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RESEARCH REPORT

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The association between objectively measured exposure to tobacco outlets and smoking cognitions: a study among non-smoking adolescents in four Dutch cities

Tessa R. D. van Deelen[1] | Gabriëlle de Vet[1] | Anne Zijp[1] | Bas van den Putte[2] | Anton E. Kunst[1] | MirteA. G. Kuipers[1]

[1]Public and Occupational Health, Amsterdam UMC location University of Amsterdam, Amsterdam, Netherlands

[2]Amsterdam School of Communication Research, University of Amsterdam, Amsterdam, Netherlands

Correspondence
Tessa R. D. van Deelen, Public and Occupational Health, Amsterdam UMC location University of Amsterdam, Meibergdreef 9, Amsterdam, 1105 AZ, Netherlands.
Email: t.r.d.vandeelen@amsterdamumc.nl

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Abstract

Aims: Exposure to tobacco products and advertising at the point of sale may be associated with pro-smoking cognitions. However, previous studies on this topic measured exposure based on self-report and did not include European countries. The aim of this study was to assess the association between objectively measured exposure to tobacco outlets and non-smoking adolescents' smoking attitudes, beliefs and norms.

Design: This cross-sectional study combined survey data with Global Positioning Systems data using geographic information system.

Setting: The four Dutch cities of Amsterdam, Eindhoven, Haarlem and Zwolle.

Participants: We retrieved data of 308 13 to 17-year-old non-smoking adolescents, mainly girls (61%), adolescents attending pre-university secondary education (71%) and without smoking friends (58%).

Measurements: Exposure was measured with a smartphone app registering for 2 weeks how often participants were within 10 m of a tobacco outlet. We distinguished between outlets without visible tobacco promotion (i.e. supermarkets), with only internal visibility and with both internal and external visibility. Participants' reported smoking cognitions were dichotomised into pro-smoking or anti-smoking. We applied multi-level logistic regression analyses and adjusted for age, sex, educational level and smoking friends.

Findings: On average, adolescents were exposed to 1.18 (SD = 1.23) tobacco outlets per day. Higher exposure to tobacco outlets was associated with higher odds of pro-smoking injunctive norm (OR = 1.35, 95% CI = 1.04–1.75). Associations with attitude (OR = 1.12, 95% CI = 0.91–1.38), social beliefs (OR = 1.15, 95% CI = 0.93–1.43), health beliefs (OR = 1.18, 95% CI = 0.97–1.44) and descriptive norm (OR = 1.15, 95% CI = 0.91–1.44) were also positive, but non-significant. Overall, associations were strongest for outlets with internal visibility, for instance, for injunctive norm (OR = 1.37, 95% CI = 1.03–1.81).

Conclusions: Global Positioning Systems-measured exposure to tobacco outlets was associated with pro-smoking cognitions among non-smoking adolescents in the Netherlands.

KEYWORDS
Adolescents, attitude, beliefs, exposure, Global Positioning Systems (GPS), norms, smoking cognitions, tobacco outlet, tobacco promotion

INTRODUCTION

The tobacco retail environment plays an important role in adolescent smoking behaviour. An experimental study in the United States [1] suggested that adolescents' exposure to tobacco products and advertising at the point of sale (POS) increases the popularity of tobacco products among them. A similar experimental study in Australia [2] concluded that exposure may weaken adolescents' intentions not to smoke. Using self-reports of exposure to tobacco POS, a longitudinal study in the United States (US) found an increased risk of smoking initiation with higher exposure levels among adolescents [3]. Other studies based on self-report showed increased smoking susceptibility among young people in the United States [4–6] and the United Kingdom (UK) [7] who reported higher exposure. The odds of smoking are even doubled for daily exposure compared to weekly [8].

Several cognitive mechanisms may mediate these observed associations. Adolescents' exposure to tobacco POS is associated with increased perceived accessibility of tobacco [1, 2] and tobacco brand recognition [8], which increase smoking susceptibility. In addition, the wide visibility of tobacco retail outlets may contribute to the perception of tobacco being a normal product [9]. Previous studies among adolescents found that exposure to tobacco outlets was associated with pro-smoking cognitions, such as attitudes (personal opinion about smoking), beliefs (conception that smoking leads to a particular social/health outcome) [2, 10] and norms (what others do and think) [1, 2]. In turn, pro-smoking cognitions may precede smoking initiation [11–14]. Most studies did not explicitly focus on non-smoking adolescents, whereas the pro-smoking cognitions among adolescents who do smoke may be partially because of them visiting tobacco POS, to access tobacco, or better recall of seeing/visiting tobacco outlets.

A limitation of previous studies is that they did not use objective real-life measurements of exposure to the POS. They instead used self-reports [10], which are likely to suffer from reporting and recall bias, or used experimental settings, whose results may not be generalizable to the real world [1, 2]. Up to now, only one American [15] and one European study [16] have measured exposure to tobacco outlets objectively, with Global Positioning System (GPS) data. Although the US study examined an association with cigar use, the European study only mapped exposure to POS, but not the association with smoking cognitions. New evidence on the association between exposure to tobacco outlets and smoking cognitions can be obtained by using objective individual-level exposure measures.

Previous studies have not been able to distinguish between exposures to tobacco outlets with different levels of visibility: inside the outlet, outside or both. The extent to which tobacco products and advertising are visible may influence the impact of tobacco outlet exposure on smoking-related outcomes. Several European countries have implemented POS policies to reduce the visibility of tobacco displays or to reduce the number of tobacco outlets [17, 18]. At the time of this study's data collection (autumn 2020), a tobacco product display was implemented in the Netherlands in supermarkets (since July 2020). However, for all other tobacco outlets, the ban was partially implemented, leaving tobacco product displays and advertising visible inside and outside the tobacco outlet.

The aim of this study was to assess to what extent objectively measured exposure to tobacco outlets and tobacco product promotion at the POS was associated with pro-smoking cognitions among non-smoking adolescents in four Dutch cities. We assessed relationships with attitudes, beliefs (social and health beliefs) and norms (descriptive and injunctive norms). We distinguished between tobacco outlets with different levels of visibility of tobacco products and advertisements.

METHODS

Design

For this study, cross-sectional data was used from the 'Tobacco out of Sight' project. We used both exposure data and survey data from students recruited through 15 secondary schools in four cities in the Netherlands (Amsterdam, Eindhoven, Haarlem and Zwolle). Both exposure and survey data were collected between October 2020 and December 2020.

All 105 schools in the four cities were included in the recruitment process and were contacted multiple times via email and phone to participate in the study. Ultimately, 16 schools agreed to send out our invitation and information letter to students ages 13 to 17 and separate documents to parents of students under 16 years old. Adolescents from 15 schools registered via our open-access website and parents gave permission via a secured page on our website [19].

Ethical considerations

The Medical Ethics Review Committee of the Academic Medical Centre concluded that this study is not subject to the Medical Research Involving Human Subjects Act (reference number: W19_305 19.363). Adolescents gave informed consent, and parental permission was required for adolescents ages younger than 16 years before participation. Participation was voluntary, and participants had the possibility to pause or withdraw participation at any moment. Participants received a gift voucher worth 10 euros after participation. The smartphone app that we developed for this study specifically was assessed by a privacy officer in light of the European Union (EU) General Data Protection Regulation.

Data

Exposure data

Adolescents downloaded our smartphone app on their personal mobile phones. The app contained all tobacco points of sale in the four cities, which have been systematically mapped between September 2019 and July 2020. Characteristics of each outlet were observed and reported using a checklist. Characteristics of the outlet included visibility of tobacco products and advertising inside and outside the outlet and the type of outlet: supermarkets (i.e. regular supermarkets and small supermarkets 'to go'), hospitality venues (i.e. bars, cafés, restaurants, hotels, casinos, snack bars and cafeterias) and other tobacco outlets selling tobacco (i.e. convenience stores, newsagents, bookstores, telephone stores, kiosks, liquor stores, night shops and tobacco specialist shops). The app registered for 14 days how often participants were close to a tobacco outlet.

Using the GPS of the participants' phones, the smartphone app measured the distance (in metres) to the entrance of the mapped outlets when a participant was within a 100 m radius from the entrance. From all these measurements, the minimum distance to the entrance of the tobacco outlet was determined for each time the participant was within the 100 m radius. Based on the study of Caryl et al. [16], an adolescent was considered exposed to a tobacco outlet if the minimum distance was 10 m or less, irrespective of duration of exposure. To calculate each participant's mean exposure per day, all individual exposures (within 10 m) in 14 days were summed and divided by 14 to form a continuous variable (exposures/day). This variable represented the 'total exposure'. For each participant, exposure data were included from the first to the 14th day of participation. If participants paused participation using the pause button in the app (n = 34), the 14-day period was extended by the time in days the pause function was used. Finally, for participants starting participation 7 to 13 days before the coronavirus disease 2019 (COVID-19) lockdown was imposed (December 2–8), exposures were multiplied to obtain exposure data extrapolated to 14 days (n = 47).

By linking exposure data with audit data, and by using the same method, we created three continuous exposure variables to separately analyse the effects of exposure to tobacco outlets with different levels of tobacco promotion visibility, respectively, solely outlets with 'no visibility', 'internal only' (i.e. only visible from inside the outlet) and 'internal and external' (i.e. visible from inside and outside the outlet). To correct for exposure to other outlets, we combined the other two categories. Three separate exposure variables were then created: (i) all exposures except to tobacco outlets without visibility, (ii) all exposures except to outlets with internal visibility and (iii) all exposures except to outlets with internal and external visibility.

Survey data

Students used the same smartphone app to answer one questionnaire once within their 14-day participation period on their socio-demographic characteristics, smoking experience and five smoking cognitions: attitude, beliefs (social and health) and norms (descriptive and injunctive).

Smoking attitude [20] was measured using the following statement: 'I think it is okay if young people my age smoke cigarettes'. Answer options were dichotomised into 'anti-smoking', including 'totally disagree' and 'disagree', and 'pro-smoking', including 'neutral', 'agree' and 'totally agree'.

Smoking beliefs were divided into social beliefs and health beliefs. Social beliefs were measured using two statements: 'by smoking tobacco I look cool' [21] and 'by smoking tobacco I look grown up' [22]. Both statements were dichotomised into 'anti-smoking' ('totally disagree' and 'disagree') and 'pro-smoking' ('neutral', 'agree' and 'totally agree'). If at least one of the two statements was 'pro-smoking', the variable was coded as 'pro-smoking'. Given that smoking is a very unhealthy behaviour and the widespread awareness of this among adolescents, participants who were positive about smoking in any sense were considered holding pro-smoking beliefs.

Health beliefs were measured using two statements: 'by smoking tobacco I am less able to exercise' [23] and 'by smoking tobacco I have trouble breathing' [22]. Answer options were dichotomised into 'anti-smoking' ('agree' and 'totally agree'), and 'pro-smoking' ('neutral', 'disagree' and 'totally disagree'). If at least one of the two statements was 'pro-smoking', the variable was coded as 'pro-smoking', as with social beliefs.

Perceived smoking norm was divided into the descriptive and injunctive smoking norm. The following question was used to determine the descriptive smoking norm: 'what proportion of your peers do you think are smokers?' [24]. Answer options included '(almost) none', 'less than 25%', 'around 25%', 'around 50%', 'around 75%' and 'almost 100%'. Because less than 25% of Dutch adolescents smoke monthly or more often [25], the answer options '(almost) none' and 'less than 25%' are optimistic to accurate, and anything above that indicates that smoking is perceived more normal than it is. Therefore, we coded 'around 25%' and higher as 'pro-smoking'.

The following statement of the questionnaire was used to determine the injunctive smoking norm: 'other young people think it is okay if young people their age smoke cigarettes' [26]. Answer options were dichotomised into 'anti-smoking', including 'totally disagree' and 'disagree', and 'pro-smoking', including 'neutral', 'agree' and 'totally agree'.

Whether participants had smoking friends was determined with the question 'how many of your best friends smoke?' Answer options were dichotomised into 'no smoking friends' ('none') and 'smoking friends' ('a few', 'half', 'most' and 'all of them').

Participants also reported their month and year of birth (to measure 'age', rounded to years) and 'sex' (girls vs boys). Educational level was measured with the question 'what is your educational level?' This variable was categorised into low (preparatory vocational secondary education), middle (higher general secondary education) and high (pre-university education). Adolescents were considered non-smoking when they answered 'no days' to the question 'how many of the past 30 days did you smoke?'

Study population

We collected exposure measurements from 394 non-smoking participants. Because of a COVID-19-related lockdown in the Netherlands, shops and schools were closed from 15 December 2020. Participants who started after December 8 were, therefore, excluded (*n* = 52), because more than half of their total exposure measurements were not representative for actual exposure.

We excluded 12 and 18 year olds (*n* = 27), and post-secondary vocational students (middelbaar beroepsonderwijs [MBO], *n* = 2), because this level is not covered by secondary education. Participants with missing answers on variables were excluded (*n* = 5), which resulted in a study population of 308 non-smoking adolescents between 13 and 17 years old.

Data analysis

The analysis plan was not pre-registered. Hence, the results are exploratory. The study population was described in terms of their socio-demographic characteristics. Average exposure per day was calculated for the total population and for adolescents with pro-smoking and anti-smoking cognitions for each of the five cognitions separately.

Because of the nesting of students within school, we analysed the association between exposure to tobacco outlets and smoking cognitions with multi-level logistic regression analyses. We created separate models for total exposure and outlets with different levels of tobacco promotion visibility; 'no visibility', 'internal only' and 'both internal and external visibility'. All analyses were adjusted for age, sex, educational level and smoking friends. For the visibility measures, we adjusted for other exposures in an additional model.

We carried out two sensitivity analyses, in which we used: (i) two alternative measures of total exposure, with 20- and 30-m distance from a tobacco outlet entrance, and (ii) alternative, more stringent definitions of anti-smoking for all cognitions, which included answer options '25%' (descriptive norm) and 'neutral' (attitude, social belief, health beliefs and injunctive norm).

In a *post hoc* analysis on the associations between exposure to tobacco outlets with internal visibility of tobacco promotion and smoking cognitions, we split the exposure variable into hospitality outlets and non-hospitality outlets. This distinction was expected to be relevant, because adolescents were more exposed to people smoking around hospitality venues compared to all other types of outlets. In this analysis, we also adjusted for other exposures.

RESULTS

Table 1 describes the study sample of 308 non-smoking adolescents and the percentages of adolescents with pro-smoking attitude, social beliefs, health beliefs and perceived descriptive and injunctive norm. The different age groups were approximately similar in size. The largest group was 16 years old (27.3%). Girls were over-represented compared to boys (60.7% vs 39.3%). For the most part, adolescents were highly educated. Most adolescents had pro-smoking injunctive norm and descriptive norm, but anti-smoking attitude, social beliefs and health beliefs. For all five cognitions, 16-year-olds had the highest

TABLE 1 Sociodemographic characteristics of the study population

		% Pro-smoking cognition				
	n (%)	*Attitude*	*Social beliefs*	*Health beliefs*	*Descriptive norm*	*Injunctive norm*
Population mean	308 (100)	39.0	30.2	35.7	59.7	69.8
Age, y (mean = 15.5)						
13	55 (17.9)	12.7	18.2	34.5	21.8	41.8
14	63 (20.5)	34.9	27.0	33.3	52.4	55.6
15	61 (19.8)	39.3	24.6	34.4	65.6	82.0
16	84 (27.3)	56.0	41.7	44.0	79.8	85.7
17	45 (14.6)	44.4	35.6	26.7	71.1	77.8
Sex						
Girls	187 (60.7)	36.4	32.1	39.0	66.3	73.3
Boys	121 (39.3)	43.0	27.3	30.6	49.6	64.5
Educational level						
High	217 (70.5)	39.2	34.1	38.7	59.9	69.6
Middle	62 (20.1)	33.9	17.7	32.3	56.5	67.7
Low	29 (9.4)	48.3	27.6	20.7	65.5	75.9
Smoking friends						
No	177 (57.5)	23.7	22.0	31.6	45.8	54.8
Yes	131 (42.5)	59.5	41.2	41.2	78.6	90.1

pro-smoking prevalence. Girls were more pro-smoking than boys, except for smoking attitude. Adolescents in the lowest educational level had most pro-smoking attitude and norms. Adolescents with smoking friends (42.5%) had the highest pro-smoking prevalence.

Table 2 shows the mean exposure per day for the total study population as well as for participants with pro-smoking and anti-smoking cognitions, stratified for outlets with different levels of tobacco promotion visibility. On average, adolescents were exposed to 1.18 tobacco outlets per day. Adolescents with pro-smoking cognitions are on average exposed to 1.30 to 1.43 tobacco outlets per day, compared to an average between 0.81 and 1.08 among adolescents with anti-smoking cognitions.

Table 3 presents the results of the multi-level logistic regression model for the association between total exposure to tobacco outlets

TABLE 2 Number of tobacco outlets by type and mean (SD) exposure per day for the total study population and stratified for each cognition of smoking and type of tobacco outlet

	Type of outlet			
	Total outlets *n*	*No visibility* *n (%)*	*Only internal visibility* *n (%)*	*Both internal and external visibility* *n (%)*
No. of outlets	870	180 (20.7)	251 (28.9)	439 (50.5)
Smoking cognitions	**Exposure to tobacco outlets per day mean (SD)**			
Population mean	1.18 (1.23)	0.42 (0.49)	1.03 (1.15)	0.56 (0.74)
Attitude				
Pro-smoking	1.38 (1.30)	0.49 (0.49)	1.23 (1.25)	0.60 (0.76)
Anti-smoking	1.04 (1.17)	0.37 (0.48)	0.90 (1.06)	0.54 (0.73)
Social beliefs				
Pro-smoking	1.43 (1.46)	0.49 (0.50)	1.28 (1.36)	0.63 (0.80)
Anti-smoking	1.07 (1.10)	0.39 (0.48)	0.92 (1.03)	0.53 (0.71)
Health beliefs				
Pro-smoking	1.36 (1.42)	0.44 (0.52)	1.22 (1.33)	0.67 (0.83)
Anti-smoking	1.08 (1.10)	0.40 (0.47)	0.92 (1.02)	0.51 (0.68)
Descriptive norm				
Pro-smoking	1.30 (1.30)	0.46 (0.49)	1.14 (1.22)	0.59 (0.75)
Anti-smoking	1.00 (1.11)	0.36 (0.47)	0.86 (1.01)	0.52 (0.72)
Injunctive norm				
Pro-smoking	1.34 (1.28)	0.47 (0.49)	1.17 (1.20)	0.61 (0.77)
Anti-smoking	0.81 (1.03)	0.30 (0.46)	0.70 (0.95)	0.46 (0.66)

TABLE 3 Multi-level logistic regression analysis for the association between total exposure to tobacco outlets and pro-smoking cognitions

	ORs with 95% CI				
	Attitude	*Social beliefs*	*Health beliefs*	*Descriptive norm*	*Injunctive norm*
Mean total exposure[a] (increase per store/day)	1.12 (0.91–1.38)	1.15 (0.93–1.43)	1.18 (0.97–1.44)	1.15 (0.91–1.44)	1.35 (1.04–1.75)
Age (increase per year)	1.35 (1.10–1.66)	1.19 (0.96–1.47)	0.93 (0.76–1.13)	1.65 (1.33–2.05)	1.57 (1.26–1.95)
Sex					
Girls	Ref	Ref	Ref	Ref	Ref
Boys	1.41 (0.84–2.37)	0.82 (0.48–1.42)	0.69 (0.42–1.15)	0.44 (0.25–0.77)	0.60 (0.34–1.06)
Educational level					
High	Ref	Ref	Ref	Ref	Ref
Middle	0.73 (0.37–1.44)	0.41 (0.18–0.90)	0.76 (0.41–1.41)	0.81 (0.42–1.59)	1.04 (0.49–2.17)
Low	1.50 (0.61–3.72)	0.71 (0.26–1.99)	0.40 (0.15–1.05)	1.82 (0.70–4.78)	2.10 (0.71–6.20)
Smoking friends					
No	Ref	Ref	Ref	Ref	Ref
Yes	3.50 (2.07–5.94)	1.92 (1.09–3.37)	1.58 (0.93–2.69)	3.15 (1.75–5.68)	4.89 (2.50–9.54)

[a]Total exposure (10m) to tobacco outlets per day.

and smoking cognitions. An increase in exposure of one outlet per day was associated with higher odds of pro-smoking injunctive norm (OR = 1.35, 95% CI = 1.04–1.75]. The associations with attitude (OR = 1.12, 95% CI = 0.91–1.38), social beliefs (OR = 1.15, 95% CI = 0.93–1.43), health beliefs (OR = 1.18, 95% CI = 0.97–1.44) and descriptive norm (OR = 1.15, 95% CI = 0.91–1.44) pointed in the same direction, but were not statistically significant. With age, the odds of pro-smoking cognitions increased significantly between 19% and 65% per year, except for health beliefs.

Table 4 presents associations in which we distinguish between tobacco outlets with different levels of visibility of tobacco promotion. Overall, ORs are greater than one. Associations were strongest for POS with only internal visibility, with CIs above or just below 1.00, but, in the adjusted model, only significant for injunctive norm. For the other types of POS, no clear associations were found in the adjusted model.

In the sensitivity analysis with exposure measured at 20- and 30-m distance from the POS, exposure was still associated with pro-smoking cognitions, but less strongly and only significantly for injunctive norm (Supporting information Table S1). In general, ORs were lower with every 10 m increase in measured distance, for instance, for pro-smoking injunctive norm the OR declined from 10-m distance (OR = 1.35, 95% CI = 1.04–1.75) to 20-m distance (OR = 1.16, 95% CI = 1.02–1.32) and 30-m distance (OR = 1.11, 95% CI = 1.02–1.22). The second sensitivity analysis (Supporting information Table S2) shows that alternative operationalisation of the cognition variables resulted in somewhat stronger associations between total exposure and, respectively, attitude (OR = 1.26, 95% CI = 0.99–1.59), social beliefs (OR = 1.32, 95% CI = 1.04–1.67) and descriptive norm (OR = 1.24, 95% CI = 0.94–1.62), but more weaker associations for health beliefs (OR = 1.14, 95% CI = 0.90–1.46) and injunctive norm (OR = 0.92, 95% CI = 0.68–1.25).

To further assess the associations for exposure to tobacco outlets with internal visibility, we have performed a *post hoc* analysis in which we distinguished hospitality and non-hospitality outlets. The lower part of Supporting information Table S3 shows that, when adjusted for all other exposures, ORs are higher for exposure to hospitality venues compared to non-hospitality venues. However, most associations are not statistically significant.

DISCUSSION

Key findings

On average, non-smoking adolescents were exposed 1.18 times per day to tobacco outlets. A one store per day increase in exposure to tobacco outlets was associated with higher odds of pro-smoking injunctive norm (35%). Associations with pro-smoking attitude (12%), social beliefs (15%), health beliefs (18%) and descriptive norm (15%) were in the same direction, but did not reach statistical significance. Associations with smoking cognitions were largest for exposure to outlets with internal tobacco promotion visibility, especially for injunctive norm. For outlets with both internal and external visibility, no significant relation was found.

Strength and limitations

Using GPS data to measure exposure to tobacco outlets enabled collection of individual-level, objective data of exposure to each tobacco outlet encountered during 14 days. These data can be considered more valid than self-reports or group-level measurements. However, GPS measurement reliability is limited by the accuracy of the GPS function of each smartphone and around outlets situated indoors. Because of inaccuracies, both false positive and false negative exposures may have been registered. If this led to random misclassification, this may have resulted in larger standard errors and a greater uncertainty of the estimates.

TABLE 4 Multi-level logistic regression analysis for the association between total exposure to tobacco outlets with different levels of visibility of tobacco products and advertising, and pro-smoking cognitions

	ORs with 95% CI				
	Attitude	*Social beliefs*	*Health beliefs*	*Descriptive norm*	*Injunctive norm*
Not adjusted for other exposures[a]					
No visibility	1.32 (0.78–2.24)	1.25 (0.72–2.16)	1.15 (0.70–1.90)	1.21 (0.68–2.14)	1.62 (0.86–3.04)
Internal visibility	1.16 (0.93–1.46)	1.18 (0.94–1.49)	1.22 (0.99–1.51)	1.18 (0.92–1.51)	1.37 (1.03–1.81)
Internal and external visibility	1.03 (0.73–1.47)	1.08 (0.75–1.56)	1.30 (0.94–1.79)	1.12 (0.77–1.62)	1.29 (0.86–1.94)
Adjusted for other exposures[b]					
No visibility	0.96 (0.44–2.11)	0.86 (0.39–1.92)	0.64 (0.30–1.35)	0.75 (0.31–1.82)	0.83 (0.31–2.22)
Internal visibility	1.64 (0.98–2.74)	1.53 (0.93–2.52)	1.41 (0.90–2.20)	1.60 (0.88–2.89)	2.25 (1.04–4.85)
Internal and external visibility	0.56 (0.29–1.07)	0.67 (0.34–1.29)	1.00 (0.56–1.76)	0.69 (0.33–1.43)	0.50 (0.20–1.25)

Note: All analyses adjusted for age, sex, educational level, and smoking friends.
[a]Each model only includes one visibility exposure variable (i.e. no visibility, internal visibility or internal and external visibility).
[b]Each model includes one visibility exposure variable (i.e. no visibility, internal visibility or internal and external visibility) and its counterpart (i.e. exposure not at outlets without visibility, exposure not at outlets with internal visibility, exposure not at outlets with internal and external visibility).

Second, because of ethical considerations, adolescents were able to pause the app at self-selected moments. In total, 34 of 308 participants used this function, for about 19 h on average. We do not know why participants paused the app and whether it was related to shop visits. Pausing could have been either at random moments or specifically at moments when visiting tobacco outlets.

Third, there is a risk of desirability bias in adolescents' survey responses. Because of the general conception that smoking is unhealthy, adolescents' answers may not reflect their true perceptions and feelings [27]. However, we have no evidence to believe that this has resulted in differential misclassification of pro-smoking cognitions.

Fourth, although we used existing scales to measure three smoking cognitions, construct validity for descriptive norm, injunctive norm and attitude were not officially determined. For social and health beliefs, we reduced the number of items to two to shorten the survey. For these shorter scales, Spearman's ρ correlations were 0.55 and 0.62, respectively (both $P < 0.001$). Validity of the descriptive smoking norm may be limited because of adolescents' difficulties and differences in interpreting percentages. Moreover, in the questionnaire, adolescents were prompted to choose between 25%-wide categories instead of estimating specific prevalence rates.

Fifth, it is difficult to generalise the results from our study in urban areas to rural areas, where the density of outlets is likely to be lower. It is very likely that adolescents in rural areas will be less often exposed to the visibility of tobacco outlets. Therefore, more research is necessary to assess whether similar associations exist in rural areas.

Interpretation

We found associations between objective exposure to tobacco outlets and pro-smoking cognitions. Similar associations were found in studies in which exposure was not measured objectively [1, 2, 10, 28]. Our results support previous findings and therefore, suggest that the hypothesis can be rejected that previous findings could be explained by self-reporting bias or reverse causation (i.e. when those who smoke or have pro-smoking cognitions are more likely to recall and report tobacco outlet exposure).

Our results support the thesis that exposure to tobacco products and advertising in the retail environment contributes to pro-smoking cognitions. This thesis was derived from marketing theories, which state that exposure to advertisements may cause feelings of familiarity and evoke positive emotions and attitudes toward the advertisement or product [29]. Moreover, visible placement of tobacco products implies the message that tobacco is a normal retail product [30].

We found that associations tended to be stronger with exposure to outlets with internal visibility than with exposures to outlets without visibility or outlets with both internal and external visibility. Outlets with only internal visibility include hospitality venues, such as bars, restaurants and cafes, where tobacco products are not only sold, but also used. Smoking inside these outlets is not allowed, and indoor smoke areas are also forbidden. Smoking, therefore, takes place outside of these venues, which increases the likelihood of adolescents' exposure as passing the venue, as opposed to entering the venue, is only needed to be exposed. Research has shown that seeing others smoking is positively associated with pro-smoking beliefs [31]. Future research may assess the role of seeing others smoking in this association.

Implications

The results of this study suggest that exposure to tobacco outlets may increase the risk of smoking initiation through pro-smoking cognitions. Further removal of tobacco promotion at the POS and reduction of the number of tobacco outlets may therefore, be important in smoking prevention. Indeed, the implementation of a POS display ban in Scotland was associated with a decrease in pro-smoking attitudes, although not in norms [32]. A European study found that the implementation of display bans at the POS was associated with reduced smoking prevalence among adolescents [33]. As theories of marketing argue, there may be a certain exposure threshold for advertisements to affect consumers [29]. A main aim may be to reduce the number of tobacco outlets and tobacco advertising below such a threshold [18].

CONCLUSION

This study indicates that objectively measured exposure to tobacco outlets is associated with pro-smoking cognitions among non-smoking adolescents in four Dutch cities. This is problematic as pro-smoking cognitions are a risk factor for smoking initiation. This evidence, therefore, provides further support for policies that aim to limit the number of tobacco outlets and the visibility of tobacco advertising at remaining outlets.

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DECLARATION OF INTERESTS

All authors declare that they have no conflicts of interest.

AUTHOR CONTRIBUTIONS

Tessa R.D. van Deelen: Conceptualization; data curation; formal analysis; investigation; methodology; project administration; software; supervision; validation; visualization; writing-original draft; writing-review and editing. **Gabriëlle de Vet:** Conceptualization; data curation;

formal analysis; methodology; validation; visualization; writing-original draft; writing-review and editing. **Anne Zijp:** Formal analysis; methodology; validation; visualization; writing-original draft; writing-review and editing. **Bas van den Putte:** Conceptualization; formal analysis; investigation; methodology; project administration; software; supervision; validation; visualization; writing-original draft; writing-review and editing. **Anton E. Kunst:** Conceptualization; formal analysis; funding acquisition; investigation; methodology; project administration; software; supervision; validation; visualization; writing-original draft; writing-review and editing. **Mirte A G Kuipers:** Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; software; supervision; validation; visualization; writing-original draft; writing-review and editing.

ORCID

Tessa R. D. van Deelen https://orcid.org/0000-0003-1159-9648
Anne Zijp https://orcid.org/0000-0002-1967-3059
Anton E. Kunst https://orcid.org/0000-0002-3313-5273
MirteA. G. Kuipers https://orcid.org/0000-0002-8133-1834

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SUPPORTING INFORMATION

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