ORIGINAL ARTICLE

E-Cigarettes and the Use of Conventional Cigarettes

A Cohort Study in 10th Grade Students in Germany

Matthis Morgenstern, Alina Nies, Michaela Goecke, Reiner Hanewinkel

Summary

Background: In 2015, 12.1% of 12– to 17-year-olds in Germany had reportedly already tried e-cigarette smoking at least once. We carried out a study of the "gateway" hypothesis, according to which the use of e-cigarettes can motivate adolescents to start smoking conventional cigarettes.

Methods: During the 2015/2016 school year, 2186 tenth-graders in the German states of Lower Saxony and Schleswig-Holstein who had never smoked conventional cigarettes before took part in a survey over a 6-month period (mean age 15.5 years, standard deviation 0.65; 53.6% female).

Results: 14.3% of the survey population (313 adolescents) said at the start of the survey period that they had already tried e-cigarettes at least once. By the end of the survey period, 12.3% (268) of those who had never smoked before had begun to experiment with conventional cigarettes. The risk of beginning such experimentation was 2.2 times higher among e-cigarette users. This association remained (relative risk = 2.18 [1.65; 2.83]) after statistical control for age, sex, state, immigrant background, type of school, socioeconomic status, various personality traits (sensation-seeking, impulsivity, anxiety, hopelessness, extraversion, agreeableness, conscientiousness, neuroticism, openness), and the use of alcohol, cannabis, and other illicit drugs. Further analysis revealed that the association between the use of e-cigarettes and the onset of conventional cigarette smoking was stronger among adolescents with low sensation-seeking scores and without any experience of alcohol intoxication.

Conclusion: Among adolescents who have never smoked, experimentation with conventional cigarettes is more common in those who have used e-cigarettes. This effect seems to be stronger among adolescents who, in general, have a lower risk of starting to smoke. The 6-month observation period of this study is too short to allow any inference regarding a connection between e-cigarette use and the development of tobacco dependence.

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Electronic cigarettes, or e-cigarettes, are battery-powered electronic devices, releasing aerosolized nicotine without combustion processes for inhalation (1). For about a decade, e-cigarettes have been freely available to consumers. Initially, e-cigarettes were sold online, later also in specialist stores. Today, a wide variety of products is on the market, including e-hookahs, a variant of e-cigarette frequently printed in bright colors and often looking like colored markers, potentially making them particularly attractive to children and adolescents.

The number of regular e-cigarette users in Germany has increased dramatically in recent years. A representative population-based cross-sectional survey of 4002 randomly selected individuals aged 14 and older conducted in 2016 found that 1 in 8 Germans had already tried e-cigarettes at least once and that experimental use of e-cigarettes among non-smokers appeared to be more widespread in adolescents than in other age groups (2).

For more than a decade, the use of conventional cigarettes has been declining among adolescents (3). While 27.5% of the 12– to 17-year-olds at least occasionally smoked conventional cigarettes in 2001, this only applied to 7.8% of persons in this age group in 2015 (4). In Germany, the proportion of children and adolescents with experience in the use of e-cigarettes and e-hookahs is substantial: In 2015, 12.1% and 13.5% of the 12– to 17-year-olds in Germany had at least once tried e-cigarettes and e-hookahs, respectively (4). In the group of 12– to 13-year-olds, experiences with the consumption of e-cigarettes may be more common than with the use of conventional cigarettes (5).

There is ongoing debate about the benefits and harms of e-cigarettes in the medical research community. Various aspects are being discussed which must be balanced according to their importance (6). Studies about long-term health effects are needed (7). In addition, the question arises as to whether there is a health risk associated with passive exposure to e-cigarette vapor, similar to the risk of passive smoking associated with conventional cigarettes (8). Furthermore, high hopes are being entertained as to the use of e-cigarettes for smoking cessation, but the data obtained so far have been very heterogeneous (9–13).

TABLE 1

Sample characteristics and attrition analysis (November/December 2015)

	Baseline total N = 4163	Never smoked, reached for FU n = 2186	Never smoked, not reached for FU, n = 172	p value attrition
Sociodemographic characteristics				
Sex (% female)	52.1	53.6	48.5	0.206
Age (M, SD), R: 14–18	15.61 (0.73)	15.49 (0.65)	15.65 (0.78)	0.003
Federal state (% Schleswig-Holstein)	57.5	58.1	41.9	<0.001
School type (% not upper secondary school)	54.8	48.8	51.1	0.552
Migration background* (% no)	73.6	76.3	64.1	<0.001
School-leaving qualification of parents (% no secondary school certification)	60.5	58.9	53.7	0.125
SES (M, SD), R 1–10	5.96 (1.57)	5.99 (1.52)	6.10 (1.65)	0.397
Personality				
Sensation Seeking (M, SD)	0 (1)	−0.21 (1)	−0.02 (1.02)	0.014
Impulsivity (M, SD)	0 (1)	−0.13 (0.99)	0.08 (1.13)	0.008
Anxiety sensitivity (M, SD)	0 (1)	0.06 (1.00)	−0.06 (0.99)	0.153
Hopelessness (M, SD)	0 (1)	−0.08 (0.91)	0.17 (1.14)	<0.001
Extraversion (M, SD)	0 (1)	−0.13 (1.02)	0.07 (1.02)	0.014
Agreeableness (M, SD)	0 (1)	0.02 (0.99)	0.06 (1.06)	0.620
Conscientiousness (M, SD)	0 (1)	0.05 (0.96)	−0.08 (0.96)	0.087
Neuroticism (M, SD)	0 (1)	0.03 (0.99)	0.07 (0.97)	0.578
Openness (M, SD)	0 (1)	0.07 (0.97)	−0.03 (1.02)	0.177
Substance consumption ever				
E-cigarettes (N [%])	1580 (38.2)	313 (14.3)	34 (20.0)	0.044
Alcohol (N [%])	3716 (89.5)	1845 (84.4)	135 (78.8)	0.055
Binge drinking (N [%])	2410 (58.2)	887 (40.6)	70 (40.8)	0.943
Cannabis (N [%])	832 (20.1)	68 (3.1)	11 (6.4)	0.018
Other illegal drugs (N [%])	375 (9.0)	74 (3.4)	11 (6.4)	0.044

*approximated by country of birth, language spoken at home and religion
FU, follow-up; R, range, M, mean; SD, standard deviation; SES, socioeconomic status

Another argument is that e-cigarettes may promote the renormalization of smoking of conventional cigarettes in society (14).

In the mid 1970s, the gateway hypothesis was developed by Denise Kandel (15). Kandel observed that the sequence of initial consumption of various drugs did not vary randomly, but showed systematic trends—for example, that the consumption of nicotine and alcohol precedes the use of illegal substances, such as cannabis or cocaine. The gateway hypothesis was strongly criticized from various sides (16), the main concern being the lack of a causal explanation. In Germany, for example, only a small proportion of the population consumes cocaine or other hard drugs despite the widespread consumption of alcohol in the population.

More recently, Eric Kandel and Denise Kandel have conducted experiments with mice to obtain data supporting the potential role of nicotine as a gateway drug (17). Their experiments showed that after prior administration of nicotine, administration of cocaine had different effects on the mouse organism, e.g. an increased striatal acetylation. This observation gave rise to concerns that the use of nicotine-containing liquids in e-cigarettes could be a gateway to the use of conventional cigarettes (16–19).

Schneider and Diehl discussed 3 potential mechanisms for the transition from e-cigarettes to conventional cigarettes (16):

- Addiction: Although the potential of e-cigarettes to cause physical and psychological dependence is not yet clearly understood, it is conceivable that tolerance development in adolescents used to nicotine consumption is responsible for transition to conventional cigarettes, driven by the urge to increase nicotine doses.

- Experience: The familiarity with habitual and ritual processes (smoking breaks, hand position, topography, etc.) resulting from regular e-cigarette consumption could promote subsequent transition to conventional cigarettes.
- Accessibility: E-cigarettes and tobacco cigarettes are typically offered via the same sales channels (tobacco shops, kiosks, gas stations).

One of the first studies to test this hypothesis evaluated a cohort of 694 adolescents and young adults (20). At baseline, only 16 of these reported experiences with e-cigarettes. Compared to adolescents without e-cigarette consumption experience, these had an 8-fold increase in the risk of smoking conventional cigarettes for the first time in their life during the 1-year follow-up period. In the meantime, additional cohort studies have been published (21). These studies were conducted in Anglo-America (22–33), the United Kingdom (34, 35) and Mexico (36). Overall, their results indicate that the initial use of e-cigarettes during adolescence may be associated with an increased risk for initiation of conventional cigarette use.

We are not aware of any longitudinal studies on cohorts in Germany on the topic of e-cigarettes. A recent review rated the methodological quality of the international studies published so far as moderate (37). Major limitations criticized were the limited number of confounding variables measured and the very high attrition rate during the follow-up period which in some studies was as high as half of the surveyed adolescents.

The aim of this study was to evaluate whether e-cigarette use in adolescence can increase the risk of conventional cigarette use. An additional question to be addressed was whether the use of e-cigarettes just represents a criterion which identifies adolescents who in any case are at increased risk of starting to smoke. For this end, we were the first to collect data on personality traits of the adolescents surveyed.

Methods

Design

Altogether, 4163 10th grade students were surveyed at baseline (2015/2016 school year; response rate of 84.5%), with 2358 (57.1%) of these students reporting that they had never tried conventional cigarettes at any time in their life. Of these, 2186 students could be successfully contacted again half a year later (re-contact rate of 92.7%). Further characteristics of this study are described in the *eBoxes 1* to *3*.

Statistical analyses

For statistical analysis, a multiple regression model was used which included all variables, i.e. sociodemographic and personality variables as well as consumption of other substances. In a further step of the analysis, interaction terms were used to test whether the various model variables had an impact on the association between e-cigarette consumption and the use of conventional cigarettes. For further information about the statistical analysis, please refer to *eBox 4*.

TABLE 2

Risk ratio for initiation of conventional cigarette use within the 6-month follow-up period

Study variable at baseline	ARR*	95% CI
Sociodemographic characteristics		
Female sex	0.85	[0.65; 1.10]
Age >15	0.89	[0.71; 1.13]
Federal state: Lower Saxony	0.92	[0.72; 1.19]
School type not upper secondary school	**1.53**	**[1.19; 1.96]**
Migration background	**1.31**	**[1.02; 1.71]**
School-leaving qualification of parents	1.15	[0.91; 1.46]
SES	0.98	[0.87; 1.10]
Personality		
Sensation Seeking	**1.22**	**[1.08; 1.38]**
Impulsivity	1.06	[0.93; 1.20]
Anxiety sensitivity	0.96	[0.85; 1.08]
Hopelessness	**1.17**	**[1.03; 1.33]**
Extraversion	1.07	[0.92; 1.22]
Agreeableness	1.01	[0.90; 1.14]
Conscientiousness	1.04	[0.93; 1.17]
Neuroticism	0.91	[0.80; 1.04]
Openness	0.94	[0.83; 1.05]
Substance consumption		
E-cigarettes ever	**2.18**	**[1.68; 2.83]**
Alcohol ever	1.24	[0.79; 1.93]
Binge drinking ever	**1.97**	**[1.48; 2.62]**
Cannabis ever	1.05	[0.64; 1.72]
Other illegal drugs ever	0.95	[0.52 ;1.71]

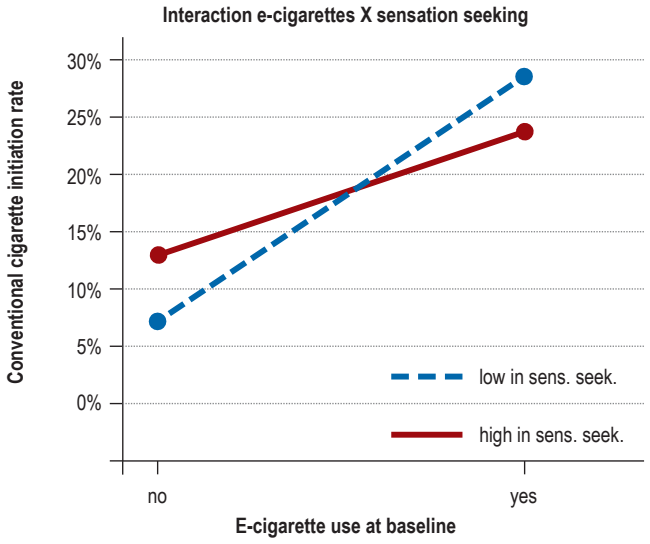
*statistically controlled for all variables in this table and for participation in the "Keep a Clear Head" program; pseudo R^2 = 0.09; statistically relevant association are marked in bold.
ARR, adjusted risk ratio; CI, confidence interval; SES, socioeconomic status

Results

Sample description and attrition analysis

Table 1 lists the characteristics of the sample, both for the entire study population at baseline and the sample included in the analysis (mean age: 15.5 years; 53.6% female). In addition, a comparison between former never-smoking students who could be successfully contacted and those who could not be contacted shows the extent of selective attrition of participants. More frequently, it was possible to successfully contact never-smokers who were younger, were surveyed in the federal state of Schleswig-Holstein, had no migration background, had lower scores on the personality traits sensation seeking, impulsivity, hopelessness, and extraversion, and had less often consumed e-cigarettes, cannabis and other illegal drugs.

FIGURE



Association between initiation of use of conventional cigarettes and use of e-cigarettes in relation to sensation seeking (sens. seek.). Sample: students who at baseline had never smoked (N = 2186)

Association between the variables studied and initiation of smoking conventional cigarettes

During the follow-up period, 268 of the 2186 formerly never-smoking adolescents (12.3%) smoked conventional cigarettes for the first time in their life. In the unadjusted model (model 1), the frequency of conventional cigarette consumption was significantly associated with gender (more rarely among female students), type of school (more rarely among upper high school students) and the personality traits sensation seeking, impulsivity, anxiety sensitivity, extraversion, and neuroticism *(eTable 1)*. In addition, smoking initiation was more frequently observed among those students who had already had experiences with alcohol, binge drinking, cannabis, and e-cigarettes. In the multiple regression model, 6 variables were identified as independent predictors *(Table 2)*:

- Type of school
- Migration background
- The personality traits sensation seeking and hopelessness
- Binge drinking
- E-cigarette consumption at baseline.

Experimental use of conventional cigarettes was at 21.6% in the group of e-cigarette consumers, while it was at 9.9% in the group of students without experience with e-cigarettes (risk ratio = 2.18).

Testing for interaction effects found significant effect modifications related to sensation seeking (risk ratio [RR] = 0.48, 95% confidence interval [CI]: [0.29; 0.82]) and experience with binge drinking (RR = 0.47, 95% confidence interval: [0.27; 0.83]). As shown in the *Figure*, the connection between the use of e-cigarettes and smoking initiation was stronger in persons with low scores in sensation seeking compared to students scoring high in sensation seeking. In the same way, the association was stronger for students without binge drinking experience compared to students with binge drinking experience.

Discussion

A cohort of 2186 10th grade students who had never smoked conventional cigarettes in their life were observed over a half-year period. An association between experiences with the consumption of e-cigarettes at baseline and the experimental use of conventional cigarettes during the follow-up period was demonstrated and still present after adjustment for numerous confounding variables.

With regard to the association between consumption of e-cigarettes and initiation of conventional cigarette use, the results obtained in this study were comparable to those of studies on US cohorts. A recent meta-analysis of 7 cohort studies reported an adjusted odds ratio of 3.62 [2.42; 5.41] for adolescents and young adults with experience in e-cigarettes consumption at baseline compared to persons without consumption experience (37). The risk ratio of 2.2 in the current German cohort corresponds to an adjusted odds ratio of 2.8; here, it has to be taken into account that considerable more confounding variables were controlled in this study compared to the 7 cohort studies included in the meta-analysis.

The personality trait "sensation seeking" is defined by the search for changing and novel experiences to feel intense sensations again and again. Sensation seeking is a construct with a physiological basis, assuming that for every individual there is an optimal arousal (38). By seeking or avoiding stimulation, arousal can be controlled on an individual level. In line with other studies, our study showed that risk-taking behavior—here the experimental use of conventional cigarettes—can be predicted based on this personality trait. However, here the more pressing question is whether the use of e-cigarettes is not merely an indication that theses persons in general seek stimulations and whether this explains why they start smoking earlier. Our study did not only show that the correlation between sensation seeking and e-cigarette use in the group of never-smoking adolescents is rather weak (correlation coefficient: r = 0.11) *(eTable 2)*, but also that in particular those students with low sensation seeking—i.e. persons with a tendency to avoid risky behavior—were encouraged by the use of e-cigarettes to try conventional cigarettes too.

In Germany, tobacco smoking among adolescents does not occur independently of the type of school attended (39). This finding was also confirmed in our analysis: In German upper secondary schools ("Gymnasium"), smoking was less common and less

students started experimenting with smoking during the follow-up period. However, the association between use of e-cigarettes and initiation of smoking was almost equally strong in upper secondary school students and non-upper secondary school students and thus can be regarded as independent of school type.

Limitations

However clear these current findings may appear, the interpretation of these data should take some limitations into account. For ethical reasons, the gateway hypothesis cannot be studied using an experimental model. In general, observational studies are more prone to systematic biases compared to randomized clinical trials and they do not allow us to establish causality (40). For example, when interpreting the results it should be taken into consideration that external validity can be affected by selection bias and internal validity by unmeasured confounding. Selection bias can occur when the study population is not randomly selected from the target population; this is the case in our study. Despite the large number of variables measured in this study, confounding of the association by one or more third variables can never be ruled out completely. Especially the impact of the immediate social environment—for example, smoking friends or smoking parents—was not adequately accounted for. Likewise, it cannot be ruled out with certainty that users of e-cigarettes had not started smoking anyway at a later point in time.

As a further limitation, the question should be discussed whether the result "ever smoked" is a clinical or health-relevant parameter at all. Even though it is well established that nicotine has a very high addictive potential, single experimental use among adolescents does not necessarily result in dependence (e1). In our data set, 83 persons changed from non-daily to daily tobacco consumption during the 6-month follow-up period. This transition, too, was associated with prior e-cigarette use (*eTable 3*).

It must be emphasized that, mainly due to the short duration of its follow-up period, this study does not allow any conclusions to be drawn about the long-term impact of the use of e-cigarettes on the development of tobacco dependence.

The method of data collection represents another limitation of this study, as it was not based on objective measurements and could be affected by systematic response bias. Multiple testing of the same sample carries the risk of alpha-error inflation; this limitation should also be kept in mind when interpreting the results. Furthermore, no data were collected on the type of liquids—with or without nicotine—consumed by the adolescents. Based on existing surveys from Germany, it can be assumed that nicotine-containing liquids are used by about one third of the e-cigarettes–consuming adolescents (2, 4, e2). Addiction, in the sense of physical and psychological dependence, as the mechanism underlying the transition to tobacco smoking as postulated by Schneider and Diehl (16), can essentially only be applied to adolescents who are exposed to nicotine when using e-cigarettes. The same applies to the experience hypothesis, i.e. the familiarity with habitual and ritual processes resulting from regular e-cigarettes consumption, which cannot be tested using data on experimental consumption.

In Germany, the sale of e-cigarettes and e-hookahs to children and adolescents was prohibited not earlier than 1 April 2016. Thus, during the follow-up period of this study, adolescents could legally purchase e-cigarettes. It cannot be ruled out that this change will have an impact on the prevalence of e-cigarette use among adolescents. However, as it can be learned from the prevalences of tobacco and alcohol consumption, the legal age to buy such products is not a key determinant of the initiation of consumption.

KEY MESSAGES

- Major risk factors for experimenting with conventional cigarettes were certain types of school (lower secondary school ["Hauptschule"], secondary school ["Realschule"], comprehensive school"[Gesamtschule]), a migration background, certain personality traits (sensation seeking and hopelessness), experience with binge drinking, and prior use of e-cigarettes.
- Among adolescents at low risk to start smoking, earlier consumption of e-cigarettes appeared to be stronger associated with later use of conventional cigarettes.
- This association was first described in a cohort of adolescents in Germany.
- The design of this study does not allow to make conclusions about causality.
- Since consumption behavior was not objectively assessed in this study, systematic distortion of the responses cannot be ruled out.

Conclusion

This study supports the ongoing discussion of potential benefits and harms of e-cigarettes by reporting empirical data. The association between e-cigarette consumption and the use of conventional cigarettes, which to date had only been shown for Anglo-American, British and Mexican samples, was also demonstrated for a cohort of adolescents in Germany. This result—which at least is not contradictory to the gateway hypothesis—should be taken into account when balancing advantages and disadvantages of e-cigarettes.

In the United States, smoking behavior among adolescents has changed significantly in recent years: The use of conventional cigarettes alone has declined, while the consumption of e-cigarettes has increased and a likewise considerable proportion of adolescents consumes both products in parallel and uses other tobacco products, such as hookahs, too (e3, e4). Whether these trends will also occur in Germany, should be carefully monitored.

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Conflict of interest
The authors declare no conflict of interest.

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► **Supplementary material**
eReferences: www.aerzteblatt-international.de/ref1418

eBoxes, eTables:
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Supplementary material to:

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A Cohort Study in 10th Grade Students in Germany

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eBOX 1

Study design

The data were obtained from a cluster-randomized study evaluating a school-based binge drinking prevention program (e5). In the two-wave, two-arm (intervention versus control) prospective study presented here, a total of 61 schools with 196 classes of 10th-grade students in the federal states of Lower Saxony and Schleswig-Holstein were included. These schools comprised 10 upper secondary schools ("Gymnasien"), 26 comprehensive schools ("Gemeinschaftsschulen") and 1 Waldorf school in Schleswig-Holstein as well as 12 upper secondary schools, 4 comprehensive schools, 3 secondary schools ("Realschulen"), 4 lower secondary schools ("Hauptschulen") and 1 upper school ("Oberschule") in Lower Saxony.

The study was approved by the relevant educational authorities and the ethics committee of the German Society of Psychology had no ethical concerns. The students' parents were informed in writing about the project and had the right to object to the participation of their child in the study. This study was registered with the German Registry of Clinical Studies (DRKS-ID: DRKS00009424).

eBOX2

Measuring contents

- **Substance use**

The consumption of conventional cigarettes was measured using the question "How many cigarettes have you smoked in your life so far?". The following answer alternatives were made provided: "none/only a few puffs/1–19/20–100/more than 100". Other substance consumption was checked with the question "Have you ever done one or more of the following?"… smoked e-cigarette or e-hookah, consumed cannabis/marihuana, consumed sniffing substances (e.g. poppers, nitrous oxide, glue), taken cocaine, taken ecstasy/XTC, other illegal drugs (methamphetamine, LSD and others)." The answer alternatives were "yes/no". Experiences with alcohol was checked using the item "Have you ever consumed alcohol" (yes/yes, only a few sips/no). Whether adolescents had ever in their life practiced in binge drinking was measured as follows: "Have you ever had «4 or more» (girls) and «5 or more» (boys) alcoholic drinks at any one occasion?" (yes/no).

- **Sociodemographic characteristics and covariates**

The following sociodemographic characteristics were collected: age, sex, type of school attended, the German federal state, and participation in the alcohol prevention program "Keep a Clear Head" (e5), as well as country of birth (mother, father, self), the language predominately spoken at home, and religion. As an indicator of socioeconomic status, information about the parents' school-leaving qualification was obtained. This was complemented by data on self-rated socioeconomic status which were collected using a 10-step scale. Respondents were ask to position themselves in comparison to people living in Germany (1 = "people with the least money, lowest education, worst jobs or jobless", 10 = "people with the most money, highest education, best jobs"). Furthermore, the Big Five personality traits (extraversion, conscientiousness, agreeableness, neuroticism, and openness) were measured, using 10 items. In addition, the Substance Use Risk Profile Scale (SURPS) was used *(eBox 3)*, covering 4 distinct personality constructs (hopelessness, anxiety sensitivity, sensation seeking, impulsivity) (e6).

eBOX 3

Substance Use Risk Profile Scale (sensation seeking, anxiety sensitivity, hopelessness, impulsivity) (e6)

1. I am content.
2. I often say something without much thinking about it.
3. I would like to try parachuting.
4. I am happy.
5. I often get myself into situations where I am involved in something I later regret.
6. I enjoy making new and exciting experiences, even if they are unconventional.
7. I think my future is promising.
8. It is frightening to feel dizzy or weak.
9. I enjoy doing things that are a bit frightening.
10. I am scared when my heartbeat changes.
11. Normally I do things without thinking about it.
12. I would like to learn how to ride a motorbike.
13. I am proud of the things I have achieved.
14. It frightens me when I am too nervous.
15. In general, I am an impulsive person.
16. I am interested in experiences as such, even if they are illegal.
17. I feel like I am a failure.
18. I get anxious when I experience unusual sensations in my body.
19. I would enjoy long hikes through wild and uninhabited country.
20. I feel at ease.
21. It worries me if I cannot properly focus on a task.
22. I think I have to manipulate others to get what I want.
23. I very much look forward to my future.

Answer alternatives:
I do not agree at all/rather do not agree/rather do agree/agree 100%
Cronbach's alphas:
sensation seeking = 0.64, anxiety sensitivity = 0.65, hopelessness = 0.86, impulsivity = 0.61

eBOX 4

Statistical analysis

All data analyses were conducted using the Stata statistical software (version 15.0). The chi-square test and the t-test were used to assess differences between adolescents who could be contacted and those who could not be contacted successfully. Predictions of smoking conventional cigarettes were calculated using Poisson regressions with robust error variances (e7) to be able to describe any association as a risk ratio (RR). Due to the clustered data structure (students in classes from schools), random axis intercepts for the class and school levels were introduced. Since random effects were not significant, neither on the school level nor on the class level (likelihood-ratio tests), they were eliminated from the final analyses for reasons of economy; as expected, this had no impact on the other coefficients. To reduce multicollinearity in the regression model, the variables country of birth, language and religion were initially dichotomized and then combined to a score (alpha = 0.85). In addition, to improve comparability of coefficients, all personality traits and the self-rated socioeconomic status were z-standardized, while the remaining variables were dichotomized: age ("0" = younger than 16 years old, "1" = older than 15 years old), type of school ("0" = upper high school, "1" = not upper high school), school-leaving qualification of parents ("0" = no university entrance qualification, "1" = at least 1 parent with university entrance qualification), and experience with alcohol ("0" = never, "1" = a few sips or more). Due to the low prevalence of the use of sniffing substances, cocaine, MDMA (ecstasy), and other illegal drugs, this consumption was summarized in a score and dichotomized ("0" = no consumption, "1" = consumption of any of these substances). The criterion "number of smoked cigarettes at the time of the second survey" was also dichotomized ("0" = none, "1" = all other categories).

eTABLE 1

Risk ratio (RR) for the initiation of conventional cigarette use within a period of 6 months (unadjusted associations)

Study variable at baseline	RR	95% CI
Sociodemographic characteristics		
Female sex	**0.78**	**[0.62; 0.98]**
Age >15	0.98	[0.78; 1.23]
Federal state: Lower Saxony	0.92	[0.73; 1.16]
School type not upper secondary school	**1.57**	**[1.25; 1.98]**
Migration background	1.23	[0.96; 1.58]
School-leaving qualification of parents	1.02	[0.81; 1.28]
SES	0.93	[0.83; 1.04]
Personality		
Sensation Seeking	**1.41**	**[1.26; 1.58]**
Impulsivity	**1.21**	**[1.09; 1.35]**
Anxiety sensitivity	**0.88**	**[0.79; 0.97]**
Hopelessness	1.03	[0.92; 1.16]
Extraversion	**1.26**	**[1.12; 1.42]**
Agreeableness	0.99	[0.88; 1.11]
Conscientiousness	0.93	[0.83; 1.03]
Neuroticism	**0.87**	**[0.77; 0.97]**
Openness	0.95	[0.86; 1.06]
Substance consumption		
E-cigarettes ever	**3.18**	**[2.55; 3.97]**
Alcohol ever	**1.80**	**[1.21; 2.67]**
Binge drinking ever	**2.58**	**[2.04; 3.26]**
Cannabis ever	**2.34**	**[1.55; 3.53]**
Other illegal drugs ever	1.32	[0.77; 2.24]

Statistically relevant associations are set in bold.
CI, confidence interval; RR, risk ration; SES, socioeconomic status

eTABLE 2

Correlation between the use of e-cigarettes and the other study variables at baseline

	Total sample N = 4163	Analysis sample (never smokers) n = 2186
Sociodemographic characteristics		
Sex (0 = male, 1 = female)	−0.08*1	−0.07*2
Age	0.16*1	0.05*3
Federal state (0 = Schl.-Holst., 1 = Lower Saxony)	0.04*2	0.06*2
Type of school (0 = upper secondary school), 1 = not upper secondary school)	0.20*1	0.14*1
Migration background (0 = no, 1 = yes)	0.12*1	0.11*1
School-leaving qualification of parents (0 = no secondary school certification, 1 = secondary school certification)	−0.09*1	−0.07*1
SES	−0.02	−0.05*3
Personality		
Sensation Seeking	0.20*1	0.11*1
Impulsivity	0.14*1	0.08*1
Anxiety sensitivity	−0.05*2	−0.02
Hopelessness	0.02	0.00
Extraversion	0.15*1	0.03
Agreeableness	−0.02	0.01
Conscientiousness	−0.04*3	−0.03
Neuroticism	−0.06*1	−0.04
Openness	−0.05*1	−0.03
Substance consumption		
Alcohol (0 = no, 1 = yes)	0.11*1	0.04
Binge drinking (0 = no, 1 = yes)	0.34*1	0.19*1
Cannabis (0 = no, 1 = yes)	0.43*1	0.16*1
Other illegal drugs (0 = no, 1 = yes)	0.19*1	0.04

*1p<0.001; *2 p<0.01; *3p<0.05; Schl.-Holst., Schleswig-Holstein; SES, socioeconomic status

eTABLE 3

Risk ratio for initiation of daily tobacco use within the 6-month follow-up period among previously non-daily users

Study variable at baseline	RR*	95% CI
Sociodemographic characteristics		
Female sex	0.81	[0.48; 1.34]
Age >15	1.15	[0.75 ; 1.77]
Federal state: Lower Saxony	0.77	[0.49; 1.23]
School type not upper secondary school	1.17	[0.73; 1.87]
Migration background	1.05	[0.63; 1.75]
School-leaving qualification of parents	1.00	[0.61; 1.64]
SES	1.04	[0.85; 1.27]
Personality		
Sensation Seeking	1.28	[0.99; 1.67]
Impulsivity	1.00	[0.80; 1.25]
Anxiety sensitivity	0.77	[0.59; 1.01]
Hopelessness	**1.41**	**[1.12; 1.76]**
Extraversion	1.28	[0.97; 1.68]
Agreeableness	1.04	[0.83; 1.30]
Conscientiousness	0.82	[0.62; 1.07]
Neuroticism	1.19	[0.94; 1.49]
Openness	1.01	[0.81; 1.25]
Substance use		
E-cigarettes ever	**2.88**	**[1.54; 5.39]**
Alcohol ever	0.81	[0.22; 3.01]
Binge drinking ever	1.83	[0.79; 4.31]
Cannabis ever	**2.19**	**[1.29; 3.71]**
Other illegal drugs ever	1.47	[0.82; 2.64]

*statistically controlled for all variables in the Table and for participation in the "Keep a Clear Head" program; statistically relevant associations are marked in bold.
CI, confidence interval; RR, risk ratio; SES, socioeconomic status