Youth vaping and smoking and parental vaping: a cross-sectional survey

**CURRENT STATUS:** UNDER REVIEW

Michael Green  
Michael.green@glasgow.ac.uk  
University of Glasgow  
*Corresponding Author*  
**ORCiD:** 0000-0003-3193-2452

Linsay Gray  
University of Glasgow Institute of Health and Wellbeing

Helen Sweeting  
University of Glasgow Institute of Health and Wellbeing

**DOI:**  
10.21203/rs.2.22187/v1

**SUBJECT AREAS**  
*Health Policy*

**KEYWORDS**  
E-cigarettes, Smoking, Youth, Parents
Abstract

Background: Concerns remain about potential negative impacts of e-cigarettes including possibilities that: youth e-cigarette use (vaping) increases risk of youth smoking; and vaping by parents may have impacts on their children’s vaping and smoking behaviour.

Methods: With cross-sectional data from 3291 youth aged 10-15 years from the Understanding Society Survey, we estimated effects of youth vaping on youth smoking (ever, current and initiation in the past year), and of parental vaping on youth smoking and vaping, and examined whether the latter differed by parental smoking status. Propensity weighting was used to adjust for measured confounders and estimate effects of vaping under alternative scenarios of no vaping vs universal adoption, and vs observed vaping levels. E-values were calculated to assess the strength of unmeasured confounding influences needed to negate our estimates.

Results: Associations between youth vaping and youth smoking were attenuated considerably by adjustment for measured confounders. Estimated effects of youth vaping on youth smoking were stronger comparing no use to universal adoption (e.g. OR for smoking initiation: 32.5; 95% CI: 9.8-107.1) than to observed levels of youth vaping (OR: 4.4; 0.6-30.9). Relatively strong unmeasured confounding would be needed to explain these effects. Associations between parental vaping and youth vaping were explained by measured confounders. However, estimates for parental vaping on youth smoking indicated effects, especially for youth with ex-smoking parents (e.g. OR for smoking initiation: 11.3; 2.7-46.4) rather than youth with currently smoking parents (OR: 1.0; 0.2-6.4). Relatively weak unmeasured confounding could explain these parental vaping effects.

Conclusions: While results for youth vaping and youth smoking associations indicated support for underlying propensities, estimated effects still required considerable
unmeasured confounding to be explained fully. However, these estimates from cross-sectional data could also be explained by smoking leading to vaping. Stronger estimates for universal vaping adoption vs observed usage, indicated that if youth vaping does increase risk of youth smoking, this effect may be stronger in the general population of youth, than among those youth who typically vape. Associations of parental vaping with youth smoking and vaping were either explained by measured confounding or could be relatively easily explained by unmeasured confounding.

Introduction

Use of e-cigarettes has been rising in the UK [1] and internationally [2], though has recently plateaued in the UK [3, 4]. We refer here to use of e-cigarettes as ‘vaping’, considered distinct from ‘smoking’ traditional cigarettes. Mounting evidence supports the view that e-cigarettes are substantially less harmful than traditional cigarettes [1, 5-9], and there is increasing evidence that they can aid successful smoking cessation [3, 9-13]. Nevertheless, potential public health benefits of e-cigarettes should be weighed against possible detriments [14, 15]. Internationally, concerns have been raised, particularly relating to youth, that because the behaviours are similar and many (but not all) e-cigarettes contain nicotine, vaping behaviour could help establish and/or maintain smoking behaviour [16-20]. As vaping prevalence has risen among adults, it is also important to understand the impacts this may have on young people who live with those adults. For example, if a smoking parent switches to vaping, what impact could this have on the risk of their children smoking and/or vaping? While vaping may be safer than smoking, nicotine exposure in adolescence specifically, may have concerning consequences including: increased risk for developing psychiatric disorders, effects on brain development and later-life cognition, and priming for future substance abuse [21]. The notion that vaping may increase risk for smoking can be contrasted with the notion of
common liabilities [19, 20]: that underlying propensities for both behaviours account for their close association among youth [2, 9, 17, 22-26]. While many studies [2, 22-25] have adjusted for measured differences in background, unmeasured common liabilities remain possible explanations [19, 27], even for more recent longitudinal studies showing vaping preceding smoking [17, 26, 28-32] and where respondents had stated no intention of smoking [33]. It is important to recognise that common liabilities and vaping increasing risk for smoking (or indeed, smoking increasing risk for vaping [32]) are not mutually exclusive explanations for associations between vaping and smoking among youth. Thus, it is more important to establish the relative contribution of each in explaining associations between youth smoking and vaping, than to try and establish any one of these as the ‘true’ explanation.

Parental smoking is among the most established risk factors for youth smoking [34], so it seems likely parental vaping could also be an important influence on youth behaviour, though it has been little studied as yet. Common liabilities are also viable explanations for associations between parental vaping and youth behaviour. A UK study has shown associations between parental vaping and youth initiation of smoking and vaping [32], though these were not the main focus of their study and were attenuated in adjusted models. If there are effects of parental vaping, these could feasibly differ depending on parental smoking status. If e-cigarettes are viewed as an aid to smoking cessation [3, 14] then parental use could make smoking seem less normative and reduce risk of smoking initiation, especially if parents completely switch from smoking to vaping. On the other hand, dual-use by parents could result in the behaviours appearing to youth as linked and complementary and increase risk for both. Indeed, a study in Mexico showed youth susceptibility to vaping and smoking to be higher where family members were either cigarette or dual users, but not where family members only vaped [35].
With an interest in understanding these issues, we can be more specific in defining the effects of interest [36], recognising that in observational studies exposures are not experienced randomly and there may be important differences between those who are and are not exposed. For example, if we are interested in the effect of youth vaping on youth smoking, we may estimate a population average effect (often referred to as an average treatment effect or ATE, using language from experimental science), which represents a comparison of outcomes between a scenario where no youth vaped to one where all youth vaped. Alternatively, we might be interested in the effect of the observed level of youth vaping (referred to as the average treatment effect among the treated or ATT). This compares a scenario of no vaping against actual observed vaping, i.e. representing what might happen if we were to intervene and stop the youth who do vape from doing so. Similarly, if we are interested in the effects of parental vaping, the ATE might compare scenarios where no parents vape vs all parents vape, while ATTs would represent hypothetical intervention to stop parents from vaping. These estimates will be identical if effects are uniform, but may differ if effects are heterogeneous, i.e. varying with the background factors that predict vaping. As well as indicating the extent of effect heterogeneity, both estimates offer useful insights. Whilst universal adoption of vaping is unlikely, ATEs offer insight into the potential impacts if vaping were adopted more widely, indicating whether preventative intervention may be needed. On the other hand, ATTs indicate what may happen if interventions were implemented to stop current vaping behaviour.

With data from a large survey designed to be representative of UK households, we estimate ATE and ATT effects of youth vaping on youth smoking and of parental vaping on youth smoking and vaping. For parental vaping, we do this for all youth, but also stratify by parental smoking status.
Methods

Sample

Respondents were from the 7th Wave of Understanding Society, a panel survey based on annual interviews conducted within UK households [27]. In fieldwork spanning 2015–2017, 4534 youth aged 10–15 were eligible for self-completion questionnaires. A total of 3635 youth (80.2% of those eligible) in 2759 households completed questionnaires. Valid survey weights designed to account for household attrition, non-response and over-sampling were available for 3291 youth (90.5% of those responding) and used throughout to render the sample representative of the UK [37]. Multiple imputation of missing values (25 datasets, using an unconstrained model in which all analysis variables predicted all others) enabled inclusion of all observed data from respondents with valid weights [38] (proportions missing for most variables were between 0 and 5.3%, though 18.6% for ethnicity; see Table 1).

### Table 1

| Observed | Missing | Imputed | Current Vaping | Ever Smoker | Current Smoker | Smoking Initiation (N = 3075a) |
|----------|---------|---------|----------------|-------------|----------------|-------------------------------|
| N (%)    | N (%)   | N (%)   | Yes %          | P-Value     | Yes %          | P-Value                      |

| All      | 3291 (100.0) | 0 (0.0) | 3291 (100.0) | 3.4 - | 7.4 - | 2.3 - | 0.9 - |
| No Vaping | 3069 (96.5) | 112 (3.4) | 3179 (96.6) | 5.5 < 0.001 | 1.2 < 0.001 | 0.5 < 0.001 |
| Current Vaping | 110 (3.5) | 112 (3.4) | 63.3 | 31.9 | 24.1 |
| Never Smoker | 3022 (92.6) | 27 (0.8) | 3047 (92.6) | 1.4 < 0.001 |
| Ever Smoker | 242 (7.4) | 244 (7.4) | 29.0 |
| Non Smoker | 3190 (97.7) | 27 (0.8) | 3216 (97.7) | 2.4 < 0.001 |
| Current Smoker | 74 (2.3) | 75 (2.3) | 47.5 |
| Never Smoker a | 3022 (99.1) | 27 (0.8) | 3046 (99.1) | 1.4 < 0.001 |
| Initiation | 28 (0.9) | 29 (0.9) | 45.8 |
| Smoker       | Male          | Female         | Age 10 | Age 11 | Age 12 | Age 13 | Age 14 | Age 15 | England | Wales | Scotland | Northern Ireland | White UK | Ethnic Minority | Couple Parents | Single Parent | Parents Never Smokers | Ex-Smoking Parent(s) | Current Smoking Parent(s) | No Parental Vaping | Parental Vaping | Parental Education - Degree | A-Level or equivalent | GSCE or equivalent |
|--------------|---------------|----------------|--------|--------|--------|--------|--------|--------|---------|-------|----------|------------------|----------|----------------|-----------------|---------------|------------------------|-------------------|------------------|---------------------|---------------------|-------------------|
|              | 1629 (49.5)   | 1629 (49.5)    | 4.2    | 0.019  | 7.5    | 0.859  | 2.4    | 0.626  | 1.2     | 0.207 |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| Female       | 1662 (50.5)   | 1662 (50.5)    | 2.7    | 7.3    | 2.2    | 0.7    |        |        |         |       |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| Age 10       | 520 (15.8)    | 520 (15.8)     | 0.8    | <0.001 | 0.0    | <0.001 | 0.0    | <0.001 | 0.0    | <0.001 |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| Age 11       | 596 (18.1)    | 596 (18.1)     | 0.0    | 1.8    | 0.2    | 0.2    |        |        |         |       |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| Age 12       | 561 (17.0)    | 561 (17.0)     | 0.7    | 1.8    | 0.2    | 0.2    |        |        |         |       |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| Age 13       | 493 (15.0)    | 493 (15.0)     | 2.7    | 5.7    | 0.8    | 0.7    |        |        |         |       |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| Age 14       | 588 (17.9)    | 588 (17.9)     | 6.9    | 14.6   | 4.7    | 3.1    |        |        |         |       |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| Age 15       | 533 (16.2)    | 533 (16.2)     | 9.2    | 20.6   | 7.7    | 1.7    |        |        |         |       |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| England      | 2830 (86.0)   | 2831 (86.0)    | 3.4    | 0.618  | 7.4    | 0.892  | 2.1    | 0.311  | 0.8    | 0.080 |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| Wales        | 111 (3.4)     | 111 (3.4)      | 2.7    | 6.4    | 1.8    | 1.0    |        |        |         |       |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| Scotland     | 263 (8.0)     | 263 (8.0)      | 3.0    | 7.6    | 3.8    | 2.4    |        |        |         |       |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| Northern Ireland | 86 (2.6) | 86 (2.6)      | 5.8    | 9.3    | 3.5    | 0.2    |        |        |         |       |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| White UK     | 2269 (84.7)   | 2764 (84.0)    | 3.6    | 0.196  | 7.9    | 0.018  | 2.4    | 0.168  | 1.0    | 0.217 |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| Ethnic Minority | 410 (15.3) | 527 (16.0)    | 2.4    | 4.7    | 1.4    | 0.4    |        |        |         |       |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| Couple Parents | 2437 (75.1) | 2472 (75.1)  | 2.6    | <0.001 | 5.8    | <0.001 | 1.6    | <0.001 | 0.7    | 0.011 |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| Single Parent | 809 (24.9)    | 819 (24.9)     | 5.9    | 12.2   | 4.3    | 1.8    |        |        |         |       |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| Parents Never Smokers | 1154 (35.6) | 1174 (35.7) | 3.0    | 0.118  | 5.7    | 0.010  | 1.3    | 0.002  | 0.9    | 0.896 |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| Ex-Smoking Parent(s) | 1282 (39.6) | 1300 (39.5) | 3.0    | 7.9    | 2.2    | 1.0    |        |        |         |       |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| Current Smoking Parent(s) | 802 (24.8) | 817 (24.8) | 4.6    | 9.2    | 3.8    | 1.0    |        |        |         |       |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| No Parental Vaping | 2857 (88.2) | 2903 (88.2) | 3.1    | 0.014  | 6.8    | <0.001 | 2.0    | 0.019  | 0.8    | 0.004 |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| Parental Vaping | 381 (11.8)  | 388 (11.8)    | 5.6    | 12.3   | 4.0    | 2.4    |        |        |         |       |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| Parental Education - Degree | 1697 (53.0) | 1741 (52.9) | 3.0    | 0.386  | 6.3    | 0.017  | 1.4    | <0.001 | 0.6    | 0.137 |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| A-Level or equivalent | 658 (20.5)  | 674 (20.5)  | 3.5    | 7.3    | 2.3    | 1.3    |        |        |         |       |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| GSCE or equivalent | 759 (23.7)  | 783 (23.8)  | 4.3    | 9.3    | 3.9    | 1.4    |        |        |         |       |         |                  |          |                |                  |               |                        |                   |             |                     |                    |                  |
| Qualification                  | No Qualifications | Qualifications | Manage Professional | Interim | Routine | Not employed | Highest Income Quartile | 2nd Quartile | 3rd Quartile | Lowest Income Quartile |
|-------------------------------|-------------------|----------------|---------------------|---------|---------|--------------|-------------------------|--------------|--------------|------------------------|
|                               | 90 (2.8)          | 93 (2.8)       | 1282 (41.1)         | 461 (14.8) | 510 (16.4) | 865 (27.7)   | 463 (14.3)               | 836 (25.8)  | 1079 (33.3) | 865 (26.7)            |
|                               |                   |                | 3.3                 | 1345 (40.9) | 490 (14.9) | 920 (28.0)   | 48 (1.5)                 | 851 (25.9)  | 1094 (33.2) | 874 (26.6)            |
|                               |                   |                | 12.7                | 1.8      | 4.4      | 5.7           | 1.9                     | 2.1         | 3.5          | 5.5                    |
|                               |                   |                | 4.5                 | < 0.001  | 7.3      | 8.2           | < 0.001                | 6.8         | 6.0          | 10.7                  |
|                               |                   |                | 0.2                 | 0.118    | 2.5      | 2.0           | 1.4                     | 2.0         | 1.4          | 4.2                    |
|                               |                   |                |                     |          | 0.006    |               | < 0.001                | 0.3         | 0.7          | 1.9                    |
|                               |                   |                |                     |          |          |               |                         |             |              |                        |
|                               |                   |                |                     |          |          |               |                         |             |              |                        |
|                               |                   |                |                     |          |          |               |                         |             |              |                        |
|                               |                   |                |                     |          |          |               |                         |             |              |                        |

Adolescents who had reported smoking in previous waves of the survey were excluded here (n = 216), so percentages indicate the proportion of those who had never smoked before who initiated smoking in this wave of the survey.

[Table 1 about here]

Measures

Youth and parents self-reported vaping in response to the question: “Do you ever use electronic cigarettes (e-cigarettes)?” (Yes/No). The present tense “Do you” wording should primarily identify current vaping, though the wording is a little ambiguous and may feasibly have been interpreted by some respondents as “Have you ever used electronic cigarettes?” Our measures of vaping could therefore include both very infrequent and/or ever use in addition to current vaping. Although this was the first time respondents were asked about vaping, smoking was self-reported by youth and parents in this and in earlier waves of the survey. Youth smoking was coded in three binary outcomes: ever, current and initiation (with the latter defined as current smokers who started smoking in the year since the previous survey, i.e. with no indication of smoking from earlier waves). Parental smoking (never, ex, current) and vaping (yes/no) were coded according to the highest level of use from either parent.
Socioeconomic position (SEP) was measured at the household level (taking the more advantaged responses from couple parents) based on highest educational level (degree or higher, A-Level or equivalent, GCSE or equivalent, or no qualifications), occupational status using NS-SEC codes (managerial or professional, intermediate, routine, or not employed), and household income, equivalised for household composition and split into quartiles. For ease of presentation, SEP measures were treated as ordinal when assessing confounder balance. Indicators of gender (male vs female), ethnicity (White UK vs ethnic minority), family structure (couple vs single parents), UK country (England, Wales, Scotland, and Northern Ireland) and interview date to account for temporal trends in smoking and vaping during fieldwork were also included, with youth age (in years) as a continuous variable.

Statistical analyses

We estimated the ATEs and ATTs using a propensity weighting procedure, which is designed to balance measured confounders across the main exposure groups, i.e. youth who did and did not vape, and youth with parents who did and did not vape [36, 39]. This involves first running logistic regression models to predict each exposure, based on measured confounders (identified a priori). Gender, age, ethnicity, family structure, household SEP, UK country and interview date were treated as potential confounders throughout, as was parental smoking (except when stratifying on this variable). For estimating effects of youth vaping, parental vaping was included as an additional confounder.

The predicted probability of each individual’s observed exposure status can then be used to calculate weights designed to help estimate ATEs and ATTs. Table 2 details these calculations. ATE weights re-weight both exposed and unexposed respondents to resemble the total sample (with regards to measured confounders), while ATT weights re-weight the
unexposed respondents to resemble the exposed group. Prior to using these weights to estimate effects, validity of the weights was assessed by examining mean differences in confounders associated with the relevant exposure [39]. Weights were deemed valid if confounder differences, expressed in standard deviation units, were reduced close to zero (with differences < 0.2 considered close to 0). Models predicting exposure probability initially used main effects of confounders only, but where imbalance remained the model was revised by adding interactions terms and then re-assessed. Improvements in confounder balance from model revisions were balanced against sufficient overlap of propensity distributions between exposed and unexposed groups by confirming that mean ATE weights were close to 1 [39, 40] (the same is not expected of mean ATT weights). Deviations from this would suggest that some individuals were being assigned extreme weights, indicating risk of making inferences not strongly supported by the available data.

Exposure effects were estimated in ATE- and ATT-weighted logistic regressions of each outcome on the exposure of interest. For comparison, we also present associations weighted for sample selection only (labelled “sample weighted associations”). Standard
errors were adjusted for clustering of youth within households. Z-tests were used to compare differences in effect estimates between strata of parental smoking and between ATEs and ATTs [41].

Analyses of smoking initiation excluded 216 youth who had reported ever smoking in previous survey waves. These prior smokers were older, more likely to be vaping and to have single parents. Since this could introduce selection bias, these differences were reduced by additional weighting back to the total sample for analyses of initiation.

It is important to emphasise that the resultant effect estimates may not necessarily reflect the true effects of interest. For example, while our method aims to balance measured confounders between exposure groups, our effect estimates may still be biased by unmeasured confounders. For this reason, we calculate e-values for each point estimate and for the lower limit of the confidence interval [42]. E-values represent the minimum strength of association (OR in our analysis) that a set of unmeasured confounders would need to have with both the outcome and exposure of interest (independent of measured confounders), in order to explain away the association, or cause its lower confidence interval to include the null (if it already includes the null the e-value for the lower limit will be 1). We also include e-values for the sample-weighted associations, to indicate how much these were reduced by the adjustments made for measured confounders.

Results

Sociodemographic patterning of youth vaping and youth smoking are shown in Table 1. There were strong associations between youth vaping and youth smoking for all smoking measures. Youth whose parents vaped were more likely to vape and smoke themselves.

Youth vaping and youth smoking

Mean ATE weights were close to 1 (0.999) indicating stability. Figure 1 shows standardised mean differences in confounders associated with youth vaping before and after propensity
weighting. Youth who vaped were more likely to be male, older, come from disadvantaged or single-parent households, and have vaping parents. Propensity weighting attenuated these differences to below the 0.2 standard deviation threshold, indicating successful balancing of confounder characteristics across exposure groups. Similar confounder balance was achieved among the sub-sample of youth who had not smoked before (results not shown).

Table 3 shows estimates of effects of youth vaping on youth smoking. Associations between youth vaping and ever smoking were attenuated by around two thirds when weighting for confounder differences to estimate both the ATE and the ATT. Estimates of ATEs for youth vaping on current smoking and smoking initiation were attenuated by 40% and 26% respectively relative to the sample-weighted associations. ATT estimates were attenuated by 74% and 92%. While confidence intervals for ATE and ATT estimates overlapped, the ATT estimate for smoking initiation was considerably weaker than the ATE estimate (p = 0.087) and its confidence intervals overlapped the null. The e-values for the lower confidence interval limits indicate that a set of unmeasured confounders would need to be associated with both smoking and vaping with ORs in excess of 9, independently of our measured confounders, to negate most of these effect estimates (the ATT effect estimate for initiation being the exception). Greater unmeasured confounding influences would be needed to negate the ATE estimates for current smoking and initiation than for the ATT estimates for these measures.
Estimates of effects of youth vaping on youth smoking

|                                | OR     | 95% CI       | E-Value for OR | E-Value for lower limit |
|--------------------------------|--------|--------------|----------------|-------------------------|
| Ever Smoked (n = 3291)         |        |              |                |                         |
| Sample weighted association    | 29.78  | 17.89–49.58  | 59.06          | 35.27                   |
| Sample average effect (ATE)    | 12.03  | 5.16–28.04   | 23.55          | 9.79                    |
| Average effect among youth who did vape (ATT) | 10.54  | 5.99–18.53   | 20.57          | 11.46                   |
| Current Smoking (n = 3291)     |        |              |                |                         |
| Sample weighted association    | 37.26  | 19.78–70.18  | 74.02          | 39.05                   |
| Sample average effect (ATE)    | 22.71  | 8.99–57.40   | 44.91          | 17.47                   |
| Average effect among youth who did vape (ATT) | 10.49  | 5.04–21.82   | 20.47          | 9.55                    |
| Smoking Initiation (n = 3075)  |        |              |                |                         |
| Sample weighted association    | 43.34  | 15.04–124.89 | 86.18          | 29.57                   |
| Sample average effect (ATE)    | 32.46  | 9.84–107.09  | 64.42          | 19.17                   |
| Average effect among youth who did vape (ATT) | 4.38   | 0.62–30.94   | 8.23           | 1.00                    |

ATE compares outcomes between a hypothetical scenario where no youth vape against one where all youth vape. ATT compares outcomes between a hypothetical scenario where no youth vape against one with actual observed youth vaping.

The e-value for the OR indicates the minimum strength of association (OR) that an unmeasured confounder would need to have with both youth vaping and youth smoking to reduce this estimate to the null. The e-value for the lower limit indicates the minimum strength of association that an unmeasured confounder would need to have with both youth vaping and youth smoking for the lower limit of the confidence intervals around this estimate to cross the null (all confounders are unmeasured for the sample weighted associations).

Parental vaping and youth smoking and vaping

There were only 12 cases of youth whose parents vaped but had never smoked. This was considered insufficient information to estimate effects of parental vaping among youth whose parents never smoked, so we present results for: all youth combined; youth with ex-smoking parents; and youth with currently smoking parents. Mean ATE weights for parental vaping were close to 1 (1.001) indicating stability. Figure 2 shows standardised mean differences in confounders associated with parental vaping for each of these groups.

Parental vaping was associated: with more parental current and less parental ex-smoking,
and with socioeconomic disadvantage and ethnic majority status among all youth (Fig. 2a); with ethnic majority status and socioeconomic disadvantage among youth with ex-smoking parents (Fig. 2b); and with ethnic majority status and having couple parents among youth with currently smoking parents (Fig. 2c). Propensity weights successfully balanced measured confounders, with the exception of a small residual bias in interview date among all youth such that youth whose parents vaped tended to be interviewed later. Similar balance was achieved for youth who had not smoked before (results not shown).

Table 4 displays estimated effects of parental vaping on youth smoking and vaping. Regarding all youth, parental vaping only showed a clear sample weighted association with ever smoking. This was not fully explained by measured confounders in the ATE/ATT estimates. ATE and ATT estimates of the effect of parental vaping on smoking initiation were stronger than the sample weighted association, with the ATT indicating a clear effect. Nevertheless, the e-values suggested that a relatively small degree of unmeasured confounding could explain these effect estimates.

| Table 4 | Estimates of effects of parental vaping on youth smoking vaping |
|---------|---------------------------------------------------------------|
| All Youth | Ex-Smoking Parents | Current Smoking Parents |
| OR | 95% CI | E-Value for OR | OR | 95% CI | E-Value for OR | OR | 95% CI | E-Value for OR |
| Youth Ever Smoking | | | | | | | | |
| Sample weighted association | | | | | | | | |
| 1.93 | 1.25–2.98 | 3.27 | 1.81 | 2.07 | 0.95–4.50 | 3.56 | 1.00 | 1.36 | 0.74–2.51 | 2.06 | 1.00 | 0.407 |
| Sample average effect (ATE) | | | | | | | | |
| 2.43 | 1.05–5.63 | 4.29 | 1.28 | 1.92 | 0.89–4.15 | 3.25 | 1.00 | 1.37 | 0.73–2.56 | 2.08 | 1.00 | 0.505 |
| Average effect among youth whose parents vaped | | | | | | | | |
| 1.68 | 1.03–2.72 | 2.75 | 1.21 | 1.84 | 0.81–4.16 | 3.08 | 1.00 | 1.51 | 0.80–2.82 | 2.39 | 1.00 | 0.702 |
|                  | N=3291 | N=1300 | N=817 |
|------------------|--------|--------|-------|
| **Youth Current Smoking** |        |        |       |
| Sample weighted association | 1.99   | 0.96-4.10 | 3.39   |
| Sample average effect (ATE)   | 1.61   | 0.62-4.20 | 2.60   |
| **Average effect among youth whose parents did vape (ATT)** | 1.27   | 0.58-2.81 | 1.86   |
| Sample weighted association |        |        |       |
| Sample average effect (ATE)   |        |        |       |
| **Youth Smoking Initiation** |        |        |       |
| Sample weighted association | 3.11   | 0.94-10.31 | 5.67   |
| Sample average effect (ATE)   | 3.50   | 0.81-15.03 | 6.46   |
| **Average effect among youth whose parents did vape (ATT)** | 3.76   | 1.27-11.19 | 6.98   |
| Sample weighted association |        |        |       |
| Sample average effect (ATE)   |        |        |       |
| **Youth Vaping** |        |        |       |
| Sample weighted association | 1.85   | 0.97-3.53 | 3.10   |
| Sample average effect (ATE)   | 1.34   | 0.58-3.09 | 2.01   |
| **Average effect among youth** | 1.48   | 0.72-3.04 | 2.32   |
Among youth with ex-smoking parents (i.e. comparing youth with ex-smoking parents who vaped, against those with ex-smoking parents who did not vape), parental vaping was associated with youth current smoking, youth smoking initiation and youth vaping. For current smoking and initiation, ATE estimates were slightly stronger than the sample weighted associations but were attenuated by 41% for youth vaping. ATT estimates were attenuated by 33-41% relative to the sample-weighted associations, but still indicated a clear effect on smoking initiation. Again, the e-values indicated that relatively little unmeasured confounding would be required to explain these effects. Among youth with current smoking parents none of the estimates indicated much evidence for relationships with parental vaping.

[Table 4 about here]

Discussion

We found cross-sectional associations between vaping and smoking among youth, and some associations between parental vaping and youth smoking and youth vaping. Our analyses suggested that confounding was a major contributor to these associations, though associations between youth vaping and youth smoking remained after adjustment for observed confounders. Our effect estimates indicated risk of youth vaping increasing youth smoking, especially if youth adopted vaping more widely, but there was little evidence overall to suggest that current levels of parental vaping are increasing risk for
youth smoking or vaping.

We used a rigorous propensity weighting procedure to estimate effects of youth vaping on youth smoking after balancing measured confounders (i.e. parental smoking and vaping, gender, age, ethnicity, family structure, household SEP, UK country and interview date) between youth who did and did not vape. Our estimates suggested that common liabilities related to these measured confounders explained considerable proportions of the close association between youth vaping and smoking. Nevertheless, unmeasured confounders (e.g. beliefs, values and personality) would need to have quite strong independent associations (ORs generally of magnitude 9 or more) with both smoking and vaping to explain the residual relationship. Unmeasured confounding of this magnitude is theoretically possible though unlikely in the form of a single strong confounding factor, but could be feasible as an aggregate effect from a set of weaker confounders [42].

We estimated the effect of youth vaping on youth smoking (as the most concerning direction of effect), but it is important to emphasise that our data were cross-sectional, and our effect estimates could be either partially or completely accounted for by effects of youth smoking on youth vaping (i.e. reverse causation, e.g. youth using e-cigarettes as a smoking cessation aid) [19], especially as others have shown longitudinal effects in both directions [32]. This would include our measure of smoking initiation as initiation within the past year could have led to vaping. However, reverse causation is less likely for the initiation estimates than for those relating to current smoking, as youth who have been smoking for longer would be excluded. Additionally, questions on vaping did not distinguish between different types of e-cigarette/vaping devices, different frequencies of, or motivations for vaping [10, 43], and our estimates may have changed if these factors could have been taken into account. Also, our data were focused on youth in the age range of 10-15 years and associations and effects could differ among older youth, as they
increasingly adopt more adult behaviours.

Our findings align with others showing strong associations between youth smoking and vaping [2, 9, 17, 19, 22–27, 31, 32, 44]. We were able to explain much of this association with a relatively limited set of measured confounders and the residual effect estimates could be at least partially explained by unmeasured confounding and/or reverse causation. Taken together with other evidence such as observed increases in youth smoking after implementation of e-cigarette sale restrictions [45–47] and continued declines in youth pro-smoking attitudes while youth vaping has been rising [48], it seems that even if there is an effect whereby vaping increases risk for smoking, it may not be the primary or dominant explanation for these associations.

What is most novel in our findings is the suggestion of differential relationships between smoking and vaping in youth. We estimated the expected differences in youth smoking outcomes comparing no youth vaping to both all youth vaping (ATEs) and to actual observed levels of youth vaping (ATTs). The latter set of estimates suggested weaker effects that would be more easily explained by unmeasured confounding, especially for initiation of smoking. This suggests that any effect of vaping on smoking may be weaker for youth already pre-disposed to vaping by background factors. This is consistent with another study that found stronger effects of vaping among youth with no intention to smoke [33]. Thus, effects of vaping on smoking could become more salient and important if vaping were adopted much more widely and by a broader range of youth, as opposed to the current low prevalence. Governments may want to prioritise preventing wider adoption, e.g. with e-cigarette age-of-sale and advertising restrictions (actions that many public health actors agree on [49]), over changing or stopping current youth vaping behaviour.

Perhaps propensities for vaping and smoking are similar enough that vaping has little
additional impact where propensity for smoking is already high. Indeed, one theoretical explanation for why young people may transition from vaping to smoking is that vaping provides experience and training in the social performance of a similar behaviour, which might otherwise be unfamiliar [20]. Such first-hand experience could come from infrequent or even singular experiences with vaping and could plausibly be more important for young people without a background predisposition to use, who may have less experience of seeing others smoke or vape. Mechanisms for why young people would begin vaping before smoking include e-cigarettes being viewed as less harmful, more acceptable, having attractive flavours, and being easier to conceal [20]; these mechanisms could also be more salient for those without a background propensity for use.

We found no support for our postulation that the effects of parental vaping would be weaker or reversed when parents had completely switched from cigarettes to e-cigarettes, compared to parents using both. Contrarily, parental vaping was most strongly associated with youth smoking and vaping among youth whose parents were ex-smokers, with little evidence of associations with parental vaping among those whose parents currently smoked. Perhaps risk for smoking among youth with currently smoking parents is high enough that parental vaping has little further influence. The relatively weak associations we found with parental vaping among all youth and those with ex-smoking parents were not all explained by measured confounders, but could have easily been explained by a relatively small degree of unmeasured confounding (e.g. ex-smoking parents who do and do not vape may have different smoking histories), and/or by reverse causation (e.g. if youth introduce their parents to e-cigarette devices). Thus, while further monitoring and research may be advisable, there appears little evidence here to support concerns about negative impacts on children where smoking parents using e-cigarettes as cessation aids.

Conclusions
Associations between youth smoking and vaping were attenuated substantially with adjustment for measured confounders, indicating support for common liabilities, but a relatively high degree of unmeasured confounding would be required to completely explain the association. Estimates of effects of youth vaping on youth smoking appeared weaker and among youth already predisposed to vaping. There was some evidence for effects of parental vaping on youth smoking and vaping, particularly among youth whose parents were ex- rather than current smokers, though unmeasured confounding could easily explain these associations. It may be important to prevent wide-scale adoption of vaping by youth, but evidence for negative impacts of parental vaping on youth was weak.

Declarations

**Ethics approval and consent to participate**

The University of Essex Ethics Committee has approved all data collection on the Understanding Society main study and innovation panel waves. All participants gave verbal informed consent, and consent was also obtained from parents/guardians for respondents under 16 years of age.

**Consent for publication**

Not applicable

**Availability of data and materials**

The datasets analysed during the current study are available from the UK Data Service repository:

https://beta.ukdataservice.ac.uk/datacatalogue/studies/study?id=6614

DOI: 10.5255/UKDA-SN-6614-12.

**Competing Interests**

The authors declare that they have no competing interests.

**Funding**
MG, LG and HS are funded by the Medical Research Council (MC_UU_12017/12 & MC_UU_12017/13) and the Scottish Government Chief Scientist Office (SPHSU12 & SPHSU13). These funding bodies had no role in the design, analysis or interpretation of the study, or in writing the manuscript. Understanding Society is an initiative funded by the Economic and Social Research Council and various Government Departments, with scientific leadership by the Institute for Social and Economic Research, University of Essex, and survey delivery by NatCen Social Research and Kantar Public. The research data are distributed by the UK Data Service (SN 6614).

Authors’ Contributions

MG conceived and designed the study, carried out the analysis, and drafted the manuscript. LG and HS both contributed to the interpretation of data and substantive revisions of the manuscript. All authors have read and approved the submitted version of the manuscript.

Acknowledgements

Not applicable.

References

1. McNeill A, Brose LS, Calder R, Hitchman SC, Hajek P, McRobbie H: E-Cigarettes: an evidence update. London: Public Health England; 2015.

2. Chapman CS, Wu L: E-cigarette prevalence and correlates of use among adolescents versus adults: a review and comparison. J Psychiatr Res 2014, 54:43-54.

3. McNeill A, Brose LS, Calder R, Bauld L, Robson D: Evidence review of e-cigarettes and heated tobacco products 2018. London: Public Health England; 2018.

4. McNeill A, Brose LS, Calder R, Bauld L, Robson D: Vaping in England, an evidence
update, February 2019. A report commissioned by Public Health England. In. London: Public Health England; 2019.

5. Abrams DB, Glasser AM, Pearson JL, Villanti AC, Collins LK, Niaura RS: Harm Minimization and Tobacco Control: Reframing Societal Views of Nicotine Use to Rapidly Save Lives. *Annual Review of Public Health* 2018, **39**:14.11-14.21.

6. Hajek P, Etter J-F, Benowitz N, Eissenberg T, McRobbie H: Electronic cigarettes: review of use, content, safety, effects on smokers and potential for harm and benefit. *Addiction* 2014, **109**(11):1801-1810.

7. Shahab L, Goniewicz ML, Blount BC, et al.: Nicotine, carcinogen, and toxin exposure in long-term e-cigarette and nicotine replacement therapy users: A cross-sectional study. *Annals of Internal Medicine* 2017, **166**(6):390-400.

8. Stephens WE: Comparing the cancer potencies of emissions from vapourised nicotine products including e-cigarettes with those of tobacco smoke. *Tobacco Control* 2018, **27**:10-17.

9. National Academies of Sciences Engineering & Medicine: *Public Health Consequences of E-Cigarettes*. Washington, DC: The National Academies Press; 2018.

10. Villanti AC, Feirman SP, Niaura RS, Pearson JL, Glasser AM, Collins LK, Abrams DB: How do we determine the impact of e-cigarettes on cigarette smoking cessation or reduction? Review and recommendations for answering the research question with scientific rigor. *Addiction* 2018, **113**(3):391-404.

11. Beard E, West R, Michie S, Brown J: Association between electronic cigarette use and changes in quit attempts, success of quit attempts, use of smoking cessation pharmacotherapy, and use of stop smoking services in England: time series analysis of population trends. *BMJ* 2016, **354**.
12. Benmarhnia T, Pierce JP, Leas E, White MM, Strong DR, Noble ML, Trinidad DR: Can E-Cigarettes and Pharmaceutical Aids Increase Smoking Cessation and Reduce Cigarette Consumption? Findings From a Nationally Representative Cohort of American Smokers. *American Journal of Epidemiology* 2018:kwy129-kwy129.

13. Li J, Hajek P, Pesola F, Wu Q, Phillips-Waller A, Przulj D, Myers Smith K, Bisal N, Sasieni P, Dawkins L et al: Cost-effectiveness of e-cigarettes compared with nicotine replacement therapy in stop smoking services in England (TEC study): a randomized controlled trial. In: *Addiction*. 2019.

14. Hilton S, Weishaar H, Sweeting H, Trevisan F, Katikireddi SV: E-cigarettes, a safer alternative for teenagers? A UK focus group study of teenagers' views. *BMJ Open* 2016, 6:e013271.

15. Eissenberg T, Bhatnagar A, Chapman S, Jordt S-E, Shihadeh A, Soule EK: Invalidity of an Oft-Cited Estimate of the Relative Harms of Electronic Cigarettes. *American Journal of Public Health* 2020, 110(2):161-162.

16. Grana RA: Electronic Cigarettes: A New Nicotine Gateway? *Journal of Adolescent Health* 2013, 52(2):135-136.

17. Leventhal AM, Strong DR, Kirkpatrick MG, Unger JB, Sussman S, Riggs NR, Stone MD, Khoddam R, Samet JM, Audrain-McGovern J: Association of electronic cigarette use with initiation of combustible tobacco product smoking in early adolescence. *JAMA* 2015, 314(7):700-707.

18. Bell K, Keane H: All gates lead to smoking: The ‘gateway theory’, e-cigarettes and the remaking of nicotine. *Social Science & Medicine* 2014, 119:45-52.

19. Etter J-F: Gateway effects and electronic cigarettes. *Addiction* 2018, 113(10):1776-1783.

20. Schneider S, Diehl K: Vaping as a Catalyst for Smoking? An Initial Model on the
Initiation of Electronic Cigarette Use and the Transition to Tobacco Smoking Among Adolescents. *Nicotine & Tobacco Research* 2016, **18**(5):647-653.

21. Kandel ER, Kandel DB: *A Molecular Basis for Nicotine as a Gateway Drug*. *New England Journal of Medicine* 2014, **371**:932-943.

22. Dutra LM, Glantz SA: *Electronic Cigarettes and Conventional Cigarette Use Among US Adolescents: A Cross-sectional Study*. *JAMA Pediatrics* 2014, **168**(7):610-617.

23. Hughes K, Bellis MA, Hardcastle KA, McHale P, Bennet A, Ireland R, Pike K: *Associations between e-cigarette access and smoking and drinking behaviours in teenagers*. *BMC Public Health* 2015, **15**:244.

24. Scottish Government: *Scottish Schools Adolescent Lifestyle and Substance Use Survey (SALSUS) 2015: Six key facts about e-cigarette use*. In.; 2017.

25. Krishnan-Sarin S, Morean ME, Camenga DR, Cavallo DA, Kong G: *E-cigarette Use Among High School and Middle School Adolescents in Connecticut*. *Nicotine & Tobacco Research* 2015, **17**(7):810-818.

26. Treur JL, Rozema AD, Mathijssen JJ, van Oers H, Vink JM: *E-cigarette and waterpipe use in two adolescent cohorts: cross-sectional and longitudinal associations with conventional cigarette smoking*. *European Journal of Epidemiology* 2018, **33**:323-334.

27. Green MJ, Hilton S: *Applying recommended evidence standards to understand the impact of e-cigarettes on youth smoking and reporting of weak scientific evidence*. *Addiction* 2018, **113**(3):405-406.

28. Leventhal AM, Stone MD, Andrabi N, et al.: *Association of e-cigarette vaping and progression to heavier patterns of cigarette smoking*. *JAMA* 2016, **316**(18):1918-1920.
29. Conner M, Grogan S, Simms-Ellis R, Flett K, Sykes-Muskett B, Cowap L, Lawton R, Armitage CJ, Meads D, Torgerson C et al: **Do electronic cigarettes increase cigarette smoking in UK adolescents? Evidence from a 12-month prospective study.** *Tobacco Control* 2018, **27**(4):365-372.

30. Best C, Haseen F, Currie D, Ozakinci G, MacKintosh AM, Stead M, Eadie D, MacGregor A, Pearce J, Amos A et al: **Relationship between trying an electronic cigarette and subsequent cigarette experimentation in Scottish adolescents: a cohort study.** *Tobacco Control* 2018, **27**(4):373-378.

31. Soneji S, Barrington-Trimis JL, Wills TA, Leventhal AM, Unger JB, Gibson LA, Yang J, Primack BA, Andrews JA, Miech RA et al: **Association Between Initial Use of e-Cigarettes and Subsequent Cigarette Smoking Among Adolescents and Young Adults: A Systematic Review and Meta-analysis.** *JAMA Pediatrics* 2017, **171**(8):788-797.

32. East K, Hitchman SC, Bakolis I, Williams S, Cheeseman H, Arnott D, McNeill A: **The Association Between Smoking and Electronic Cigarette Use in a Cohort of Young People.** *Journal of Adolescent Health* 2018, **62**(5):539-547.

33. Barrington-Trimis JL, Urman R, Berhane K, Unger JB, Cruz TB, Pentz MA, Samet JM, Leventhal AM, McConnell R: **E-Cigarettes and Future Cigarette Use.** *Pediatrics* 2016, **138**(1).

34. Tyas SL, Pederson LL: **Psychosocial factors related to adolescent smoking: a critical review of the literature.** *Tobacco Control* 1998, **7**(4):409-420.

35. Lozano P, Arillo-Santillán E, Barrientos-Gutierrez I, Reynales Shigematsu LM, Thrasher JF: **E-Cigarette Social Norms and Risk Perceptions Among Susceptible Adolescents in a Country That Bans E-Cigarettes.** *Health Educ Behav* 2019, **46**(2):275-285.
36. Austin PC: *An Introduction to Propensity Score Methods for Reducing the Effects of Confounding in Observational Studies*. *Multivariate Behavioral Research* 2011, **46**(3):399-424.

37. Knies G: *Understanding Society: Waves 1-7, 2009-2016 and harmonised BHPS: Waves 1-18, 1991-2009, User Guide*. In. Colchester: University of Essex; 2017.

38. Seaman SR, White IR, Copas AJ, Li L: *Combining Multiple Imputation and Inverse-Probability Weighting*. *Biometrics* 2012, **68**:129-137.

39. Austin PC, Stuart EA: *Moving towards best practice when using inverse probability of treatment weighting (IPTW) using the propensity score to estimate causal treatment effects in observational studies*. *Statistics in Medicine* 2015, **34**:3661-3679.

40. Cole SR, Hernán MA: *Constructing Inverse Probability Weights for Marginal Structural Models*. *American Journal of Epidemiology* 2008, **168**(6):656-664.

41. Clogg CC, Petkova E, Haritou A: *Statistical methods for comparing regression coefficients between models*. *American Journal of Sociology* 1995, **100**:1261-1293.

42. VanderWeele TJ, Ding P: *Sensitivity Analysis in Observational Research: Introducing the E-Value*. *Annals of Internal Medicine* 2017, **167**(4):268-274.

43. Hitchman SC, Brose LS, Brown J, Robson D, McNeill A: *Associations Between E-Cigarette Type, Frequency of Use, and Quitting Smoking: Findings From a Longitudinal Online Panel Survey in Great Britain*. *Nicotine & Tobacco Research* 2015, **17**(10):1187-1194.

44. Park J-Y, Seo D-C, Lin H-C: *E-Cigarette Use and Intention to Initiate or Quit Smoking Among US Youths*. *American Journal of Public Health* 2016, **106**(4):672-678.

45. Friedman AS: *How does electronic cigarette access affect adolescent*
smoking? Journal of Health Economics 2015, 44:300-308.

46. Pesko MF, Currie JM: The Effect of E-Cigarette Minimum Legal Sale Age Laws on Traditional Cigarette Use and Birth Outcomes among Pregnant Teenagers. In: National Bureau of Economic Research Working Paper Series. 2016.

47. Dhaval D, Bo F, Pesko MF: The Effects of E-Cigarette Minimum Legal Sale Age Laws on Youth Substance Use. In: National Bureau of Economic Research Working Paper Series. 2017.

48. Hallingberg B, Maynard O, Bauld L, Brown R, Gray L, Lowthian E, MacKintosh A, Moore L, Munafò M, Moore G: Have e-cigarettes renormalised or displaced youth smoking? Results of a segmented regression analysis of repeated cross sectional survey data in England, Scotland and Wales. Tobacco Control In Press.

49. Weishaar H, Ikegwuonu T, Smith KE, Buckton CH, Hilton S: E-Cigarettes: A Disruptive Technology? An Analysis of Health Actors’ Positions on E-Cigarette Regulation in Scotland. International Journal of Environmental Research and Public Health 2019, 16(17):3103.

Figures
Figure 1

Standardised Mean Differences in Confounders Associated with Youth Vaping. The shaded band indicates the area we considered close to zero.
Figure 2
Standardised Mean Differences in Confounders Associated with Parental Vaping

The shaded bands indicate the area we considered close to zero.