9% Mixed/Bi-racial and 4.6% reported “other”. The analysis sample was representative of the school populations (Ed-Data, accessed July 8, 2014).

3.2. Use prevalence

Table 1 shows the demographic and behavioral characteristics of the sample by e-cigarette, and cigarette/alcohol use.

Table 2
Logistic regression results for lifetime e-cigarette use (n = 410).

	E-cigarette use (n = 45) OR (95% CI)	Cigarette or alcohol use (n = 160) OR (95% CI)
Demographics		
Age	1.95 (0.99–3.87)+	1.10 (0.70–1.74)
Gender (female = 1)	0.66 (0.32–1.36)	1.38 (0.87–2.18)
Free lunch(yes = 1, No = 0)	1.96 (0.92–4.15)+	1.22 (0.73–2.05)
Ethnicity (white [^] vs. others)	0.56 (0.26–1.22)	0.76 (0.47–1.23)
Contextual factors		
Parent ownership	2.29 (1.01–5.15)*	3.21 (1.66–6.20)***
Peer use	2.56 (0.71–9.25)	3.48 (1.27–9.54)*
Executive function	4.99 (1.80–13.86)**	2.43 (1.13–5.22)*

OR = regression estimates were converted to odds ratios.

CI = confidence intervals. [^]It indicates the ethnicity of reference group.

+ p < 0.01, *p < 0.05, **p < 0.01, ***p < 0.001.

Lifetime use was 11% for e-cigarettes, 6.8% for cigarettes, 38.1% for alcohol, and 39% for use of gateway drugs (either cigarettes or alcohol). Among e-cigarette users, 28.9% were White, 26.7% Hispanic, and 24.4% mixed/bi-racial; 80% reported alcohol use and 42.2% reported cigarette use; 17.8% owned their own e-cigarettes and 28.9% had one or both parents who owned an e-cigarette. E-cigarette users had an average of 30% of friends who also used e-cigarettes. Among gateway drug users, 37.5% were White, 28.1% Hispanic and 20% mixed/bi-racial; 17.5% reported cigarette use, 97.5% reported alcohol use and 23.1% reported e-cigarette use; 26.9% reported parent ownership of an e-cigarette and had an average of 20% of friends who used e-cigarettes.

3.3. Demographic, contextual, and EF relationships to e-cigarette and substance use

Logistic regression results are shown in Table 2. For e-cigarette use, age (OR = 1.95, 95% CI = 0.99–3.87) and receiving free lunch (OR = 1.96, 95% CI = 0.92–4.15) were marginally associated any e-cigarette use. Parent ownership of e-cigarettes (OR = 2.29, 95% CI = 1.01–5.15) and EF problems (OR = 4.99, 95% CI = 1.80–13.86) showed significant relationships to e-cigarette use. Adolescents with EF problems were almost five times more likely to use e-cigarettes compared to others.

Results on gateway drug use are also shown in Table 2. None of the demographic variables were significantly related to cigarette or alcohol use. Parent ownership of e-cigarettes (OR = 3.21, 95% CI = 1.66–6.20) and peer e-cigarette use (OR = 3.48, 95% CI = 1.27–9.54) independently predicted cigarette/alcohol use. Similar to results for e-cigarette use, EF problems was a major predictor of cigarette/alcohol use (OR = 2.43, 95% CI 1.13–5.22).

4. Discussion

This study expands existing research on adolescent e-cigarette use by focusing on early adolescence, a developmental period that has served as an “early warning” period marked by risk for experimentation with cigarettes, alcohol, and other substances, changes in parent and peer influences as contexts for use, and changes in brain functioning associated with executive cognitive function (EF). The study also addresses a major gap in our understanding of e-cigarette use by examining the simultaneous influences of demographic characteristics, use contexts, and EF on early adolescent e-cigarette use. The findings have several implications for curbing the alarming rapid increase in e-cigarette use among youth, designing prevention programs that include e-cigarette use along with other substances, and changing current policy related to minors’ access to e-cigarettes. Perhaps the most significant finding of this study is that executive function (EF) problems showed the strongest relationship to e-cigarette use. Adolescents with EF problems were almost five times more likely than other adolescents to use e-cigarettes and over two times more likely to have used cigarette or alcohol. These results support previous research findings on the strong longitudinal relationship of EF to tobacco and alcohol use in children and early adolescents (Pentz & Riggs, 2013; Riggs et al., 2012) and suggest that EF skills training might be an effective strategy for preventing e-cigarette use in early adolescents.

A second finding relates to higher use rates of e-cigarettes compared to cigarettes. Nationally and in California, adolescent cigarette use rates are declining. There are several possible explanations for the relatively higher e-cigarette use rates. One is that e-cigarettes may not simply be a substitute for cigarettes, or a novelty, but rather may signal a higher addiction potential than conventional cigarettes, especially if nicotine levels and patterns of nicotine intake exceed those of cigarettes (Grana, Benowitz, & Glantz, 2014). Alternatively, the barriers to initiation of e-cigarette use may be lower compared to cigarettes. E-cigarettes are more available, perceived as trendy, and are easier to hide because the odor does not linger (Hampton, 2014). In addition,

e-cigarettes could be perceived as safer than conventional cigarettes (Choi & Forster, 2014), and currently have no market or sales restrictions to minors (ChangeLab Solutions, 2014).

Other findings relate to demographic characteristics of users that did not always support previous studies. In the present study, there were no significant differences in e-cigarette use based on age, gender, race/ethnicity, or socioeconomic status measured as being in a free lunch program at school. Previous studies on college students and adults have suggested that e-cigarette use, or at least risk for use based on awareness and willingness to try, is higher among Whites than Hispanics, males, lower socioeconomic groups, and older adults (e.g., Cho et al., 2011; Dutra & Glantz, 2014). The differences in our study could relate to the younger age group used, size of the sample, or regional differences.

An additional important finding relates to contexts for use. As has been shown in research on tobacco and alcohol use (Pentz & Riggs, 2013), both parents and peers were important influences on e-cigarette use. Although not reaching conventional levels of significance ($p < 0.15$), adolescent risk for e-cigarette use more than doubled if peers also used. In addition, the finding that adolescents were over two times more likely to use e-cigarettes if their parents owned one suggests that a major source of e-cigarettes might be their parents. The present study could not determine whether adolescents take their parents’ e-cigarettes without their knowledge, or whether parents who may be using e-cigarettes to quit smoking offer their child an e-cigarette because they believe it is benign, or whether parent ownership represents a modeling influence on adolescent use behavior.

Influences were similar for e-cigarette as well as tobacco or alcohol use in this study. Taken together, the findings support the possibility that e-cigarette use may represent a more general constellation of substance use behavior rather than a singular behavior.

4.1. Strengths and limitations

To our knowledge, this is the first study to examine demographic, contextual, and particularly EF as predictors of e-cigarette use among early adolescents, and use of tobacco or alcohol. The findings are also the first to suggest that e-cigarette use, at least among adolescents, may be emerging as a universal population-based problem, not limited by gender, socioeconomic status, or ethnicity. However, there are a few limitations to the present study. Similar to most recent studies of e-cigarette use, the data were cross-sectional. Thus, we could not address transition or progression of e-cigarette use in adolescents. Second, the study was intended primarily as a survey study of multiple health risk behaviors as an extension of a larger prevention trial rather than as a detailed, specific study of e-cigarette use and e-cigarette use risk. Similar to other recent studies, detailed measurement of e-cigarette use and use predictors is still evolving, e.g., nicotine dosage, puffing behavior, and taste. In addition, the present study used the BRIEF to measure EF, which some have suggested may represent more of a measure of problem behavior rather than EF per se (McAuley et al., 2010). However, it is considered an appropriate and ecologically valid measure of EF skills that are associated with goals and actions in everyday situations, which was the focus of the present study (Toplak et al., 2013). Finally, while the sample from which the data were drawn are representative of Southern California populations of adolescents in urban areas, as well as White, Hispanic/Latino, and bi-racial groups represented in national surveys, the results may not generalize to other populations. Nevertheless, our results suggest that e-cigarette use among early adolescents is an important problem which may worsen without attention to e-cigarettes in substance use prevention programs and in policies for restricting youth access to substances.

5. Conclusions

The present study findings challenge at least two assumptions about adolescent e-cigarette use and have implications for prevention

programming and policy change regarding e-cigarette use with minors. First, the differences in findings about gender, socioeconomic, and ethnicity compared to findings from studies on young adults raises the possibility that e-cigarette use may be more ubiquitous among youth than adults and may mean something entirely different to the different cohorts that these age groups represent. For example, college students, other young adults, and even older adults may be using e-cigarettes because they are sophisticated products that are allowable in bars and nightclubs, and/or they are perceived as safe alternatives to cigarette use, and/or they are trying to quit smoking. Youth, on the other hand, may be using e-cigarettes because there are currently no legal age restrictions on use, they look cool, taste better than cigarettes, and are perceived as safer. Not yet known is whether an additional attraction to youth may be that e-cigarettes are perceived as physiologically more potent than cigarettes. A second assumption is that e-cigarette use may be a novel substitute for cigarette use. Novelty seeking has already been shown to predict experimentation with and growth in adolescent substance use (Crawford et al., 2003). The present study findings suggest that cigarette and e-cigarette use co-occur. However, the cross-sectional design did not allow for any evaluation of substance switching that might have signaled a novelty effect.

5.1. Future directions

The findings from the present study raise several questions to pursue in future research. First would be a longitudinal study to examine differences in early adolescent trajectories of use, particularly among those who transition from cigarettes to e-cigarette use versus those who “jump” directly into e-cigarette use. Second is the question of where early adolescents obtain e-cigarettes other than from parents or peers, and if from parents, why, e.g., parents are trying to quit smoking themselves and perceive e-cigarettes as a safer alternative for their adolescent to experiment with. The implication is that under current regulatory practice and policy, adolescents are not restricted from purchasing e-cigarettes themselves. Third, little is known about the social or cultural meaning of e-cigarettes compared to cigarettes and other substances. Such knowledge could be incorporated into future substance use prevention programs. Finally, the strength of the relationship of EF problems to e-cigarette use suggests that substance use prevention programs should include e-cigarette use and emphasize EF skills training that target emotional regulation, impulse control, goal setting, and planful decision-making.

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Contributors

Dr. Pentz is the principal investigator on the Pathways study and contributed to a substantial portion of the writing and interpretation of results for this paper.

Ms. Shin conducted the statistical analysis for this paper.

Dr. Riggs is a co-investigator on the Pathways study. He developed the executive function scale and wrote sections related to executive function for this paper.

Dr. Unger participated in interpretation of the results and writing the final manuscript.

Ms. Collison conducted a significant portion of the background research for this paper and also contributed to writing.

Dr. Chou contributed to this paper through conceptualization, data analysis and writing.

All authors have reviewed and approved the final manuscript.

Conflict of interest

All authors declare that they have no conflict of interest.

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