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A geographically explicit ecological momentary assessment (GEMA) mixed method for understanding substance use

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## 1A geographically explicit ecological momentary assessment (GEMA) mixed method for 2understanding substance use

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## 12Research highlights

- 13 • We describe a novel mixed method for understanding substance use behavior  
14 • Mobile tobacco use surveys and GPS data were mapped and guided interviews  
15 • Reliable measures of situational factors associated with smoking were collected  
16 • Participant experiences of smoking contexts and practices were revealed  
17 • In-depth findings on marginalized smokers may inform tailored tobacco interventions

## 18Key words

19Ecological momentary assessment; geolocation; space-time geography; qualitative GIS; tobacco; health  
20disparities; United States; sexual and gender minorities

## 21Abstract

22Tobacco use is increasingly concentrated within marginalized groups, including LGBTQ+ young adults.  
23Developing tailored interventions to reduce tobacco-related health disparities requires understanding  
24the mechanisms linking individual and contextual factors associated with tobacco use to behavior. This  
25paper presents an in-depth exploration of three cases from a novel mixed method study designed to

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26 identify the situational factors and place-based practices of substance use among high-risk individuals.  
27 We combined geographically explicit ecological momentary assessment (GEMA) with an adapted travel  
28 diary-interview method. Participants (young adult bisexual smokers, ages 18-26) reported on non-  
29 smoking and smoking situations for 30 days with a smartphone app. GEMA surveys captured internal  
30 and external situational factors (e.g., craving intensity, location type, seeing others smoking). Continuous  
31 locational data was collected via smartphone GPS. Subsequently, participants completed in-depth  
32 interviews reviewing maps of their own GEMA data. GEMA data and transcripts were analyzed  
33 separately and integrated at the case level in a matrix. Using GEMA maps to guide the interview  
34 grounded discussion in participants' everyday smoking situations and routines. Interviews clarified  
35 participant interpretation of GEMA measures and revealed experiences and meanings of smoking  
36 locations and practices. The GEMA method identified the most frequent smoking locations/times for  
37 each participant (e.g., afternoons at university). Interviews provided description of associated situational  
38 factors and perceptions of smoking contexts (e.g., peer rejection of bisexual identity) and the roles of  
39 smoking therein (e.g., physically escape uncomfortable environments). In conclusion, this mixed method  
40 contributes to advancing qualitative GIS and other hypothesis generating approaches working to reveal  
41 the richness of individuals' experiences of the everyday contexts of health behavior, while also providing  
42 reliable measures of situational predictors of behaviors of interest, such as substance use. Limitations of  
43 and future directions for the method are discussed.

## 44 **Introduction**

45 Tobacco control policies have reduced smoking rates among higher income populations, leaving  
46 "smoking islands" (Thompson, Pearce and Barnett 2007) of high tobacco use among poor and minority  
47 groups. Understanding of how and why high rates of tobacco use persist among marginalized groups is  
48 needed to develop tailored interventions that can effectively reduce tobacco-related health disparities  
49 and experiences of social exclusion related to smoker stigma for these individuals (Blosnich, Lee and

50Horn 2013, Frohlich et al. 2012, Lee, Griffin and Melvin 2009, Pearce, Barnett and Moon 2012). Interest  
51in the roles of context in understanding tobacco and other substance use disparities has grown in recent  
52years (Thomas, Richardson and Cheung 2008, Barnett et al. 2017). Calls have been made for examining  
53not only area-level effects on tobacco use, (e.g., residential segregation (Moon, Pearce and Barnett  
542012)), but also the social contexts, social practices, and meanings of tobacco use from the perspectives  
55of smokers themselves (e.g., Blue et al. 2016, Poland et al. 2006, Frohlich et al. 2002, Glenn et al. 2017,  
56Pearce et al. 2012).

57Novel research methods could further propel tobacco research beyond identifying individual and area-  
58level predictors of tobacco use to understanding the underlying mechanisms linking these to behavior. To  
59this end, we present a novel mixed method for identifying and understanding the situational factors and  
60place-based practices of substance use. We piloted the integration of geographically explicit ecological  
61momentary assessment (GEMA) (Kirchner & Shiffman, 2016) with an adapted travel diary-interview  
62method similar to those often employed in space-time geographical studies (e.g., Schwanen and De Jong  
632008) to understand where and when individuals smoke, as well as how and why.

64Ecological momentary assessment (EMA) methods employ “repeated collection of real-time data on  
65subjects’ behavior and experience in their natural environments,” (Shiffman et al. 2008, 3). This can be  
66achieved through a variety of data collection tools, including written diaries, cell phones, electronic  
67diaries, and physiological sensors with which participants report on factors such as their current state,  
68activities, and observations of their surroundings. These momentary assessments are completed  
69repeatedly over a pre-defined time period (e.g., a month) (Shiffman et al. 2008). While most tobacco  
70surveillance studies ask participants to report global characterizations of their tobacco use (e.g., ‘How  
71many cigarettes do you smoke per day on average?’), a key methodological advantage of EMA is that it  
72largely avoids retrospective recall, which is systematically biased toward emotionally salient or unique

73experiences, dependent upon context and mood at the time of recalling events, and biased by cognitive  
74heuristics used to summarize experience (Shiffman et al. 2008).

75Tobacco use is particularly well-suited for study with EMA because it is an episodic behavior with  
76discernable small-scale events thought to be related to mood and context as the individual goes about  
77everyday life (Thrul, Buhler and Ferguson 2015, Thrul, Labhart and Kuntsche 2017, Shiffman 2009,  
78McCarthy et al. 2006, Ferguson and Shiffman 2011). Recently, the EMA method has been expanded by  
79integrating Global Positioning System (GPS) tracking data; referred to as geographically explicit ecological  
80momentary assessment (GEMA) (Epstein et al. 2014, Mitchell et al. 2014, Chow et al. 2017, Kirchner and  
81Shiffman 2016). GEMA allows for spatial analyses of relationships such as those between participant self-  
82reports (e.g., drug craving intensity), location types (e.g., home) and objective environmental ratings  
83(e.g., neighborhood disorder).

84GEMA is an ecologically strong approach to understanding tobacco use contexts because it conceives of  
85an individual's interaction with their environment in terms of their activity space, meaning everywhere  
86they actually spend time in everyday life in addition to their place of residence (e.g., commuting path,  
87friends' homes, nightlife venues) (Shareck et al. 2015). However, because GEMA surveys must be kept  
88short to reduce participant burden and encourage data collection compliance, they cannot capture the  
89richness of individuals' experiences of smoking contexts and practices. These types of interactions  
90between the individual and their activity space locations are key to understanding environmental  
91influences on social or health outcomes (Mennis, Mason, & Cao, 2013), such as tobacco-related health  
92disparities.

93Space-time geography also takes an activity space approach, focusing on individuals' continuous paths  
94through time and space in understanding human behavior and experience (Rainham et al. 2010). A  
95qualitative space-time geographical approach may shed light on the experiential and relational

96dimensions missing from GEMA measures that interplay with how and why tobacco use folds into  
97individuals' space-time paths.

98Qualitative and mixed methods space-time geographical approaches have examined individuals'  
99experiences of logistical constraints on their movements through time and space (e.g., limited reach in  
100space due to reliance on public transit (Hernandez and Rossel 2015), juggling everyday activities (e.g.,  
101managing work demands alongside parenting activities (Schwanen 2008)), arrhythmias between the  
102body and everyday environments (e.g., older age (Lager, Hoven and Huigen 2016)), and embodied  
103experiences of everyday contexts that influence mobility (e.g., feeling unwelcome in a high-end store  
104due to one's appearance (McQuoid and Dijst 2012)).

105Similar to EMA diaries, participants in space-time geographical studies have used travel diaries in real  
106time over a number of sample days to record information such as where they go, transportation modes,  
107activities performed, and times of departure and arrival (e.g., Berg et al. 2014, McQuoid, Jowsey and  
108Taulikar 2017, McQuoid 2017). These diaries guide subsequent interviews, prompting participants to  
109recreate the sample days. This grounds discussion in participants' everyday contexts and encourages  
110description of experiences, routines, and habits that participants might otherwise find too mundane or  
111unremarkable to bring up. Travel diaries could be replaced by viewing and discussing maps of the  
112participant's GEMA data, providing interviewer and interviewee the opportunity to reflect on spatial  
113patterns of tobacco use and discuss experiential dimensions of tobacco use contexts and practices.

114A growing body of research has integrated geographic information systems (GIS) with qualitative data  
115and methods to explain the processes producing spatial patterns, knowledge, relationships, and  
116interactions, and their resulting social and political impacts (Elwood & Cope, 2009). Some have used  
117qualitative data and GIS as separate but complementary research components, as in the use of GPS  
118tracking, ethnographic observation, and in-depth interviews (Naybor et al., 2016, see also Pavlovskaya,

1192004). Others have visualized and interpreted qualitative data within a GIS software platform. For  
120example, participants use the VERITAS web mapping application to mark activity space locations and  
121trips and draw perceived neighborhood boundaries (Chaix et al., 2012). Meijering and Weitkamp (2016)  
122merged information recorded in participant travel and activity diaries with the GPS tracking data, which  
123informed the content discussed in subsequent interviews. Geo-narrative (Kwan, 2008; Kwan & Ding,  
1242008) uses GIS to visualize emotions associated with different times and locations along participants'  
125daily space-time paths (e.g., colored red to illustrate fear), geo-references various qualitative data  
126sources (e.g., memos and photos), and integrates basic qualitative data coding functions within GIS.  
127Mennis and colleagues (2013) used structured interviews to collect data on participants' activity space  
128locations, including perceptions of safety and risk in these places. They then visualized participants'  
129perceptions, interpretations, and feelings about everyday locations with cartographic symbols.

130One prior GEMA study incorporated a qualitative GIS approach (Pearson et al. 2016) consisting of a  
131'place' survey wherein research assistants sat with participants and geo-tagged their personal mobility  
132maps with tobacco rules and norms for locations participants had visited. Additionally, some EMA  
133studies have used qualitative methods, such as interviews, before or after EMA data collection to inform  
134EMA study design or assess participant acceptability of data collection protocol (e.g., Attwood et al.  
1352017, Naughton et al. 2016, Brookie et al. 2017). To our knowledge, no prior study has employed a  
136qualitative GIS mixed method design in which participants discuss and interpret maps of their GEMA  
137data regarding reported behaviors (e.g., smoking) and experiences (e.g., nicotine cravings) during in-  
138depth interviews.

139We draw from a GEMA-interview mixed method pilot study to provide an in-depth exploration of three  
140bisexual young adult smokers in the San Francisco Bay Area. Bisexual individuals are an exemplar group  
141for studying tobacco-use disparities, as little is known about why tobacco use rates are higher nationally

142among bisexuals than heterosexual, gay, or lesbian individuals (Emory et al. 2016). Proposed  
143explanations for elevated tobacco use among sexual and gender minorities as a group include the  
144minority stress model (Blosnich et al. 2013, Meyer 2003), having smokers in one's peer network  
145(Remafedi 2007), the role of bars in sexual and gender minority communities and the pleasure-  
146enhancing relationship between alcohol and nicotine (Blosnich et al. 2013, McKee et al. 2004, Gubner et  
147al. 2017), tobacco retail and marketing density in neighborhoods with concentrations of same-sex  
148couples (Lee et al. 2016), and the targeting of sexual and gender minorities in tobacco marketing  
149campaigns (Stevens, Carlson and Hinman 2004).

150We aim to understand: 1) participants' spatial and temporal patterns of smoking and cravings; 2)  
151situational factors and place-based practices driving patterns of smoking and cravings; and 3) how, if at  
152all, bisexual identity interplays with situational factors and place-practices of smoking and cravings. We  
153discuss the complementarity, strengths, and weaknesses of the mixed method and conclude with future  
154directions for research and applications.

## 155 **GEMA-Interview Mixed Method**

### 156 **Study design**

157We employed an explanatory sequential mixed method approach (Figure 1) (Curry and Nunez-Smith  
1582015, Onwuegbuzie and Teddlie 2003). Participants were recruited from a larger GEMA study of smokers  
159ages 18-26 in Alameda and San Francisco Counties, California (n=145). Eligible participants smoked at  
160least 100 cigarettes in their lifetime, currently smoked at least one cigarette per day at least three days  
161per week, and owned and used daily a smartphone with GPS capabilities. Participants were recruited  
162through Facebook and, to a lesser extent, Craigslist and LGBTQ youth serving organizations.  
163Advertisements linked to the study's website with an eligibility questionnaire. If eligible, participants



164were taken to the informed consent webpage. In order to verify participants' identities, participants sent  
165a picture of their ID.

166For the mixed methods pilot, those with medium or high GEMA data compliance (completed >50% of  
167prompted GEMA surveys) were recruited to ensure adequately rich GEMA data at the case level. Those  
168who selected 'bisexual' and/or wrote in 'pansexual' or 'queer' on the baseline survey were selected for  
169the mixed method pilot. We use 'bisexual' in this paper as short-hand for expressing attraction to one's  
170own and other genders.

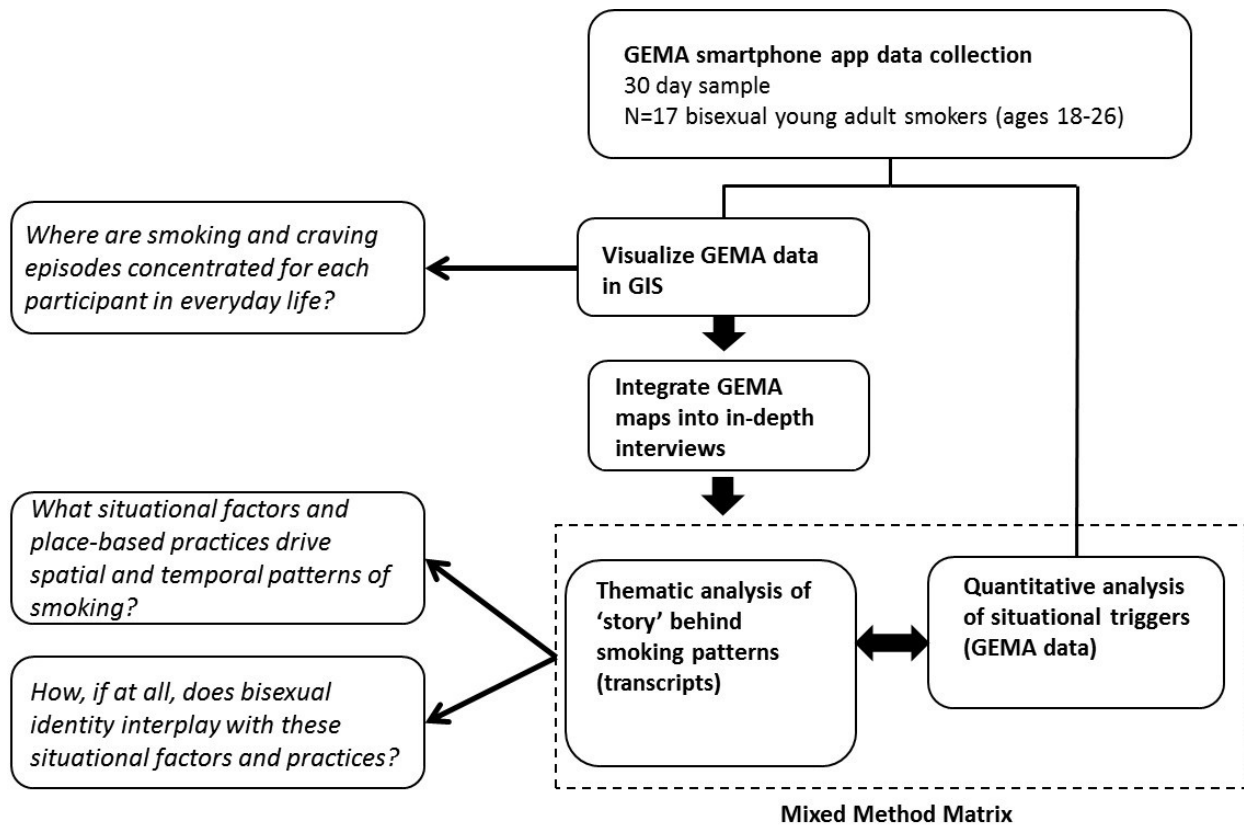
171The resulting sample (n=17) was composed mostly of female young adults (ages 18-26) who all identified  
172as bisexual, pansexual, and/or queer. Most identified as bisexual (76%) and cisgendered female (71%)  
173with three gender queer individuals assigned female at birth and two cisgendered men. They were from  
174a variety of socioeconomic backgrounds as determined by mother's highest education and a variety of  
175racial/ethnic groups, although African Americans were under-represented.

176Participants received up to \$180 in incentives in the form of an Amazon Gift Card. Incentive amounts  
177varied by participant compliance with the smartphone app administered surveys. Participants received  
178\$60 for completing the face-to-face interview.

179First, GEMA data were collected using a smartphone app over a 30-day period. Then, qualitative data  
180were collected, consisting of in-depth interviews guided by maps of participants' GEMA data that  
181visualized their paths over the course of data collection and spatial patterns of smoking and cigarette  
182craving reports. The interviews informed and interpreted the quantitative data in greater depth. The  
183quantitative and qualitative data sets were analyzed separately and then integrated in a Mixed Method  
184Matrix (O'Cathain, Murphy and Nicholl 2010). Quantitative and qualitative findings were discussed for  
185each case. Then, we performed a qualitative cross case analysis to discover patterns across all cases  
186regarding the situational factors and place-based practices driving smoking patterns, as well as the role

187of bisexual identity. Ethics approval for this study was granted by University of California, San Francisco  
 188Institutional Review Board.

189**Figure 1: GEMA-interview mixed method study design**



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191 **Geographically Explicit Ecological Momentary Assessment (GEMA)**

192 **smartphone method**

193 Participants completed a baseline survey on an online survey platform (Qualtrics) regarding basic  
 194 demographics, smoking history, and current behavior. GEMA data were collected using the PiLR Health  
 195 platform (pilirhealth.com). Participants used their own smartphones and the study app to collect data on  
 196 non-smoking and smoking situations over 30 days. The study app collected continuous location sensor  
 197 data throughout the data collection period (we aimed for a data point every two minutes; in reality, the  
 198 frequency varied across phone operation systems (Android vs. iOS), OS version, and phone type).

199Participants were instructed to report every time they smoked a cigarette (*cigarette reports*). A random  
200subset of up to a maximum of three of these cigarette reports each day triggered a survey prompt  
201(*smoking surveys*). The likelihood for a cigarette report to trigger a smoking survey was adjusted  
202according to the participant's baseline smoking rate. Participants were also prompted at random three  
203times per day (*random surveys*) to complete a survey to allow for assessment of non-smoking as well as  
204smoking situations. These procedures are consistent with those previously reported in the literature  
205(Jahnel et al., 2017, Shiffman et al., 2002, Shiffman & Paty, 2006). Researchers could access the GEMA  
206platform backend and download participant data.

207Smoking survey and random survey questions were developed from the literature and our previous  
208studies (Thrul, Bühler and Ferguson 2014, Thrul et al. 2015, Cronk and Piasecki 2010, Kirchner et al.  
2092013). Questions examined aspects of each sampled situation that were both internal and external to  
210the individual. For example, to capture 'internal' factors, participants were prompted to report their  
211mood and intensity of their cigarette craving. For 'external' factors, participants reported what type of  
212location they were in, if they were drinking or eating, and if specific smoking triggers, such as others  
213smoking, ashtrays, or tobacco advertisements, were present, for example. The number of survey  
214questions was limited to prevent interference with participants' daily activities. The GEMA software  
215automatically logged participants' responses with GPS coordinates for every completed survey to collect  
216a location data point exactly when the survey was submitted. All data were time and date-stamped to  
217allow for temporal analysis of smoking behavior.

218GEMA data were descriptively analyzed using Stata 14 (StataCorp 2015). For the present analysis,  
219cigarette reports and smoking surveys were examined, focusing on smoking locations, times of high  
220frequency of smoking at each location, presence of others, and reports of specific smoking triggers (e.g.,

221ashtrays, cigarette packs). Baseline survey data were used to compare and contrast the GEMA data with  
222how participants globally recall and report their smoking behavior.

### 223**Map-interview method**

224GEMA data were visualized in ArcGIS upon completion of the GEMA data collection period for each  
225participant. Map layers were created to visualize where participants went during the data collection  
226period (using location sensor data), where they had reported high cravings for tobacco (using smoking  
227survey and random survey data), and where they had reported smoking (using cigarette report data).  
228Map layers were made for the entire 30-day GEMA data collection period, one weekday, and one  
229weekend day as close to the interview date as possible to increase the likelihood that participants could  
230recall the experiences and events of those two sample days.

231Interviews were held within a few days of GEMA data completion. The first author conducted the  
232interviews, which lasted about an hour. During interviews, the participant was shown the map layers of  
233high cravings, cigarette reports, and location sensor data on a laptop in Google Earth. The interviewer  
234toggled between the map layers to reveal differences in spatial patterns (e.g., areas where the  
235participant had frequently reported high cravings but not many cigarette reports). The participant was  
236invited to explore the data by zooming in and out and panning over the maps. The interviewer prompted  
237the participant to discuss apparent spatial clusters of reported smoking and high cravings as well as  
238places where they had spent time but did not report these tobacco use experiences and behaviors. This  
239encouraged discussion regarding the locations, times, triggers, situational experiences, and routines  
240linked to the use of and craving for tobacco in everyday life. Then, the maps of two recent sample days  
241were shown. The participant was asked to 'lead' the interviewer through each sample day, providing  
242such vivid 'play-by-play' detail of their activities, movements, and experiences, including tobacco use and

243craving episodes, that someone could make a movie of their day. Participants spontaneously compared  
244or were asked to compare and contrast the events of those sample days with their 'usual routine.'

245Interviews were audio recorded, transcribed verbatim, and coded by the first author in Dedoose  
246qualitative analysis software (SocioCultural Research Consultants 2015). Memos of initial impressions of  
247the data were kept throughout data collection and initial coding. Analysis aimed at identifying the  
248situational factors and place-based practices of smoking driving the spatial and temporal patterns of  
249smoking identified in the GEMA maps and descriptive analysis, and to reveal how, if at all, bisexual  
250identity interplays with these situational factors and place-based practices. Thematic analysis followed  
251an integrative inductive-deductive approach (Bradley, Curry and Devers 2007). The initial coding list was  
252developed from domains from the GEMA surveys to facilitate integration of the qualitative and  
253quantitative data at the case level: smoking location types (e.g., home, car), smoking episodes, and  
254cravings for cigarettes. Then, excerpts concerning smoking episodes and cravings were re-examined by  
255location type to identify emergent themes regarding the experiences driving smoking and cravings in  
256each location (e.g., experiences of marginalization due to sexual identity; feeling fatigue) and the role of  
257tobacco in these situations (e.g., escape; impose a break and energize).

### 258Data integration

259Following independent data analysis of the quantitative and qualitative data sets, the first and second  
260authors met to discuss their findings for three cases. This provided discoveries of where findings were in  
261disagreement or alignment, weaknesses in each method, and where one method complemented the  
262other. It also provided an opportunity to follow a thread of interest (O'Cathain et al. 2010) from one data  
263set to the other. For example, if a dramatic shift in a participant's cigarette consumption pattern was  
264observed in the GEMA data, the transcript could be searched for content to explain this shift. The first  
265author kept memos regarding these observations throughout the findings presentation and discussion

266process. The GEMA and map-interview findings were then integrated for each case in a Mixed Method  
267Matrix (O’Cathain et al. 2010). The rows represented each case and the columns contained findings from  
268the baseline survey, cigarette reports, smoking surveys, and interviews.

### 269 **Exploring three cases**

270Figure 2 depicts an abbreviated version of the Mixed Method Matrix. Data sources are listed in the  
271second row. We explore these cases below, focusing on what each method brought to our understanding  
272of each case, methodological weaknesses that emerged in analysis, and ways in which the GEMA and  
273map-interview methods complemented one another. Pseudonyms were assigned to each case, some  
274participant details were changed, and maps of participant data are displayed without georeferencing  
275information such as streets and landmarks to protect participant confidentiality.

276Figure 2: Mixed Method Matrix, Three Cases

	Participant recall (past 30 days)	Smoking regularity	Frequent smoking locations	Frequent smoking times	Smoked alone?	Smoked alone, locations/ times	Smoking triggers	Smoking location experiences	Role of smoking
Data source	Baseline survey	Cigarette reports	Smoking Surveys	Cigarette reports	Smoking Surveys	Smoking Surveys	Smoking Surveys	Interview	Interview
<b>Stacey</b>	Smoked 30 out of the past 30 days  Average 5 cigarettes per day  Not within first 30 min. of day	3-11 cigarette reports per day  Average 6 per day	Home (34%): Morning, evening  Vehicle (29%): Morning, afternoon  Restaurant (13%): Afternoon, evening	Morning (37%)  Afternoon (34%)  Evening (29%)	Alone (65%)  Around others (35%): Partner, Family	Home: morning and afternoon  Car: Morning, afternoon	Others smoking (13%)  Lighter/ matches (7%)  Cigarette pack (3%)	- <b>School</b> : Feeling of failure in classes. Overhears racial/sexual discriminatory slurs. - <b>Car</b> : Bad commute traffic, feeling late. - <b>Home</b> : Feeling of failure about living with parents. Struggles with homework. Drinks alcohol with family and boyfriend. - <b>Walking</b> : Feels good. Liminal space between stress of school and home. - <b>Restaurant/Bar</b> : Mentioned lunch with family with alcohol.	- <b>School</b> : Smokes in parked car to escape and take a break from studies. - <b>Car</b> : Stress coping. - <b>Home</b> : Regroup and take a break outside the house. Co-use with alcohol. - <b>Walking</b> : Transitional practice. - <b>Restaurant/Bar</b> : Co-use with alcohol.
<b>Sofia</b>	Smoked 30 out of the past 30 days  Average 5 cigarettes per day  Not within first 30 min. of day	1-8 cigarette reports per day  Average 2.8 per day	Other's home (40%):  Afternoon, evening  Other (walking) (23%): Afternoon  Workplace (13%): Afternoon, evening	Afternoon (46%)  Evening (37%)  Morning (18%)	Alone (36%)  Around others (64%): Partner, Friends, Co-workers	Other's home: Afternoon  Other (walking): Afternoon	Lighter/ matches (32%)  Ash tray (28%)  Others smoking (15%)	- <b>School</b> : Confusing schedule. Skips breakfast. Few smoking restrictions. Smoking acceptance in "queer co-ops". Biphobia in LGBT settings. - <b>Work</b> : Tiring. Buys cigarettes at corner store. Smokes before and after work & on breaks. - <b>Partner's home</b> : Mostly sleeps here. Does not like to smoke around boyfriend, but smokes outside his building. - <b>Walking</b> : When alone no shame, smoking restrictions.	- <b>School</b> : Feeling of routine/stability. Hunger suppressant. Smoking stigma bonds "outcast" group - <b>Work</b> : Energizes. Maintain sense of routine. Positive association with work break. Relax and reward after work. - <b>Partner's home</b> : Satisfy addiction. Cope with stress. Maintain sense of routine. - <b>Walking</b> : Habitual association. Opportunity to satisfy addiction without shame.
<b>Adrian</b>	Smoked 18 out of the past 30 days  Average 6 cigarettes/day  Not within first 30 min. of day	1-29 cigarette reports per day  Average 5.6 per day	Home (72%): Morning, evening  Vehicle (9%)  Other (9%)	Morning (36%)  Evening (36%)  Afternoon (28%),	Alone (78%)  Around others (22%): Friends Co-workers	Home: Morning, evening	Lighter/ matches (28%)  Cigarette (19%)  Ash tray (6%)	- <b>Home</b> : No smoking restrictions. Works a lot. Visual triggers. Romantic breakup. Fears alcohol dependence. - <b>School</b> : Stressful. Informal exceptions to campus smoking ban. Hides smoking from faculty. Emotional/mental labor managing bisexual identity. - <b>Restaurant/Bar</b> : Smoking breaks with lesbian/gay students. Experiences biphobia. Difficult to indicate romantic interest to same-sex strangers. - <b>Fieldwork sites</b> : Professional image. Stigma for smoking cigarettes in public.	- <b>Home</b> : Sooth, stay awake, prepare for activity outside of home. Continues smoking to avoid alcohol dependence. - <b>School</b> : Calm down, escape, and regroup from school demands and biphobia. Vapes to avoid smoking stigma. - <b>Restaurant/Bar</b> : Bonding with lesbian/gay smokers. Uses cigarette/light exchange as prop for signaling romantic interest to same-sex. - <b>Fieldwork sites</b> : Vapes to avoid smoking stigma.

## 223 **Stacey**

224 Stacey is a White, non-Hispanic, cisgendered, bisexual woman in her mid-20's. She lives at home with her  
225 parents in an outer suburb and is studying full-time at a community college. In the baseline survey, she  
226 reported being a daily smoker, smoking five cigarettes per day on average, and never smoking within the  
227 first 30 minutes of waking (an indicator of nicotine dependence) (Shiffman et al. 2008).

228 The GEMA data provided a more reliable and contextualized picture of Stacey's smoking behavior. Her  
229 GEMA data showed she smoked slightly more per day than reported in her baseline survey. She smoked  
230 most frequently at home, in her vehicle, and at restaurant/bars, during the morning, afternoon, and  
231 slightly less in evenings. She usually smoked alone, overwhelmingly so while in her car and to a large  
232 extent while at home. Her smoking did not seem driven by seeing other smokers (Remafedi 2007), or by  
233 common visual triggers for smoking, such as tobacco advertising (Stevens et al. 2004, Lee et al. 2016).  
234 What, then, drove Stacey's smoking within the times and places she smoked most?

235 The map-interview revealed the experiences and smoking practices embedded within Stacey's frequent  
236 smoking locations and times. The locations most relevant to her smoking did not entirely match those  
237 identified by her GEMA data (home, vehicle, restaurant/bar). Contrary to Stacey's craving and cigarette  
238 report maps, the most intensively discussed locations were school, car, home, walking, and to a lesser  
239 extent restaurant/bar. The GEMA data did not indicate 'school' or 'walking' as frequent smoking  
240 locations, and a restaurant was only discussed fleetingly during the interview in reference to a family  
241 lunch. The integration of findings from both methods allowed us to obtain a clearer and more nuanced  
242 picture of Stacey's smoking behavior in several ways.

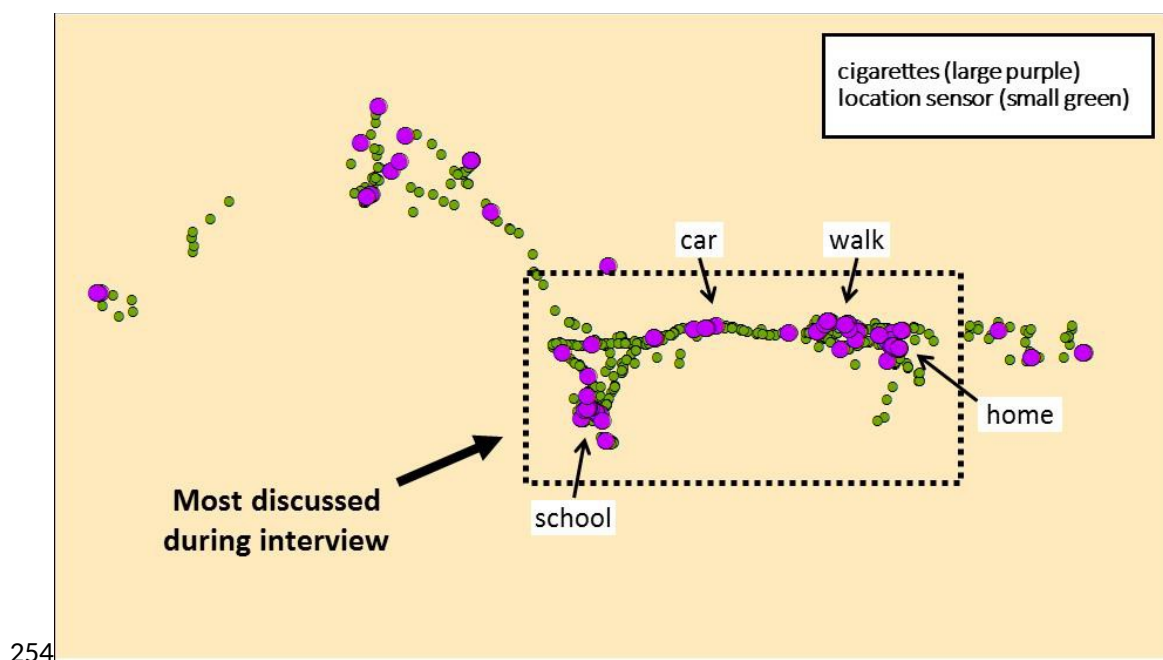
243 First, the interview revealed an additional meaning of 'smoking in the car' obscured in the smoking  
244 survey data. While reasonable interpretation of the smoking survey data suggests she smoked a lot while  
245 driving, the interview clarified that she also smoked frequently in her car while parked at school



246(discussed in more detail below). Therefore, a substantial number of cigarettes reported as smoked in  
 247her 'car' in the smoking surveys might more accurately be reported as 'school'.

248Second, the discrepancy between the most relevant smoking locations may also be due to recall bias  
 249toward intensely emotional experiences (Shiffman et al. 2008). While restaurants/bars are one of  
 250Stacey's top three most frequent smoking locations on surveys, they were likely glossed over during the  
 251interview because Stacey's smoking practices in other locations - school, car, home, and while walking -  
 252were associated with more emotionally compelling experiences (Map 1).

253**Map 1: Stacey's smoking reports and location sensor data, 30 days**



255Stacey described intensely negative experiences linked to smoking at school, in her car, and at home,  
 256while smoking while walking was experienced as largely positive. At school, Stacey experiences failure in  
 257her classes. She overhears students using racial and homophobic slurs and homophobic comments from her  
 258lesbian and gay peers both at school and at parties and events. Smoking provides her with a reason to  
 259physically escape this negatively experienced environment, as smoking is restricted to the school parking

260lot. While driving to and from school, she chain smokes to cope with “miserable” commute traffic. At  
261home, she feels like a failure for having moved back in with her parents. She struggles with homework  
262and drinks alcohol with her family and boyfriend. She steps outside the house to smoke, take a break  
263and regroup, and is also likely driven in her smoking by co-use with alcohol. While walking dogs in her  
264neighborhood after school, however, smoking is a distinctly positive experience. She experiences this  
265time between school and home as a liminal space. Smoking becomes a transitional practice with which  
266to “turn the page” on her day.

267In short, the GEMA data complemented the interview by compensating for participant discounting of  
268seemingly unremarkable events (e.g., smoking at restaurants/bars) and recall bias toward emotionally  
269powerful experiences. The map-interview complemented the GEMA by clarifying the meaning of  
270locations reported in smoking surveys (e.g., the parked car as a cocooned environment at school), and  
271provided insight into the experiences and place-based practices that help explain why Stacey smokes  
272most frequently in particular places and at particular times, including concrete smoking experiences  
273related to minority stress (Blosnich et al. 2013) and intragroup marginalization (Callis 2013) as a bisexual.

#### 274Sofia

275Sofia is an Hispanic, cisgendered, bisexual woman in her late teens. While her smoking surveys showed  
276both cigarettes and a small amount of smokeless tobacco (e.g., chew) use, she clarified during the  
277interview that the smokeless tobacco reports were app user error. She lives in a university dorm in an  
278urban environment, studying full-time and working full-time.

279In the baseline survey, Sofia reported being a regular smoker, smoking five cigarettes per day on average,  
280and never smoking within the first 30 minutes of the day. Her cigarette report data indicated fewer  
281cigarettes per day than indicated in the baseline survey. As the interview did not indicate a shift from her  
282usual smoking pattern, she may have under-reported her cigarette consumption during GEMA data

283collection. She smoked most often at someone else's home, an 'other location' she wrote-in as 'walking',  
284and at work, mostly in the afternoon and evening. When she smoked she was most often around others;  
285usually her boyfriend, friends, or co-workers. Relevant visual smoking triggers for Sofia were seeing  
286lighters/matches, an ash tray, and others smoking. In short, the GEMA data suggests Sofia smokes most  
287often at someone else's home, while walking, and at work, in the afternoon and evening. Seeing tobacco  
288paraphernalia and often being around other smokers may be driving her cigarette use.

289The map-interview described Sofia's experiences and smoking practices within the same locations  
290identified by the GEMA method (other's home, walking, workplace). It also added the relevance of her  
291school experience, including her difficulties juggling everyday activities and how this interplays with  
292smoking. Sofia often has troubles keeping track of her work and class schedule and skips breakfast. Her  
293cigarette consumption increased dramatically within a week of moving out of her family home into the  
294university environment. Informal exceptions to the university campus smoking ban and the absence of  
295family disapproval means she can "smoke whenever I want". Smoking is a hunger suppressant and  
296provides her with a momentary sense of calm and a portable practice with which to impose rhythmic  
297regularity and a sense of routine on her complex work-school schedule (see also Blue et al. 2016).

298The interview revealed that the 'other's home' location reported in the smoking surveys is her non-  
299smoker boyfriend's home where she sleeps most nights and smokes outside of his building. Her full-time  
300food service job is located next to a corner store where she buys cigarettes. She smokes before and after  
301work and on breaks. Smoking gives her energy when she is tired and she associates it positively with  
302being on break and rewarding herself after work. While walking alone between work, classes, and her  
303and her boyfriend's homes, Sofia can smoke without feeling ashamed in front of her non-smoker friends  
304and boyfriend. She identified a strongly habitual relationship between stepping outside alone to walk  
305somewhere with reaching for her cigarette pack.

306In short, the smoking locations discussed in Sofia's interview matched those identified in the smoking  
307surveys, offering a smooth flow from the quantitative GEMA findings regarding Sofia's spatial patterns of  
308smoking to in-depth qualitative findings regarding her experiences and place-based practices within  
309smoking locations.

### 310Adrian

311Adrian is a Latino, cisgendered, bisexual man in his early 20's. He is in graduate school and active in  
312LGBTQ+ organizing. Adrian smokes cigarettes and uses a nicotine vaporizer ("vape pen"). He lives in an  
313urban environment in an apartment with one housemate. Adrian reported smoking 18 out of the past 30  
314days on his baseline survey, with an average of six cigarettes per day. Like Stacey and Sofia, he did not  
315report smoking upon waking. His average daily cigarette consumption recorded with the GEMA app was  
316comparable to the baseline survey.

317Adrian's cigarette reports showed wide consumption fluctuation over the data collection period (range:  
318one to 29 cigarettes per day), reporting far fewer cigarettes in the first two weeks of data collection than  
319in the final two. While this could indicate user or functional app error, the interview revealed that he  
320went through a romantic breakup and unexpected school demands that precipitated the smoking surge.  
321While the cigarette reports were therefore likely reflective of his actual use, the 'binge' posed a serious  
322challenge for the GEMA method. Because the smoking surveys were triggered in anticipation of a lower  
323number of cigarettes per day and capped at a maximum number of three, the smoking surveys collected  
324for this participant in the second half of the data collection period are more reflective of morning  
325smoking episodes. Therefore, the smoking survey data cannot reliably speak to situational factors of  
326smoking later in the day.

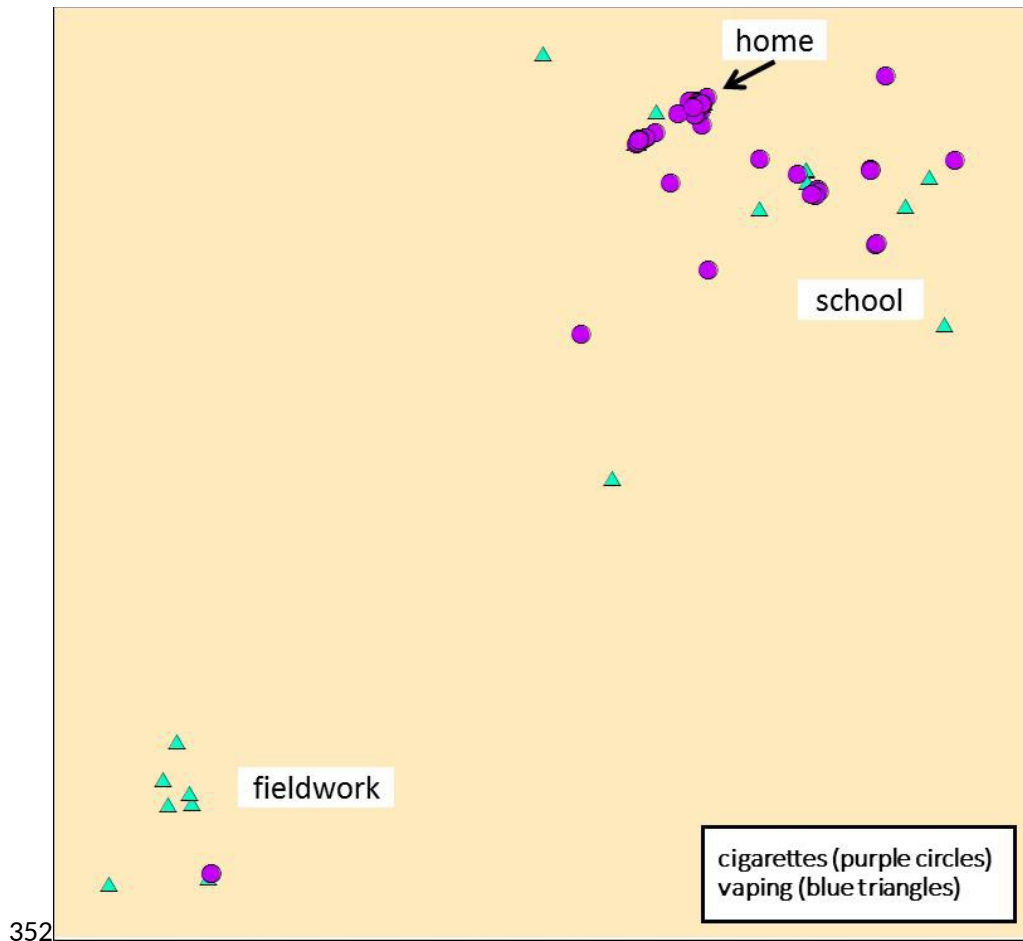
327The morning-focused smoking survey data suggested Adrian smoked mostly at home. However, cigarette  
328reports showed he smoked fairly evenly across the day, suggesting greater diversity in smoking locations.

329Overwhelmingly, smoking surveys indicated he smoked alone, and if not alone, around friends, co-  
330workers, or acquaintances. At home, he mostly smoked alone and in the morning and evening. Based on  
331the question about specific smoking triggers, two visual triggers seemed relevant to Adrian: seeing  
332lighters/matches and cigarettes.

333The interview helped balance the morning-biased picture created by the smoking surveys. As in the  
334smoking surveys, home was discussed as the most important smoking location. Other smoking locations  
335were school, fieldwork, LGBTQ+ organizing sites, and restaurants/bars. Vehicles were mentioned only in  
336passing. Home is where Adrian does most of his graduate and LGBTQ+ organizing work. While he  
337conceals smoking in other settings, at home he leaves visual triggers such as lighters lying around. He  
338and his roommate do not have tobacco restrictions for the apartment. Adrian smokes while he works, to  
339stay up at night, and feel “more at ease” for upcoming outside activities (e.g., public speaking). Home  
340was also primarily where he grieved his romantic relationship. Adrian fears that if he quits nicotine  
341during a stressful time he will drink too much alcohol. As such, his continued nicotine use is a strategy for  
342avoiding what he perceives as more concerning substance use.

343Adrian discussed graduate fieldwork and LGBTQ+ organizing sites during the interview; most likely the  
344‘other’ locations reported in the smoking surveys. Adrian’s maps of cigarette and vaping reports showed  
345contrasting spatial patterns of consumption for the two tobacco products (Map 2). This prompted  
346discussion regarding the situations in which Adrian uses one tobacco product over the other. He  
347explained that university, fieldwork, and LGBTQ+ organizing places are “areas of high investment” where  
348he wants to create a professional image and do “damage control” against smoker stigma, unlike home  
349where he freely smokes cigarettes. Adrian finds vaping to be more socially acceptable and therefore tries  
350to either hide cigarette consumption or vape in “high investment” places.

**351Map 2: Cigarette and vaping reports selection, 30 days, Adrian**



353At university, Adrian manages his bisexual identity as well as his professional image. He described feeling  
 354that his bisexual identity is “interrogated” by lesbian and gay graduate cohort members. He feels he must  
 355perform a “trapeze line walk” as a bisexual man in order to be accepted as an organizer in the LGBTQ+  
 356community and not be perceived as a “predator” by lesbian/bisexual women, all the while without  
 357negating the aspect of his identity that involves attraction to women. Within straight spaces, he tries not  
 358to be perceived as gay. He describes this performative identity management as “emotional/mental  
 359labor” from which smoking helps him calm down, escape, recharge, and regroup in the moment.

360Finally, the interview shed light on an important evening smoking location not adequately captured in  
 361the Adrian’s smoking surveys: restaurants/bars. Adrian frequently attends happy hours at bars where he  
 362smokes outside with his lesbian and gay graduate cohort members. Discovering that they smoke was a

363bonding point for them. Adrian also finds smoking provides a prop for initiating interaction with  
364strangers of the same sex. While he finds women more readily interpret contact from unknown men as  
365an indication of romantic interest, Adrian finds it harder to communicate interest to other men by simply  
366starting a conversation. He finds that exchanging a cigarette or light facilitates physical proximity and  
367exchange of something of value.

368In short, the integration of the interview with the GEMA data confirmed that Adrian's smoking pattern  
369did shift dramatically over the final two weeks of data collection. While this challenged the reliability of  
370the smoking survey data regarding situational factors associated with cigarettes smoked later in the day,  
371the interview helped compensate for this by providing insight into the experiences and smoking  
372practices of evening smoking locations (e.g., bars). Viewing the maps of cigarette and vaping reports  
373during the interview sparked discussion that may not have otherwise arisen regarding the participants'  
374contextually-dependent use of different tobacco products.

## 375Discussion

376This paper presented a mixed method combining geographically explicit ecological momentary  
377assessment (GEMA) and an adaptation of the travel diary-interview method often employed in space-  
378time geography, exploring three cases of bisexual young adult smokers. The integration of a qualitative  
379GIS approach with GEMA is a contribution to GEMA studies (Epstein et al. 2014, Pearson et al. 2016,  
380Mitchell et al. 2014, Chow et al. 2017, Kirchner and Shiffman 2016) and mixed methods space-time  
381geographical approaches (Schwanen and De Jong 2008, Naybor et al. 2016). Together, these methods  
382identified each participants' most frequent smoking locations/times (e.g., afternoons on university  
383campus) and associated situational factors (e.g., seeing tobacco paraphernalia). It revealed participant  
384experiences of smoking locations/times (e.g., peer rejection of bisexual identity at school) and the role of  
385tobacco use therein (e.g., physically escape uncomfortable environments). These exploratory findings



386 suggest the potential to illuminate how smoking as a practice is embedded and perpetuated within the  
387 everyday contexts of individuals' lives, identifying pathways between the characteristics and social  
388 contexts of where they live, their individual attributes, and their smoking behavior (Pearce et al. 2012,  
389 Poland et al. 2006, Frohlich et al. 2002). They suggest the ability to describe the spatio-temporal patterns  
390 of smoking practices, as well as the materiality, competencies, and meanings that fold into their  
391 reproduction in everyday life (Blue et al. 2016).

392 The inductive advantages of visualizing and exploring self-reported data with participants can help  
393 generate hypotheses about the contexts of health behaviors (Mennis et al. 2013), such as how and why  
394 in everyday life smoking is linked to stress for marginalized groups (Blosnich et al. 2013, Meyer 2003). It  
395 may provide a window into the concrete everyday situations in which the stresses of having a  
396 stigmatized or minority status manifest and provide the practice of smoking with meaning and utility for  
397 the individual. More practical contributions may include identifying for a particular group the most  
398 relevant places for tobacco intervention outreach, the situational factors and experiences of smoking  
399 most important to address in cessation support and counseling materials, and the unique smoking  
400 practice-related experiences that must be acknowledged in order to engage individuals with tobacco  
401 prevention messages and treatment.

## 402 **Strengths**

403 The integration of the GEMA and map-interview methods demonstrated several advantages in  
404 understanding participants' everyday contexts and practices of smoking. One was in providing  
405 opportunities for confirmation of findings (O'Cathain et al. 2010). For example, Adrian's cigarette 'binge'  
406 in the second half of his GEMA data collection period appeared at first due to either participant  
407 compliance or app functioning, but was confirmed by the interview as a credible representation of his  
408 consumption pattern. Furthermore, analyzing both data sets by smoking location offered opportunities

409for confirmation of the most relevant locations for each participant from both the cumulative  
410perspective of the GEMA data and the global perspective of the participant, as observed in Sofia's GEMA  
411and interview data where smoking locations mapped onto each other. We also observed confirmation  
412regarding visual smoking triggers. For example, Adrian's GEMA data suggested tobacco paraphernalia  
413(e.g., lighters) as one of his smoking triggers and he described feeling encouraged to smoke more by  
414seeing these objects around his apartment.

415The GEMA and map-interview methods complemented one another by helping compensate for  
416independent methodological weaknesses. The GEMA data helped balance the autobiographical recall  
417bias inherent to the interview method (Shiffman et al. 2008). Stacey only mentioned smoking in  
418restaurants and bars in passing during the interview despite these being identified as important by the  
419GEMA data. This would suggest that her experiences in these locations are less remarkable to her than in  
420locations where her smoking practices are embedded in more emotionally compelling experiences.  
421Without the GEMA data, this smoking location would have gone largely unnoticed in our analysis of this  
422case.

423The convenience of the GEMA data collection by smartphone app allowed for a longer sampling period  
424than feasible with traditional travel diaries, which are most often only collected for a week or less. This  
425provided a more reliable impression of each participant's 'typical' tobacco use patterns while still  
426providing map layers for 'play-by-play' discussion of individual sample days. Integration of GEMA maps  
427into the interview prompted discussion of content that may not have otherwise come up. For example,  
428Adrian's cigarette and vape pen use map layers showed distinct spatial patterns of use, prompting a  
429discussion on how he uses one tobacco product over the other depending on the place and situation.

430The interview provided clarification regarding participants' interpretations of the GEMA survey  
431measures, the descriptions of which are necessarily brief in the GEMA surveys. For example, the

432interviews revealed two 'car' location meanings for Stacey, clarified that Sofia's 'other's home' location  
433was her boyfriend's home, and that Adrian's 'other' locations were likely graduate fieldwork and LGBTQ+  
434organizing sites. The interview provided in-depth understanding of the ways in which participants  
435experience smoking locations and the meanings and functions of smoking in these locations. The  
436participant accounts presented here revealed dimensions of their social contexts of smoking (Poland et  
437al. 2006), such as experiences of minority stress and intragroup marginalization, and the role and  
438meanings of tobacco use in those situations (Blue et al. 2016). This level of understanding is not possible  
439to glean from multiple choice, pre-defined responses in GEMA surveys.

440Finally, while the GEMA method is designed to assess moment-to-moment factors of interest, the  
441interview provided more holistic understanding of how participants experience everyday life, including  
442the juggling of activities and sequencing of events. Part of the function of smoking for Sofia, for example,  
443is to provide a portable, stable rhythm that she can impose on her hectic schedule. Stacey's transitional  
444practice of smoking while walking dogs after school is given meaning and function by her experience of  
445the sequence of contexts and activities along her daily space-time path (Schwanen 2006).

#### 446Limitations

447Several limitations in this mixed-method approach became apparent while exploring the three cases. On  
448a practical level, the integration of the GEMA and interview data at the case level is time consuming,  
449requiring team discussion of individual cases. This presents a challenge to scaling up analysis for a larger  
450sample size, especially one large enough for statistical analyses across cases (O'Cathain et al. 2010).  
451Furthermore, while interviewing only those participants who achieve medium or high data collection  
452compliance throughout the GEMA sampling period ensures high quality GEMA data at the case level, this  
453may bias participant selection toward those who are more conscientious or able to engage with data  
454collection protocol.

455The full range of contextual factors influencing smoking practices may not all be reliably detected and  
456reported by study participants (Kirchner and Shiffman 2016). Both the GEMA and map-interview  
457methods rely upon participants' awareness and perception of their surroundings and actions, as well as  
458their ability and willingness to comply with the GEMA data collection procedures and engage in the  
459interview process. Some place characteristics relevant to tobacco use, such as racial and ethnic  
460segregation and area-level deprivation (e.g., Moon et al. 2012), may not be adequately captured in this  
461way. Future studies could integrate area-level characteristics into the GEMA-interview method with using  
462an activity space approach (Epstein et al., 2014). Relatedly, all measures used in this study, except for  
463GPS data, relied on participant self-reports and may thus be impacted by social desirability bias. As  
464smoking is increasingly stigmatized and subject to social norms that discourage cigarette use (Graham  
4652012), participants may underreport their smoking behavior in both GEMA surveys and interviews.  
466Computerized assessments have shown to decrease social desirability bias compared to in-person  
467interviews (Booth-Kewley, Larson and Miyoshi 2007), which may point to an advantage of using the  
468method to guide follow-up interviews. It should be noted that previous studies using data collection  
469procedures similar to the current investigation have found strong correlations between cigarette reports  
470and biochemically verified breath carbon-monoxide (Shiffman & Paty, 2006). Passive tracking of smoking  
471episodes, for example by using wearable sensors (Sazonov, Lopez-Meyer and Tiffany 2013), could bypass  
472potential self-report biases completely.

473The GEMA method appears compromised by large fluctuations or changes in tobacco use over the data  
474collection period, as demonstrated by Adrian's 'binge' in the second half of his data collection period.  
475The sampling of tobacco use episodes by using a fixed likelihood of sampling each smoking occasion  
476means that sampled smoking situations are skewed toward early in the day during periods of significant  
477increase from the participant's baseline use patterns. This methodological weakness was only partially  
478compensated for by the interview discussion of Adrian's evening tobacco use situations. These findings

479are in line with previous studies reporting a high variability in cigarettes smoked per day among a  
480substantial subset of smokers (e.g., Hughes et al. 2017). In fact, variability may be even more  
481pronounced among light and intermittent smokers (Shiffman et al. 2012), which is consistent with the  
482smoking behavior reported by Adrian. Results suggest that a different GEMA sampling approach may be  
483needed to survey a representative subset of smoking occasions for participants with highly variable day-  
484to-day smoking patterns.

485Finally, while Stacey, Adrian, and Sofia's accounts draw tentative links between tobacco use and  
486experiences of social exclusion as bisexuals, this pilot study did not include measures of discrimination in  
487the GEMA surveys. Future studies could incorporate explicit measures of social exclusion experience in  
488GEMA surveys to further investigate this topic. Future studies could also better hone in on issues  
489relevant to bisexuals by including a non-bisexual comparison group.

## 490Conclusion

491This GEMA-interview mixed method shows potential for revealing the richness of individuals'  
492experiences of everyday contexts and practices while providing reliable measures of situational factors  
493associated with health behaviors, such as substance use. These types of findings can aid in generating  
494hypotheses that may be tested with other methods on larger samples to explain health disparity-related  
495behaviors, such as tobacco use among minority groups. The method may also inform the development of  
496tailored health interventions to reduce health disparities, such as tobacco cessation smartphone apps,  
497online cessation groups, and curriculum for cessation counselors and lay health workers. Future studies  
498could integrate exposure to area-level characteristics into this mixed-method using an activity space  
499approach. Social exclusion measures could be integrated into the GEMA surveys to better capture  
500potential relationships between substance use and experiences of marginalization. GEMA-interview  
501mixed methods such as this could provide in-depth understandings of a variety of health behaviors,

502 including the consumption of a different substances (e.g., marijuana, alcohol, opioids) independently or  
 503 in co-use situations within a variety of populations.

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