HHS Public Access

Author manuscript

Addiction. Author manuscript; available in PMC 2021 September 01.

Published in final edited form as:

Addiction. 2020 September ; 115(9): 1728–1735. doi:10.1111/add.15001.

Youth Daily Exposure to Tobacco Outlets and Cigarette Smoking Behaviors: Does Exposure within Activity Space Matter?

Sharon Lipperman-Kreda, PhD.[1,*], **Laura J. Finan, Ph.D.**[2], **Sarah D. Kowitt, PhD, MPH**[3], **Joel W. Grube, PhD.**[1], **Melissa Abadi, PhD.**[4], **Anna Balassone, BA.**[1], **Emily Kaner, BS.**[1]

[1]Prevention Research Center, Pacific Institute for Research and Evaluation, 2150 Shattuck Avenue, Suite 601, Berkeley, CA 94704

[2]Department of Psychology, Illinois State University, Campus Box 4620, Normal, IL 61790-4620

[3]Department of Family Medicine, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

[4]Pacific Institute for Research and Evaluation, One Riverfront Plaza, Suite 2100, 401 West Main Street, Louisville, KY 40202

Abstract

Aims: To examine whether daily exposure to tobacco outlets within activity spaces is associated with cigarette smoking and with the number of cigarettes smoked by youth that day.

Design: The study used Geographic Ecological Momentary Assessment (GEMA) data that combined daily surveys with ecological momentary assessment of global positioning systems (GPS) using geographic information systems (GIS) to allow for real-time data collection of participants' environments and behaviors.

Setting: Eight mid-sized California (USA) city areas.

Participants: The analytic sample included 1,065 days, which were clustered within 100 smoker and non-smoker participants (16–20 years old, 60% female).

Measurements: Any cigarette smoking and number of cigarettes smoked on a given day, the number of tobacco outlets within 100m of activity space polylines each day, the number of minutes participants spent within 100m of tobacco outlets each day, and demographic characteristics (age, sex, race/ethnicity and perceived SES).

Findings: Controlling for demographic characteristics, the findings of multilevel mixed effects logistic models were inconclusive whether or not the number of tobacco outlets within 100m of youths' activity space polylines or the number of minutes spent within 100m of tobacco outlets were associated with whether the participant smoked cigarettes on a given day (OR=1.05, p=0.24; OR=0.99, p=0.81, respectively). However, in multilevel zero-inflated negative binomial models the risk of smoking an additional cigarette on a given day increased with each additional tobacco outlet (IRR=1.04, p<0.05) and each additional minute spent within 100m of tobacco outlets (IRR=1.01, p<0.001) each day.

[*]Correspondence should be addressed to Sharon Lipperman-Kreda, Prevention Research Center, Pacific Institute for Research and Evaluation, 2150 Shattuck Avenue, Suite 601, Berkeley, CA 94704, skreda@prev.org.

Conclusions: Among young people in urban California USA, differences in day-to-day exposure to tobacco outlets within activity spaces does not seem to be significantly associated with whether a person smokes a cigarette on a given day, but higher exposure to tobacco outlets appears to be positively associated with the number of cigarettes smoked on that day.

Keywords

Youth; Cigarette smoking; Activity spaces; GEMA; Tobacco outlets

INTRODUCTION

Tobacco use remains the leading cause of preventable death globally [1]. It has long been known that initiation of tobacco use during the adolescent and young adult years contributes to continued use in adulthood [2]. Understanding the factors that contribute to young people's risk for engagement with tobacco has both short- and long-term prevention and public health applications.

Ecological models of health behavior stipulate that the environments in which individuals spend their time impact their health risks and behaviors [3]. Tobacco outlet density is hypothesized to be one important environmental factor that may be associated with tobacco use through a variety of mechanisms including increased access which may be higher in socioeconomic deprived areas, exposure to marketing, exposure to others who use this substance (i.e., role models), or through favorable tobacco use norms in the landscape of available goods in the community [4–11]. Extant research has investigated the impact of tobacco outlet density around young peoples' homes and schools and their tobacco use [12–15], and a recent meta-analysis suggests density around homes may be a particularly salient risk [16].

Although relying on indicators of tobacco outlet density around young people's homes and schools plays an important role in understanding how these environmental characteristics may negatively impact health, they may fail to capture potential exposure to tobacco outlets within *activity spaces* or the broader environments where youths spend their time. For example, exposure may occur in other settings such as traveling to and from locations, community centers, parks, or malls. Indeed, a pilot study found that traditional measures of tobacco outlet density around homes and schools may misrepresent youths' environmental exposures [17]. A small body of work has examined the impact of tobacco outlet exposure within activity spaces on individuals' smoking behavior. A study of young adults found that the mean proximity of tobacco outlets within an individual's activity space was associated with smoking [18]. Among adolescents, a study showed that young people experience considerable exposure to tobacco outlets within their activity spaces and that frequency of exposure increases within income deprived areas [19]. Further, among 16–20-year-olds, greater numbers of tobacco outlets within activity spaces were associated with greater tobacco use on a given day through exposure to peer use [20]. Though this research area is growing, there is a paucity of studies exploring to what extent youths' exposure to tobacco outlets within their activity spaces is an important determinant of cigarette smoking behaviors. Such research may inform policy and prevention programs designed to limit

exposure to tobacco outlets in young people's daily lives and would highlight the importance of considering areas that go beyond residential or school neighborhoods in research and practice.

Therefore, the current study extends past research on tobacco outlet density around youth specific locations to also include youths' activity spaces. Specifically, this study uses Geographic Ecological Momentary Assessment (GEMA) data combining daily surveys with ecological momentary assessment of global positioning systems (GPS) using geographic information systems (GIS) to allow for real-time data collection of participants' environments and behaviors. Specifically, the following research questions were examined.

1. Are daily number of tobacco outlets within 100m of activity space's polylines or the number of minutes within 100m of outlets associated with cigarette smoking by youth that day?
2. Are these exposure indicators associated with the number of cigarettes smoked that day?

METHODS

Study Cities and Participants

Study cities.—We collected data from youth aged 16–20 years (n=101 participants) in eight mid-sized California city areas. Cities were selected from an existing geographically diverse sample of 50 noncontiguous California cities (population range: 50,000 to 500,000) [13, 21]. To select the eight cities, we considered cities within a 50-mile radius of Oakland CA, where our research center was located at the time of the study. Of the 50 cities, 11 met this criterion. To maximize variation in youth exposure to tobacco outlets in their living environments, we first stratified these cities based on measures of socioeconomic status (SES) (i.e., a measure derived from: median household income, percentage of population with a college education, and percentage of population unemployed) and tobacco outlet density (i.e., number of licensed tobacco outlets per 10,000 persons) and then randomly selected eight cities representing low versus high SES and low versus high tobacco outlet density. We recruited participants who lived in these 8 cities or in cities that were within a 10-mile buffer of the eight cities. On June 9, 2016, California had raised the minimum tobacco sales age to 21, which applied to all cities across the state. Data collection occurred after the law went into effect (February 2017–May 2018).

Participants.—We recruited participants through internet and social media advertisements such as Craigslist and Facebook. Also, participants were recruited through flyers distributed to youth serving organizations in the study cities, by contacting participants from a previous study, and by referral. Potential participants were screened for eligibility (i.e., age, city of residence, and speak English). Also, to assure enough power to address the aims of the overall project, the sample was stratified by tobacco use status at screening (~50% any past-month tobacco users). Parental consent was obtained for those younger than 18 years old. All participants provided signed consent or assent to participate in the research. The Pacific Institute for Research and Evaluation (PIRE) institutional review board (Federal-wide Assurance #FWA00003078) approved the study prior to implementation.

Procedures

Initial survey.—After recruitment, participants completed an initial online survey (30 minutes), which included questions about demographic characteristics and past month tobacco use.

GEMA.—Using GPS-enabled smartphones with a survey application, participants then responded to brief daily surveys and location coordinates (latitude and longitude) were obtained at one-minute intervals for 14 days. The research team provided GPS-enabled phones to participants and briefed them about study procedures. The phone survey application was programed to send reminders to complete the survey each evening at 8pm. Youth had a 3-hour window to respond to the survey each day. Each participant in the study provided, on average, 11.4 days of data (Range 4–14 days).

Incentives.—As compensation for their time, participants could receive up to $150. They received $10 for completing the initial survey, $5 for each daily survey, and a $20 bonus if they completed all surveys. Additionally, they received $40 for returning the phone at the end of the study and $10 for returning the charger. Participants could use the phones with unlimited texting and calling during the study. Upon completion of the study, they received a resource card that included links to resources and referral information on how to quit tobacco.

Analytical Sample

Data were obtained from participants for a total of 1,483 days. From this total, we excluded data for days in which participants were tracked for less than 360 min (n=123) and for some participants, for days that exceeded the 14 study days (n=73). Of the remaining 1,287 days, 222 days were missing study variables used for the analyses. The final analytic sample therefore included 1,065 days, which were clustered within 100 participants. Sample characteristics are in Table 1.

Measures

Cigarette smoking behaviors.—Each day, participants were asked, “Since this time yesterday, did you smoke at least one cigarette?” Response options were yes (coded as 1) or no (coded as 0). Those who responded yes were also asked, “How many cigarettes did you smoke since this time yesterday?” Participants indicated the number of cigarettes they smoked. Those who responded no to the first question received a value of 0 to this question.

Exposure to tobacco outlets within activity space.—Using the Dun & Bradstreet, INC (D&B) commercial list, the North American Industry Classification System (NAICS) codes were used to identify probable tobacco outlets in the eight cities and within a 10-mile buffer of city boundaries. Specifically, probable tobacco outlets were searched using the NAICS codes of the top ten retail industries that sell tobacco products including supermarkets and other grocery (except convenience) stores (445110), convenience stores (445120), tobacco stores (453991), gasoline stations with convenience stores (447110), warehouse clubs and supercenters (452910), news dealers and newsstands (451212), beer, wine, and liquor stores (445310), pharmacies and drug stores (446110), discount department

stores (452112) and other gasoline stations (447190). These codes are industries that represent approximately 98% of all tobacco sales and were used in a study that validated the use of commercial lists to identify tobacco outlets in states that do not have a comprehensive list of tobacco outlet addresses [22]. Chains with policies restricting the sale of tobacco (e.g., Target and CVS) were excluded from the list. To ensure our study included places that sell alternative nicotine delivery systems (ANDS) but do not sell other tobacco products (e.g., hookah bars), we conducted an online search of places that sell hookahs and e-cigarettes in study areas. All identified tobacco outlets were contacted by phone to verify business status, sale of tobacco products, address, and hours of operation. Next, these outlets were visited by observers to record outlet GPS point locations and obtain data about tobacco products and marketing (not reported in the current study).

Tobacco outlet addresses and participants' GPS locations were geocoded, and activity spaces were constructed by joining sequential GPS points into a polyline, which was then buffered and overlaid with tobacco outlet locations. An example of a participant's activity space and our approach was published earlier [20]. Exposure measures included (a) the number of tobacco outlets within 100m of activity space's polylines each day, and (b) the number of minutes participants spent within 100m of tobacco outlets. These measures were weighted by the time participants were within the study area each day.

Control variables.—All control variables were obtained from the initial survey and included sex assigned at birth (male, female, or intersex), race/ethnicity (non-Hispanic White), age, and perceived SES. Perceived SES was a continuous variable that asked participants, "Compared with other people in America, how rich or poor do you consider yourself?" Respondents could answer on a 7-point scale ranging from rich to poor. We reverse coded these responses (1 = poor; 7 = rich) for the analyses. Previous research has found that perceived SES is associated with health behaviors [23–25].

Tobacco use history.—In the initial survey, participants were asked about past month tobacco use including use cigarettes, cigars, cigarillos, or little cigars, blunts, smokeless tobacco, or e-cigarettes. These items were used to describe the tobacco use history of the sample.

Data Analysis

We first examined means, standard deviations, or frequencies of study variables. Next, to assess the associations between any cigarette smoking on a given day (outcome) and exposure to tobacco outlets within activity spaces (exposure measures), we used multilevel mixed effects logistic models to control for clustering of observations within participants over time. Finally, preliminary specification tests indicated that the number of cigarettes smoked outcome was negative binomial distributed with considerable zero inflation. Therefore, zero-inflated negative binomial models were used to assess the associations between the exposure measures and this outcome, with a sandwich variance estimator to correct for loss of unit independence related to nesting of assessments within participants. A logistic distribution was assumed to represent zero inflation and further specification tests were conducted to assess correlates of this component of each analysis model; each

covariate was tested separately to be included in the inflation equations. As none of the covariates were significant, only the constant estimate was included in the zero-inflation component of the models. The ICCs for cigarette smoking and number of cigarettes smoked on a given day by city were 0.12 and 0.04, respectively, suggesting that participants' cities had small effects on daily cigarette smoking behaviors. Analyses were conducted with Stata version 15.0. We ran separate models for each of the exposure measures due to multicollinearity of these measures. For all analyses, we set critical $\alpha = .05$ and used 2-tailed statistical tests. Sensitivity analyses were conducted restricting the sample to only participants who reported any cigarette smoking during the GEMA (GEMA cigarette smokers; 243 observations clustered within 23 participants). Since the analysis was not pre-registered, the results should be considered exploratory.

RESULTS

Sample Characteristics and Descriptive Statistics

Of the 100 participants, 60.0% (n=60) were female and over a third identified as non-Hispanic White (37.0%, n=37). Participants' mean age was 18.16 (SD=1.50). Subjective SES was about average on the seven-point scale (Mean=3.80, SD=1.37). In the initial survey, 33.7% (n=34) reported past month use of any tobacco product and 17.8% (n=18) reported smoking part or all of a cigarette in the past month. In the daily surveys, cigarette smoking was reported on 9.95% of the 1,065 study days (n=106 days) and on average participants reported smoking 0.40 (SD=1.53) cigarettes each day (range: 0.00 – 18.00). Among those who reported cigarette smoking during the GEMA, the average number of cigarettes smoked was 1.76 (SD=2.81; range 0.00–18.00). In terms of exposure to tobacco outlets, participants were exposed to an average of 4.27 (SD=4.95) tobacco outlets within 100m of activity space polylines per day. On average, they were within 100m of tobacco outlets for 17.09 minutes (SD=47.29) per day. Study variables, sample characteristics, and tobacco use history are in Table 1.

Cigarette Smoking and Exposure to Tobacco Outlets in Activity Spaces

Any cigarette smoking on a given day.—Controlling for demographic characteristics (age, sex, race/ethnicity and perceived SES), the findings were inconclusive as to whether either the number of tobacco outlets within 100m of youths' activity space polylines or the number of minutes spent within 100m of tobacco outlets were associated with whether the participant smoked cigarettes on a given day (Table 2). Restricting the sample to GEMA cigarette smokers, findings were the same for the number of outlets within 100m of activity space's polylines (OR=1.07, CI=0.98, 1.16) and the number of minutes spent within 100m of tobacco outlets (OR=1.00, CI=0.98, 1.02).

Number of cigarettes smoked on a day.—Controlling for demographic characteristics, exposure to each additional tobacco outlet within 100m of activity space polylines on a given day increased the risk of smoking an additional cigarette that day by four percent (IRR=1.04, p<0.05). Similarly, each additional minute spent within 100m of tobacco outlets increased the risk of smoking an additional cigarette, controlling for demographic characteristics (IRR=1.01, p<0.001). Results are displayed in Table 3.

Restricting the sample to GEMA cigarette smokers, results were the same for the number of tobacco outlets within 100m of activity space's polylines (IRR=1.04, CI=1.01, 1.07; $p<0.05$) and the number of minutes within 100m of tobacco outlets (IRR=1.01, CI=1.00, 1.01; $p<0.001$) exposures.

DISCUSSION

We investigated the associations of cigarette smoking behaviors with the number of tobacco outlets 16–20-year-old youths were exposed to on that day and time they spent within proximity of those outlets. By considering exposure to tobacco outlets in the broader environments where participants interact daily, this study addresses an important gap in extant research about environmental risks for cigarette smoking in the youth population [16]. We found that among young people, differences in day-to-day exposure to tobacco outlets within activity spaces was not uniquely associated with whether a participant smoked a cigarette on a given day, but it was positively associated with the number of cigarettes smoked on that day.

Past research by Shareck and colleagues has found that the number of tobacco outlets within 500m of young adults' regular activity locations (i.e., studying, working, grocery shopping, physical activity, leisure activity and other activities) is associated with smoking status (i.e., being a current smoker) [18]. Although the current study found no association between exposures to tobacco outlets within youths' activity spaces on a given day and smoking any cigarettes on that day, exposure and time spent near outlets were both associated with the number of cigarettes youth smoked. These results complement and extend Shareck and colleague's findings by assessing earlier in the lifespan (16–20 years versus 18–25 years), a new location (California, US versus Montreal, Canada), and a novel assessment of the outcomes (smoking on a given day versus cross-sectional assessment of smoking status). Further, whereas in the current study we used GPS tracking data to assess participants' environments and exposure to tobacco outlets in real time, the previous study used a retrospective activity space questionnaire to collect information on respondents' regular activity locations and assessed the number of tobacco outlets within 500m of those locations. To the best of our knowledge, no other published study has considered the association between tobacco outlet activity space exposures and cigarette smoking behaviors among young people using real-time measures. Additional research is needed to accurately assess individual travel patterns and the retail environment to understand cigarette smoking and other tobacco use behaviors among this vulnerable population [19, 26, 27].

We found that the number of and time around tobacco outlets within activity spaces each day were associated with the number of cigarettes participants reported smoking on that day but not their cigarette smoking status on that day. It is possible that effects of exposure to tobacco outlets on young people's cigarette smoking status may be long-term and may accumulate through perceived community norms and exposure to point-of-sale tobacco marketing. In other words, perhaps it is less of a momentary process, but rather the impact of consecutive exposures over time. Indeed, using traditional measures of youths' exposure to tobacco outlets around their homes, previous cross-sectional research has shown that living

in neighborhoods with greater numbers of tobacco outlets was associated with lifetime, past-month or past-year cigarette smoking among young people [12–15].

However, daily exposure to tobacco outlets within activity spaces seems to matter for cigarette smoking quantity such that on any given day, exposure to an additional tobacco outlet increased the likelihood of youth smoking an additional cigarette by four percent. Though these small effect sizes are similar to those identified in a recent meta-analysis examining tobacco outlet density around residential areas and adolescents' past-month cigarette smoking status [16], the studies in the meta-analysis were based on much larger samples and varied greatly in how variables were defined across studies. Moreover, the outcomes are different (i.e., smoking quantity versus status) making it hard to compare. Our current results suggest that, unlike the effects on cigarette smoking status or initiation on a given day, the effects of daily exposure to tobacco outlets on cigarette quantity may be momentary via creating more opportunities for youth to illegally buy cigarettes through tobacco outlets. A review paper that evaluated efforts to prevent the sale of tobacco to youth concluded that every intervention that has successfully disrupted the sale of tobacco to minors has been associated with an observed reduction in tobacco use among youth [28]. Also, similar to findings among adults, perhaps exposure to outlets reinforces this health risk habit as youth are cued through seeing tobacco marketing, others smoking, or are simply reminded of cigarettes in these environments [26, 27].

Results of the current study present several important prevention implications. First, they suggest the importance of policies to regulate young people's exposure to tobacco outlets beyond residential or school neighborhoods. The findings also provide support for regulating youth access and availability of cigarettes through retail outlets. Reducing availability of tobacco products may be important for the youth population in general, but in particular for youth in socially disadvantaged areas who encounter high levels of exposure to tobacco outlets in their daily routine activity spaces [19] or in communities with greater youth retail access to tobacco [29]. Finally, results of the current study emphasize the importance of considering individuals' travel patterns and activity spaces when assessing exposure to tobacco outlets and tobacco use behaviors.

A few study limitations should be noted. First, the data came from a convenience sample of youth in California and results may not generalize to other populations or locations. Second, we relied on self-reported measures of cigarette smoking behaviors. Assessment of smoking status through other mechanisms (e.g., salivary cotinine) in future research may enhance the validity of these reports. Third, we did not control for or consider other potential factors that may have influenced youth cigarette smoking behaviors such as family or peer tobacco use, tobacco beliefs, or exposure to other environmental factors such as neighborhood deprivation or local smoking norms within activity spaces. Future research should operationalize and examine effects of momentary changes in such environmental factors within individuals' activity spaces. Finally, due to the cross-sectional design of the study we cannot definitively determine the direction of causality. For example, although in the current study we obtained novel fine-grained spatial and temporal information on individuals' mobility patterns, environmental exposures, and behaviors, our analyses do not allow for examination of the possibility that youth may select into certain environments (e.g., tobacco

outlets) based on their tobacco use behaviors (i.e., selective daily mobility) [30, 31]. Despite these possible shortcomings, by using a cutting-edge methodology to assess the effects of real-time exposure to tobacco outlets on youth cigarette smoking, this study highlights the importance of considering young people's exposure to tobacco outlets in the broader environment where they interact daily for future research, policy development, and prevention interventions.

ACKNOWLEDGEMENTS

Funding: This research and preparation of this manuscript were supported by grant 25IR-0029 from the California Tobacco-Related Disease Research Program (TRDRP) and grant P60-AA006282 from the National Institute on Alcohol Abuse and Alcoholism (NIAAA) of the National Institutes of Health (NIH). The content is solely the responsibility of the authors and does not necessarily represent the official views of the TRDRP, NIAAA or NIH.

References

1. Centers for Disease Control and Prevention. Smoking and Tobacco Use: Fast Facts 2019 [Available from: https://www.cdc.gov/tobacco/data_statistics/fact_sheets/fast_facts/.
2. Chassin L, Presson CC, Sherman SJ, Edwards DA. The natural history of cigarette smoking: Predicting young-adult smoking outcomes from adolescent smoking patterns. Health Psychology. 1990;9(6):701–16. [PubMed: 2286181]
3. Sallis JF, Owen N. Ecological Models of Health Behavior In: Glanz K, Rimer BK, Viswanath K, editors. Health Behavior: Theory, Research, and Practice. 5th ed San Francisco, CA: Jossey-Bass; 2015 p. 43–64.
4. Lee JGL, Sun DL, Schleicher NM, Ribisl KM, Luke DA, Henriksen L. Inequalities in tobacco outlet density by race, ethnicity and socioeconomic status, 2012, USA: results from the ASPiRE Study. Journal Of Epidemiology And Community Health. 2017;71(5):487–92. [PubMed: 28249990]
5. Shortt NK, Tisch C, Pearce J, Mitchell R, Richardson EA, Hill S, et al. A cross-sectional analysis of the relationship between tobacco and alcohol outlet density and neighbourhood deprivation. BMC Public Health. 2015;15(1):1–9. [PubMed: 25563658]
6. Dalglish E, McLaughlin D, Dobson A, Gartner C. Cigarette availability and price in low and high socioeconomic areas. Australian & New Zealand Journal of Public Health. 2013;37(4):371–6. [PubMed: 23895481]
7. Yu D, Peterson NA, Sheffer MA, Reid RJ, Schnieder JE. Tobacco outlet density and demographics: analysing the relationships with a spatial regression approach. Public Health (Elsevier). 2010;124(7):412–6.
8. Lipperman-Kreda S, Grube JW. Students' perception of community disapproval, perceived enforcement of school antismoking policies, personal beliefs, and their cigarette smoking behaviors: Results from a structural equation modeling analysis. Nicotine & Tobacco Research. 2009;11(5):531–9. [PubMed: 19346507]
9. Henriksen L. Comprehensive tobacco marketing restrictions: promotion, packaging, price and place. Tobacco Control: An International Journal. 2012;21(2):147–53.
10. Leatherdale ST, Strath JM. Tobacco Retailer Density Surrounding Schools and Cigarette Access Behaviors Among Underage Smoking Students. Annals of Behavioral Medicine. 2007;33(1):105–11. [PubMed: 17291176]
11. Loomis BR, Kim AE, Busey AH, Farrelly MC, Willett JG, Juster HR. The density of tobacco retailers and its association with attitudes toward smoking, exposure to point-of-sale tobacco advertising, cigarette purchasing, and smoking among New York youth. Preventive Medicine: An International Journal Devoted to Practice and Theory. 2012;55(5):468–74.
12. Schleicher NC, Johnson TO, Fortmann SP, Henriksen L. Tobacco outlet density near home and school: Associations with smoking and norms among US teens. Preventive Medicine: An International Journal Devoted to Practice and Theory. 2016;91:287–93.

13. Lipperman-Kreda S, Mair C, Grube JW, Friend KB, Jackson P, Watson D. Density and proximity of tobacco outlets to homes and schools: Relations with youth cigarette smoking. Prevention Science. 2014;15(5):738–44. [PubMed: 24254336]
14. McCarthy WJ, Mistry R, Lu Y, Patel M, Zheng H, Dietsch B. Density of tobacco retailers near schools: effects on tobacco use among students. American Journal of Public Health. 2009;99(11):2006–13. [PubMed: 19820214]
15. Novak SP, Reardon SF, Raudenbush SW, Buka SL. Retail Tobacco Outlet Density and Youth Cigarette Smoking: A Propensity-Modeling Approach. American Journal of Public Health. 2006;96(4):670–6. [PubMed: 16507726]
16. Finan LJ, Lipperman-Kreda S, Abadi M, Grube JW, Kaner E, Balassone A, et al. Tobacco outlet density and adolescents' cigarette smoking: a meta-analysis. Tobacco Control. 2019;28(1):27–33. [PubMed: 29519934]
17. Lipperman-Kreda S, Morrison C, Grube JW, Gaidus A. Youth activity spaces and daily exposure to tobacco outlets. Health & Place. 2015;34:30–3. [PubMed: 25879915]
18. Shareck M, Kestens Y, Vallée J, Datta G, Frohlich KL. The added value of accounting for activity space when examining the association between tobacco retailer availability and smoking among young adults. Tobacco Control: An International Journal. 2016;25(4):406–12.
19. Caryl F, Shortt NK, Pearce J, Reid G, Mitchell R. Socioeconomic inequalities in children's exposure to tobacco retailing based on individual-level GPS data in Scotland. Tobacco Control. 2019.
20. Kowitt SD, Lipperman-Kreda S. How is exposure to tobacco outlets within activity spaces associated with daily tobacco use among youth? A mediation analysis. Nicotine & Tobacco Research: Official Journal Of The Society For Research On Nicotine And Tobacco. 2019.
21. Lipperman-Kreda S, Grube JW, Friend KB, Mair C. Tobacco outlet density, retailer cigarette sales without ID checks and enforcement of underage tobacco laws: associations with youths' cigarette smoking and beliefs. Addiction. 2016;111(3):525–32. [PubMed: 26430730]
22. D'Angelo H, Fleischhacker S, Rose SW, Ribisl KM. Field validation of secondary data sources for enumerating retail tobacco outlets in a state without tobacco outlet licensing. Health & Place. 2014;28:38–44. [PubMed: 24742811]
23. Goodman E, Huang B, Schafer-Kalkhoff T, Adler NE. Perceived socioeconomic status: A new type of identity that influences adolescents' self-rated health. Journal of Adolescent Health. 2007;41(5):479–87. [PubMed: 17950168]
24. Goodman E, Adler NE, Kawachi I, Frazier AL, Huang B, Colditz GA. Adolescents' perceptions of social status: development and evaluation of a new indicator. Pediatrics. 2001;108(2):E31-E. [PubMed: 11483841]
25. Quon EC, McGrath JJ. Subjective socioeconomic status and adolescent health: A meta-analysis. Health Psychology. 2014;33(5):433–47. [PubMed: 24245837]
26. Kirchner TR, Cantrell J, Anesetti-Rothermel A, Ganz O, Vallone DM, Abrams DB. Geospatial exposure to point-of-sale tobacco: Real-time craving and smoking-cessation outcomes. American Journal of Preventive Medicine. 2013;45(4):379–85. [PubMed: 24050412]
27. Kirchner TR, C Jennifer. Anesetti-Rothermel Andrew. Pearson Jennifer. Cha Sarah. Kreslake Jennifer. Ganz Ollie. Tacelosky Michael. Abrams David., Vallone D. Individual mobility patterns and real-time geo-spatial exposure to point-of-sale tobacco marketing. In: Proceedings, of ACM Wireless Health 2012 , editors. New York, NY: AMC; 2012 p. 1–8.
28. DiFranza JR. Which interventions against the sale of tobacco to minors can be expected to reduce smoking? Tobacco Control: An International Journal. 2012;21(4):436–42.
29. Lipperman-Kreda S, Grube JW, Friend KB. Contextual and community factors associated with youth access to cigarettes through commercial sources. Tobacco Control: An International Journal. 2014;23(1):39–44.
30. Chaix B, Kestens Y, Perchoux C, Karusisi N, Merlo J, Labadi K. An interactive mapping tool to assess individual mobility patterns in neighborhood studies. American Journal of Preventive Medicine. 2012;43(4):440–50. [PubMed: 22992364]

31. Chaix B, Méline J, Duncan S, Merrien C, Karusisi N, Perchoux C, et al. GPS tracking in neighborhood and health studies: A step forward for environmental exposure assessment, a step backward for causal inference? Health & Place. 2013;21:46–51. [PubMed: 23425661]

Table 1:

Study variables and sample characteristics

	Percent (n)	Mean (SD)	Range
Daily Exposures and Behaviors (N=1,065 days)			
Number of outlets within 100m of activity space polylines		4.27 (4.95)	0.00–27.07
Number of minutes within 100m of outlets within activity space		17.09 (47.29)	0.00–573.00
Any cigarette use on a day	9.95 (106)		
Number of cigarettes per day, full sample		0.40 (1.53)	0.00–18.00
Number of cigarettes per day, cigarette smokers only		1.76 (2.81)	0.00–18.00
Tobacco Use History and Demographics (N=100)			
Past month tobacco use	33.7 (34)		
Past month cigarette smoking	17.8 (18)		
Female	60.00 (60)		
Non-Hispanic White	37.00 (37)		
Age		18.16 (1.50)	16.00–20.00
Subjective SES[1]		3.80 (1.37)	1.00–7.00

[1]7-point scale from Poor (1) to Rich (7)

Table 2:

Results of multilevel mixed effects logistic regression model to assess associations between exposure to tobacco outlets within activity spaces and any cigarette smoking on a given day

	Any cigarette smoking per day			
	OR (95% CI)	**P value**	**OR (95% CI)**	**P value**
Number of outlets within 100m of activity space polylines	1.05 (0.96, 1.15)	0.242	--	--
Number of minutes within 100m of outlets within activity space	--	--	0.99 (0.98, 1.01)	0.813
Age	1.62 (0.74, 3.55)	0.229	1.61 (0.75, 3.51)	0.224
Female	0. 82 (0.93, 7.31)	0.861	0.89 (0.10, 7.92)	0.916
Non-Hispanic White	0.74 (0.77, 7.11)	0.797	0.78 (0.10, 7.39)	0.830
Subjective SES	0.61 (0.26, 1.44)	0.262	0.62 (0.28, 1.36)	0.234

Table 3:

Results of zero-inflated negative binomial regression model to assess associations between daily exposure to tobacco outlets within activity spaces and number of cigarettes smoked per day

	Number of cigarettes smoked per day			
	IRR (95% CI)	**P value**	**IRR (95% CI)**	**P value**
Number of outlets witdin 100m of activity space polylines	1.04 (1.01, 1.06) *	0.004	--	--
Number of minutes within 100m of outlets within activity space	--	--	1.01 (1.00, 1.01) **	0.000
Age	0.99 (0.68, 1.45)	0.964	0.94 (0.65, 1.37)	0.765
Female	1.24 (0.66, 2.33)	0.500	1.12 (0.65, 1.95)	0.676
Non-Hispanic White	1.18 (0.78, 1.81)	0.420	1.15 (0.78, 1.73)	0.474
Subjective SES	0.79 (0.69, 0.91) **	0.001	0.79 (0.69, 0.90) **	0.000

* $p \leq 0.05$;

** $p \leq 0.001$