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ORIGINAL PAPER

As Violence Unfolds: A Space–Time Study of Situational Triggers of Violent Victimization Among Urban Youth

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Abstract

Objectives This study clarifies three important issues regarding situational or opportunity theories of victimization: (1) whether engaging in risk activities triggers violent assault during specific, often fleeting moments, (2) how environmental settings along individuals' daily paths affect their risk of violent assault, and (3) whether situational triggers have differential effects on violent assault during the day versus night.

Methods Using an innovative GIS-assisted interview technique, 298 young male violent assault victims in Philadelphia, PA described their activity paths over the course of the day of being assaulted. Case-crossover analyses compared each subject's exposure status at the time of assault with his own statuses earlier in the day (stratified by daytime and nighttime).

Results Being at an outdoor/public space, conducting unstructured activities, and absence of guardians increase the likelihood of violent victimization at a fine spatial–temporal scale at both daytime and nighttime. Yet, the presence of friends and environmental characteristics have differential effects on violent victimization at daytime versus nighttime. Moreover, individual risk activities appeared to exhibit better predictive performance than did environmental characteristics in our space–time situational analyses.

Conclusion This study demonstrates the value of documenting how individuals navigate their daily activity space, and ultimately advances our understanding of youth violence from a real-time, real-life standpoint.

Keywords Violent victimization · Situational triggers · Routine activities · Social disorganization · Spatio-temporal analysis

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Introduction

Current explanations of criminal victimization are often situational in nature. Classic victimization theories postulate that demographic characteristics and structural constraints lead to lifestyle types (Hindelang et al. 1978) and routine activities (Cohen and Felson 1979) that contribute to personal victimization. Specifically, the occurrence of predatory crimes requires the convergence in *space* and *time* of motivated offenders, suitable targets, and the absence of capable guardians. Cohen et al. (1981) elaborated on how five situational elements—exposure, proximity, guardianship, target attractiveness, and definitional properties of specific crimes—mediate the victimization risk associated with repetitive and predictable life routines (Hawley 1950).

While macro-level analyses of opportunity or situational explanations of crime or victimization rates provide generally confirmatory evidence (Cohen and Felson 1979; Cohen et al. 1980; Messner and Blau 1987; Roncek and Maier 1991), results at the individual-level are more mixed. In a recent review of victimization trends and correlates, Lauritsen and Rezey (2018) reminded us that inconsistent findings regarding individual-level, situational factors of victimization might be due to inadequate attention to the sociostructural context (see also Maimon and Browning 2012).

Clarifying the ambiguities about situational explanations of victimization is imperative in enhancing crime prevention and control efforts (e.g. Cornish and Clarke 2003; Felson and Clarke 1995). The overall purpose of the current investigation is to provide an empirically accurate and theoretically meaningful assessment of the situational approach as applied to violent victimization among urban youth. Specifically, we move beyond prior efforts in three important ways:

First, we introduce a more accurate way of conceptualizing and measuring situational risk factors for violent assault than previous research did. The notion of induction or hazard period characterizes the period between causal action and disease initiation (Rothman 1981), and if applied in our context could help advance our understanding of how risk activities and environmental settings bring about an assault. Because violent incidents often occur within a short span of time (e.g. several minutes), the interval between the action of a situational risk factor and the victimization experience must be brief. We therefore conceptualize such proximal risk factors as *situational triggers*.

Existing research on violent victimization has focused on between-individual comparisons (e.g. Felson et al. 2013; Lauritsen et al. 1992; Lauritsen and Rezey 2018). That is, victims of assault are found more likely to participate in high-risk activities than non-victims over a prolonged study period (e.g. over the past 6 or 12 month). Yet, studies aimed at understanding why the same high-risk person experiences victimization at a particular location and time but not another are scarce. Proximal predictors of victimization in the immediate context (i.e. triggers)—including where the individuals are, whom they are with, and what they are doing (Pervin 1978)—that shortly thereafter instigate violent exchanges, should be causally more meaningful than risk factors derived from more distant time periods.

Second, we capture the extent to which youth are exposed to all sorts of environmental risks during the micro-intervals of their daily routines and the risk of being assaulted from these exposures at highly resolute levels of geographic specificity. Weisburd (2012), among others (e.g. Miethe and Meier 1994; Rice and Smith 2002), called for integrating social features of places into situational analysis of crime events. He argued that microgeographic units, such as street segments or specific facilities, function as "small-scale social systems"

or a type of "microcommunity", whereby social disorganization characteristics have direct relevance (Taylor 1997; Weisburd et al. 2014; Wikström et al. 2010). To ensure an empirically accurate assessment, it is also important to acknowledge that individuals do not solely conduct their routine activities within the confines of their residential area (Basta et al. 2010). It is necessary to document daily activity paths rather than assuming that activities are bounded within residential neighborhoods.

Third, we take into account the temporal variation in everyday routines, and examine the differential impact of situational triggers on violent victimization during the day versus night. Since human activity is constrained by biological and social factors, relative densities of motivated offenders, victims and capable guardians are likely to vary over time at specific places (Haberman and Ratcliffe 2015). Personal contact crimes, for instance, peak during the evening and the night, dropping steeply after about 2:00 a.m. (Averdijk and Bernasco 2015). Darkness not only provides cover for offenders, but may also influence how situational dynamics work. For example, when fewer people are on the street during nighttime, potential guardians may be less likely (either less willing or less capable) to engage in informal social control and intervene when seeing or hearing violent incidents. Thus, the impact that the type of activity, the company that one keeps, and the surrounding environment have on violent victimization may be time-dependent.

We seek to fill these knowledge gaps by introducing a highly innovative data collection effort and modeling individuals' step-by-step movement through urban landscapes over the course of their daily activities. It is worth noting that the term "violent victimization" subsumes a wide range of behaviors such as intimate partner violence or violence between family members, but our study focuses on violent victimization among urban youth in the community, school and other similar settings.

Situational Elements of Violent Victimization

Sampson and Lauritsen (1994) classified risk factors for violent victimization into three categories: *individual*, *situational* and *community*. While individual risk factors are defined as the relatively stable "ascribed and achieved characteristics of individuals" (Sampson and Lauritsen 1994, p. 2), situational explanations seek the causes of violent victimization in the immediate, actual, dynamic circumstances in which crimes are committed (Birkbeck and LaFree 1993). The situational approach does not deny that certain individual characteristics (e.g. age or physical vulnerability) lead to personal victimization for some people but not others (Skogan and Maxfield 1981). Yet, the more relevant question is: Why does a given person experience victimization under a particular situation but not another?

The presence of friends, especially deviant friends, may increase the situational risk of violence (Averdijk and Bernasco 2015; Lauritsen and Rezey 2018; Ruiter and Bernasco 2018; Schreck et al. 2002; Tillyer and Tillyer 2016). Adolescent and young adult peer groups often value behaviors that demonstrate separation or rebellion from authority. Such ties of friendship and shared daily activities increase the likelihood that an individual will routinely be exposed to motivated offenders and vulnerable. Not only may friends provoke outsiders, thereby putting those in their company in danger, they may actually commit crimes against those in their company for status- or respect-seeking (Decker and Van Winkle 1996; Lauritsen et al. 1991; Schreck et al. 2002; Warr 2002). Conversely, research on "friendship protection hypothesis" suggests that in certain social contexts (e.g. walking through a dangerous neighborhood at night), the presence of a friend can reduce target

suitability, and thus provide protection and guardianship against victimization (Boulton et al. 1999; Kendrick et al. 2012).

The presence of capable guardians or handlers are likely to decrease the risk of victimization. Osgood et al. (1996) argued that such "authority figures" are expected to intervene when they observe the unfolding of crime and violence. They have been granted authority over a young individual, and it is their responsibility to exert social control. In addition, they are likely to have established an emotional bond or attachment to the young individual. Practically, the presence of parents or adult family members would make criminal activity against an individual inconvenient.

What an individual does at a particular location and time also affects his/her risk of victimization. Osgood et al. (1996) specified that unstructured activities (or activities that carry no agenda for how time is to be spent) result in deviance and crime among youth because such activities are less likely to be supervised by responsible guardians and offer more opportunities for deviance. This lack of planning and organization in activities such as sneaking out of the house or driving around aimlessly with friends also leads to an increased risk of violent victimization (Schreck et al. 2002; Schreck and Fisher 2004; Tillyer et al. 2011). Henson et al. (2010) argued that such leisure activities increase "exposure to offenders, enhance vulnerability, or diminish guardianship" (p. 305).

Consuming illicit drugs and alcohol may increase the risk of violent victimization. Situational mechanisms that link substance use to victimization include: (1) Substance use often takes place under risky circumstances where supervision and intervention by guardians are unlikely; (2) substance use may lead to temporary decreases in self-control and increases in aggression, and (3) substance use limits the physiological functioning of the subject. Individuals under the influence of drugs and/or alcohol are less likely to recognize the potential risk of victimization, thereby omitting precautionary measures. When violent exchanges occur, they are less capable of defending themselves (Felson and Burchfield 2004; Gover 2004; Pedersen 2001; Spano and Freilich 2009).

Weapon carrying serves as a situational catalyst for assault. Real or perceived need for self-protection is the main reason for youth weapon carrying (Lowry et al. 1998; Vaughn et al. 2012). Empirical studies, however, have repeatedly demonstrated that carrying a handgun or other weapon is associated with assault-related injuries and hospitalization (e.g. Branas et al. 2009a; Lowry et al. 1998; Pickett et al. 2005). One explanation is that youth who carry weapons are more likely to engage in violent exchanges and/or contribute to the escalation of violence because a handgun or other weapons "gives them courage to go places they might otherwise avoid or because the weapon provides a sense of invulnerability that emboldens them in conflicts that arise regardless of location" (Lowry et al. 1998, p. 126). Unfortunately, their actual risk of violent victimization increases (Loughran et al. 2016).

Where an individual is located also affects the risk of violent victimization. From an opportunity or situational perspective, locations that increase an individual's exposure (e.g. physical visibility and accessibility) and proximity (e.g. physical distance) to potential offenders, and decrease guardianship (e.g. the effectiveness of persons or objects in preventing violations from occurring) lead to an increased risk of victimization (Cohen et al. 1981). As such, existing research differentiates between private and public spaces (Meier and Miethe 1993; Pratt and Turanovic 2016). Individuals are most likely to be victimized in public spaces because they create the greatest number of offender-target-inadequate guardianship convergences for youth violence (Brantingham and Brantingham 1993): Many people have access to public places (e.g. streets, entertainment facilities or bars, or public transport stations), thus creating pools of potential offenders and attractive targets

who are anonymous to each other. Unlike private spaces (e.g. homes) where the owners or users exert *personal* or *assigned responsibility*, social control in public spaces is limited given that strangers or ordinary citizens only have *diffuse job* or *general responsibility* to discourage crime (Felson 1995). Empirical studies have confirmed that being outdoors in public space increases an individual's likelihood of victimization (Averdijk and Bernasco 2015; Felson et al. 2013; LaFree and Birkbeck 1991; Miethe and McDowall 1993).

Environmental Condition, Activity Space, and Violent Victimization

While acknowledging the importance of examining outdoor public space in situational analysis of victimization, we argue that the situational component of *where the action is taking place* needs to be further developed. Essentially, individual routine activities are embedded within social and spatial contexts where varying levels of criminal opportunity exist. Drawing on the social disorganization perspective (Bursik 1988; Kornhauser 1978; Sampson and Groves 1989; Shaw and Mckay 1942), previous studies have shown that socioeconomic deprivation, population heterogeneity, residential instability, and lack of institutional resources are associated with individuals' violent victimization as well as neighborhoods' high victimization rates (e.g. Lauritsen 2001; Lauritsen and Rezey 2018; Smith et al. 2000). These structural disadvantages result in the inability of the community to realize the common values of its residents, accumulate social capital, solve common experience problems, and maintain effective social controls (Sampson et al. 1997).

Despite the insights drawn from the social disorganization perspective, there are limitations associated with investigating contextual effects at the area level (e.g. census-tracts or block-groups). Wikström et al. (2010) argued that the units of analysis commonly used in exploring environmental risks are "generally too *large* to approximate settings and often too *heterogeneous* to warrant the assumption that the neighborhood environment is homogenous in causally relevant features" (Wikström et al. 2010, p. 58; see also Rice and Smith 2002; Smith et al. 2000). *Behavior-setting*,[1] instead, is a concept that directly links the community context to individual actions (Taylor 1997; Wikström and Sampson 2003). Temptations, provocations and deterrence are important casual mechanisms determining the relevance of a setting to crime and violence (Wikström and Treiber 2009). It is therefore necessary to investigate whether social disorganization characteristics that affect violent victimization at the area level also exhibit influence in behavior-settings.

This is also consistent with the call for integrating social features of places into situational analysis of crime events at the microgeographic scale (Miethe and Meier 1994; Rice and Smith 2002; Weisburd 2012; Weisburd et al. 2014). Weisburd et al. (2012) demonstrated strong street-to-street variability in social structural factors reflecting social disorganization such as property value, public housing assistance, physical disorder, and collective efficacy. Importantly, these social features of places are strongly related to whether a street segment was identified as a chronic crime hot spot. Similarly, environmental characteristics alongside the micro-intervals of individuals' daily routines may function as triggers of violent victimization besides individual risk activities.

Moreover, young people move around extensively during daily activities, and thus are exposed to a range of different settings that stretch far beyond their residential

[1] Behavioral setting is defined as "the part of the environment which an individual can, at a particular moment in time, access with his or her sense" (Wikström et al. 2010, p. 61).

neighborhoods (Basta et al. 2010; Browning and Soller 2014). Conventional approaches to contextual effects "risk a form of determinism by linking residential context characteristics with features of activity locations, absent recognition of the complexity of everyday activity spaces and the choices and constraints urban actors face in navigating their environments" (Browning et al. 2017, p. 47). The residential census unit employed (e.g. tract or block group) is assumed to capture the complete exposure space. Focusing on an arbitrarily limited geographic context, however, restricts our capacity to understand the combined effects of multiple relevant environments (Browning and Soller 2014; Inagami et al. 2007). For instance, the negative impact of residence in a disadvantaged neighborhood may be buffered by extra-neighborhood influences (e.g. engaging in structured activities at a more advantaged location). Examining only a subset of daily activity exposures introduces bias when estimating the effects of environmental (and other situational) factors.

The concept of activity spaces helps illustrate the processes by which environmental contexts influence the routine spatial exposures of individuals. Activity spaces refer to the set of locations and settings to which individuals are regularly exposed (Kwan 2013). Matthews and Yang (2013) suggested embracing a continuous view of the world, in contrast with the discrete view implicit in polygon-based measures of neighborhoods. Although the location and characteristics of residential neighborhoods are likely determinants of activity space features, the daily activity trajectories of urban youth extend beyond the residential boundary, "resulting in both substantial within individual variability in everyday exposures and variability between individual youth who reside in the same neighborhood" (Browning et al. 2017, p. 46). Thus, to genuinely capture the causal processes linking contextual influences to violent victimization, we must build *actual* exposures into theoretical models and data collection efforts.

To date, only a handful of studies have collected geographic location data of individuals' routine activities and investigated how behavior-settings influence crime and violence (e.g. the *Peterborough Adolescent and Young Adult Development Study* and the *Adolescent Health and Development in Context Study*). Wiebe and colleagues conducted the *Space–Time Adolescent Risk Study* (STARS), a population-based case–control study aimed at understanding violent victimization among urban youth, and the parent study of the current investigation. By collecting individual movement data, they demonstrated that defining environmental exposures based on participant home address (i.e. residence-based measures) resulted in significant misclassification compared to daily travel path measures (Basta et al. 2010; Culyba et al. 2018). Wiebe and colleagues also revealed the stark variability in the percent of time that gunshot cases, non-gunshot cases, and controls, respectively, spent in different types of places and modes of transportation (providing evidence for measurement validity of their space–time methodology), and identified correlates of gunshot wound assault and non-gunshot wound assault, respectively, from an epidemiological perspective (Dong et al. 2017; Kondo et al. 2017; Wiebe et al. 2013, 2016).

Building on these public health research efforts from the STARS, the current study operationalizes situational risk factors in ways that are more consistent with the routine activities and social disorganization perspective and evaluates their *triggering* effects on violence. Additionally, while prior research has linked darkness with the risk of victimization (Averdijk and Bernasco 2015; Haberman and Ratcliffe 2015), it is not yet clear how situational risk factors may differentially affect violent victimization by time of day. This is crucial for furthering our understanding of the situational correlates of violence.

Methods

Study Subjects and Design

Participants for the current study were 298 young males aged 10–24 years in Philadelphia, Pennsylvania, who sustained a violent injury (either a gunshot wound or a non-gunshot wound including laceration, contusion, or fracture from being hit, struck with object and etc.).[2] Study subjects were recruited from the emergency departments of a pediatric and an adult Level I trauma center located adjacently in central Philadelphia. In the screening process conducted by our well-trained academic associates,[3] the patients who were assaulted by someone he lived with or an intimate partner were excluded from the study. All subjects were enrolled using informed consent or, for minors, assent with parental informed consent. This study was approved by the University of Pennsylvania institutional review board.

A *case-crossover* study design is appropriate for the current investigation for three reasons. First, we are interested in identifying situational *triggers* of violence. The case-crossover design "applies best if the exposure is intermittent, the effect on risk is immediate and transient, and the outcome is abrupt" (Maclure and Mittleman 2000, p. 193). As discussed above, we aimed to understand—was the assault triggered by risky activities that occurred just before or the environment of the assault site? Second, given violent assault is a statistically rare outcome, the case-crossover design is efficient because we can minimize the cost of studying non-assaulted adolescents and young adults (i.e. the vast majority) as in a typical cohort study. For instance, when examining any type of victimization, Averdijk and Bernasco (2015) pooled two waves of space–time budget data and reached a sample size of 55 from an original cohort of approximately 900 adolescents.[4] Similarly, a total of 78 victimization situations (vandalism, theft, threat, or assault) were reported by 45 participants when a sample of 1334 young adults reported their time use and activities per 10-min timeslot for 4 days (Ruiter and Bernasco 2018). Third, a defining characteristic of the case-crossover design is that the exposure status of each subject at the time of outcome onset is compared with the level of exposure in a "control" time period that is more remote from the time of outcome onset (i.e. earlier in time). That is, each subject serves as his own control, and all time-invariant characteristics of the subjects (e.g. low self-control or aggression) are controlled for, thereby eliminating potentially a large source of bias.

This type of design has been used in studying the etiology of acute outcomes such as myocardial infarctions (Maclure 1991; Zanobetti and Schwartz 2005), injuries (McEvoy et al. 2005; Redelmeier and Tibshirani 1997), and violent crime (Haggård-Grann et al. 2006; Lundholm et al. 2013). The current study further extends classic crossover study, in which only one pre-event time is used as the comparison period, by taking repeated measurements of the subjects' exposure status over the course of the day. By comparing the period immediately before the assault with all prior "control" periods (stratified by

[2] Out of the 298 study subjects, 123 (41.3%) suffered gunshot wound assault and 175 (58.7%) suffered non-gunshot wound assault. A small number of female subjects ($N=31$) were also recruited in the STARS. However, due to the small sample size, we dropped them from the analysis.

[3] Academic associates are individuals who were trained in recruiting patents for clinical studies.

[4] First (12- to 13-year-olds) and fourth (15- to 16-year-olds) graders were included in Averdijk and Bernasco (2015). The first grade in the Netherlands is similar to the seventh grade in the United States; the fourth grade is similar to the tenth grade.

daytime and nighttime), we further reduce bias associated with arbitrary selection of "control" periods.[5]

Space–Time Activity and Geographic Data

Subjects were interviewed in the hospital, at the subject's home, or at our research office. Interviews were completed at a median of 4 days (interquartile range 3–5 days) after assault. Upon study entry, each subject completed an intake questionnaire about demographics, school performance, risk-taking behaviors, and exposure to violence. Most subjects (91%) were African-American, and the median age was 18 years (see Appendix Table 5 for descriptive characteristics of violent assault victims). Importantly, we developed innovative approaches to collect two additional types of data (see Wiebe et al. 2016 for additional methodological details):

First, we collected a detailed record of each subject's activities using a custom geographic information system (GIS) application (see Fig. 1 in "Appendix"). Each interview started by an interviewer sitting next to a subject, looking together at a computerized detailed street map of the subject's residential area as well as, when zoomed out, all of Philadelphia, and essentially saying "please show me where you woke up on the day you were assaulted and walk me step-by-step through your day". Within the GIS application, the interviewer clicked the screen, putting the first point at that location (i.e. where the subject woke up) on the map. The subject then sequentially reported his activities by time and location for the day of assault. Whenever the subject reported a change in location or activity/behavior, a new point was added onto the map.[6] We chose this continuous-narrative approach because, during pilot work, we found that respondents felt constrained and struggling to differentiate one fixed time-period from the next. In this way, we heard young people's stories, and then binned the narrative data and mapped data into sequential segments.[7]

More specifically, at each point, the subject reported his status on topics including time, activity, mode of transportation, companions, indoors or outdoors, perception of safety, weapon carrying, and substance use through his own words. The latitude and longitude of each point were recorded automatically in the background of the GIS application as the point was created by the interviewer. Through drawing points on the street map, the interviewer created a graphic that provided a detailed record of how, when, where, and with

[5] This is particularly meaningful when prior research provides little insight on what constitutes an appropriate control window. This is true of crime and violence; hardly any research has investigated the induction or hazard period associated with situational correlates or triggers of crime and violence and provided useful information on "wash-out periods". Arbitrary selection of "control" periods can produce substantial bias to parameter estimates (Mittleman and Mostofsky 2014).

[6] We chose our method of plotting a new point on the map only when a subject reported a change in status in terms of location or any of the activities and behaviors mentioned in the next paragraph because it is an efficient way to obtain and document a considerable volume of detailed information from each subject. This significantly shortened the time needed for the mapping exercise and reduced the burden for the participants of recalling irrelevant details (e.g. if a subject was walking alone for a prolonged period of time, only two points need to be recorded).

[7] Our novel approach is different from the space–time budget method, which collects information at fixed intervals about the main activity, the function of the place where the activity was performed, and any persons present in the setting for each hour of the day (Averdijk and Bernasco 2015; Wikström et al. 2012). We move beyond prior research by not saying "please tell me what you did in the first 10 min, and then the second 10 min (or the first hour and second hour) and so on".

whom the subject spent time over the course of the full day (until assaulted) as he walked or otherwise traveled from location to location and from activity to activity.

To prepare activity path data between the recorded points, we restructured each subject's record by inserting new rows so that each subject has one observation (row) for each minute of the subject's reporting period. Using ArcGIS software (ESRI, Inc.), we overlaid this modified record on a street map of Philadelphia and generated the latitude and longitude coordinates for each of the newly created observations. The coordinates were derived by estimating where on the map, between two recorded points, the subject would have been at that time as a function of their travel speed. Since no changes in a subject's activity status occurred at times between the instances when new points were created, during the data management process we coded each newly created point to have the same activity status information that appeared in the original point that most immediately preceded the new point.

This frequency of data, however, is higher than needed for answering our research questions. We explored binning the data at different durations; 10-min bins were found to detect differences over time while not overstepping the limits of the granularity of our data.[8] This is also consistent with Ruiter and Bernasco (2018), in which participants reported their time use and victimization experiences per 10-min timeslot for 4 days using a smartphone time use survey application. Accordingly, we kept only every tenth record of each subject's path. In other words, each subject's activity path consists of one observation for every 10 min that had elapsed over the course of the activity period they reported. For each point we kept in the working data record, the value it is assigned for each of the variables tapping the subject's behaviors and activities is the value the subject had reported for that actual point, or if the point is an interstitial point that we created, is the value the subject reported for the original point that had been most recently reported. On average, we covered 10 h of their day (approximately 60 path points) before the assault.

The reliability of the activity path data was established in several ways: (1) we conducted two pilot studies prior to the main data collection. The aims were to develop and test the feasibility of recruitment and consent/assent protocols and the mapping and data collection techniques to use with the STARS. A total of 30 test subjects were interviewed, and there was a mapping task served to evaluate how well 10–19 year-old patients with assaultive injuries were able to read a neighborhood map, concentrate on such a task, recall daily activities on the day of injury, and communicate the locations of their activities. We found that test subjects as young as 10 years old were able to accomplish the task, with younger subjects requiring more time but completing the task nevertheless. We also obtained good test–retest reliability when the same test subject was interviewed by a second interviewer; (2) as mentioned above, face validity of the activity path data were demonstrated in published studies using these same data (e.g. Wiebe et al. 2013, 2016); and (3) following what Bernasco et al. (2013) did with the space–time budget data, we checked the correspondence between the items measuring weapon carrying and substance use in the activity path data and similar measures in the intake questionnaire. The results indicated very low levels of inconsistency: only 1 respondent who reported carrying a weapon during his daily path

[8] Also, to each path point we attached data about characteristics of the built and social environment that was present at the location. Because those data are comprised of smoothed surface layers, when attached to the minute-specific point data there is considerable autocorrelation, with values of adjacent points being more similar than values of points that are further separated in time (and space). Ten-minute segments adequately address this issue.

said he never carried a weapon in the intake questionnaire, and less than 2 percent of the respondents who reported using substances during their daily paths said they never used substance in the intake questionnaire.[9] These percentages are comparable to the numbers reported by Bernasco et al. (2013).

Second, we accessed geographic data including characteristics of streets, buildings and neighborhoods from the University of Pennsylvania Cartographic Modeling Lab (CML). The CML compiled geographically-specific information from the U.S. Census, the Philadelphia Housing Authority, the Philadelphia Police Department, the Philadelphia Health Management Corporation's (PHMC) Southeastern Pennsylvania Household Health Survey,[10] and the Philadelphia Neighborhood Information System. Information on the source, coding, and format of data used to create surface layers representing environmental exposures is presented in "Appendix" (Table 6).

Each geographic variable was originally in either point or polygon format—geographically referenced with a pair of latitude and longitude coordinates (either explicitly or as a geographic centroid for polygons such as Census block groups). To avoid the problems of boundary effects and modifiable areal unit problem (MAUP), we spatially smoothed geographic variables[11] and converted them to raster map layers (using kernel density estimation for point data and inverse distance weighting based on the centroids of polygon data) that spanned the entire surface area of Philadelphia (Waller and Gotway 2004). These variables (i.e. raster data) therefore were expressed as continuous variables and represented the prevalence of risk (or protection) for violence at any specific location.

Finally, we appended the activity path data—based on latitude and longitude coordinates of subjects' activities, to values that represent the environmental risk (or protection) to which the subject, while at that specific location, was exposed. Each minute-specific point has values attached as its level of exposure for all the environmental variables. When aggregated to 10-min intervals for analysis, the point we kept was assigned a value equal to the median level of exposure observed for the 9 min-specific points immediately preceding the index point (the value of the index point is included in the median calculation). In this way, we derived variables that provide time-weighted estimates of the extent to which each subject was exposed at any and all times over the course of their reported periods of activity (see Fig. 2 in "Appendix" for an illustration of how activity path data were appended to geographic data layers).

[9] We did not check the reverse pattern because it is highly possible that any individual who ever carried a weapon or used substances decided not to conduct those behaviors on that particular day.

[10] The survey asks people in Southeastern Pennsylvania about their health, their medical care, and what it is like to live in their neighborhoods. Interviews were conducted by telephone (landline and cell phone) using a random-digit dial methodology; twenty percent of interviews are conducted with cell phone respondents. For additional details about the survey methodology, please see: http://www.chdbdata.org/household-health-survey.

[11] The spatially smoothing process estimates the value of a variable at any specific point on a surface layer by calculating a weighted average of the values at nearby observed locations or spatially contiguous entities. Smoothing methods are frequently used to improve measurement accuracy and create more robust estimates (Waller and Gotway 2004).

Measurement

Violent Victimization

The current study uses a direct, situational measure of *violent victimization*. Rather than inquiring about subjects' victimization history during the past month or year as is typical in prior research, eligible cases were patients admitted to the emergency department for treatment of a traumatic injury which they self-reported was intentionally inflicted by another person (or a group of people) with or without a weapon. We coded it "1" for the path point where the subject was assaulted (i.e. always the final victimization point), and "0" for other points. Slightly more than half (53%; $N = 158$) of the subjects were assaulted at night (i.e. when the sun was down).[12] Because individuals who experienced less serious victimization had a lower chance of presenting to an emergency department, the measure tapped the more serious end of violent victimization.

Individual Risk Activities

Individual risk activities were also operationalized as situational variables: they applied not to the person but to the person-time (i.e. observation/path points). Informed by previous research, we constructed 6 dichotomous risk activity indicators:

Derived from the open-ended responses on companions, *presence of friends* is a binary variable indicating whether the subject was with friends only at a path point. The variable equals "1" if the subject was with friends only in a behavior-setting, and "0" otherwise. For instance, a romantic partner was covered by this measure, but siblings or other family members were not.

Absence of adult guardians is a binary variable indicating whether any adult family member was present at a path point. The variable equals "1" if no guardian was present, and "0" otherwise. If the subject was in mixed company and any adult family member was present, the subject was considered having guardianship (i.e. assigned a value of "0").[13]

Respondents were considered at an *outdoor/public space* when they reported an outdoors status at a path point or their transportation mode equaled "car/motorcycle, bus (school or SEPTA),[14] or trolley/subway/train". The variable equals "1" if the subject was at an outdoor/public space, and "0" otherwise. Supplementary information on what a location is for or looks like comes from the raster map layers.

Unstructured activities were operationalized on the basis of three features: (a) if they carry no agenda on how time is to be spent; (b) if their timeframe is undecided so that they have no fixed end point or result, or (c) if they include socializing as their main activity (Bernasco et al. 2013; Osgood et al. 1996; Wikström et al. 2012). Having such theoretical criteria is necessary because, rather than using a pre-defined coding list, the participants reported their activities at each path point in the format of free text (e.g. we recorded approximately 800 unique descriptions for the activity field in the GIS-assisted interview).

[12] We accessed sunrise/sunset times from the National Weather Service.

[13] As a robustness check, we also created a measure covering both adult family members and other adults known to the subject. Substantively similar findings were obtained. Given that other adults known to the subject have varying levels of responsibility and/or attachment to the subject, we reported results considering adult family members only in this paper.

[14] SEPTA is an acronym for Southeastern Pennsylvania Transportation Authority.

We coded it "1" for unstructured activities, and "0" otherwise. Like previous studies, there is some arbitrariness in defining activities as unstructured.

Weapon carrying is a binary variable indicating whether the subject carried any weapon at a path point. The weapon could be a gun, a bladed (e.g. knife or razor), or a blunt (e.g. bat or brass) weapon. We coded it "1" if the subject carried a weapon, and "0" otherwise.

Substance use is a binary variable indicating whether the subject used any illegal drugs (e.g. marijuana or crack cocaine) or alcohol (e.g. beer, wine, or liquor) at a path point. We coded this measure "1" if the subject reported using any substance, and "0" otherwise.

Environmental Characteristics

To examine potential triggering effects of environmental characteristics on violence at the microgeographic scale, these characteristics were also operationalized as situational variables. Specifically, environmental characteristic variables were constructed as latent measures using factor analysis (see Table 6 in "Appendix" for the source, coding, and format of geographic data):

Environmental socioeconomic status captures the socioeconomic status of a behavior-setting (or path point) along a subject's daily travel trajectory. We constructed the measure using five variables including median household income, per capita income, population per 1000 with at least some college education, unemployed population per 1000 persons age 16+ years (−) and African American population per 1000 persons (−).

Environmental institutional resources were measured by the density of police and fire stations at a path point along a subject's daily travel trajectory.

Environmental collective efficacy assesses how neighbors feel close to and trust each other as well as their willingness to work together to improve their neighborhoods (Sampson et al. 1997). Five questions from the Southeastern Pennsylvania Household Health Survey were used to measure collective efficacy at a path point along a subject's daily travel trajectory. We converted questions with ordinal response options into raster map layers by recoding ordinal scale responses into a dichotomous outcome (0/1), calculating the proportion coded "1" per census tract, and transforming the census tract data into raster. Other questions that elicited a count or continuous outcome were converted to raster directly (Appendix Table 6).

Environmental opportunities for crime were assessed by six variables capturing the density of alcohol outlets (all types), disorderly conducts, narcotic arrests, vacant properties, vandalism and criminal mischief, and exposure to physical violence at a path point along a subject's daily travel trajectory. Prior research has documented the reliability and validity of these data (e.g. Branas et al. 2011; Hohl et al. 2017).

Environmental gun ownership was measured by a question from the Southeastern Pennsylvania Household Health Survey: "Are there any firearms, such as handguns, shotguns, or rifles in or around your home?" The proportion coded "yes" per census tract was transformed into a raster layer and then standardized.

Supplementary analyses indicated that there was sufficient variation in the levels of exposure to environmental characteristics. Figure 3 in "Appendix" reported differences between the maximum and minimum level of exposure to environmental characteristics experienced by subjects during their daily activities. Between 30% and 50% of the subjects experienced a highest level of exposure to an environmental variable that was at least one standard deviation greater than the lowest level of exposure to the variable. Table 7 in "Appendix" also showed that although subjects tended to spend time in places that were

similar to their residential area, environmental characteristics of their home location were only moderately correlated with those at the point of assault.

Data Analysis

Data analysis proceeded in three main steps. First, we presented descriptive statistics of situational risk factors including individual risk activities and environmental characteristics to which the subjects had been exposed over the course of a day (stratified by daytime and nighttime). In the second step, we estimated the multivariate relationships between situational risk factors and violent victimization, respectively, during daytime and nighttime period. Given our case-crossover research design, conditional logistic regressions with robust standard errors[15] were used to determine whether a subject's activities and conditions of his surroundings differed at the victimization point compared to earlier times. We essentially compared each subject's exposure status at the time they were victimized (i.e. during the last 10 min of their activity path) to their own levels of exposure at each point (i.e. during each 10-min interval) earlier in the day. In this way, we investigated the *triggering* effects of situational risk factors on violence. To be clear, path points during daytime were not compared with path points during nighttime even if they preceded the victimization. For example, if the violent victimization occurred in the evening, only 10-min segments after sunset were used in the conditional logistic regression models. Conversely, it is possible that a subject woke up in the morning before the sunrise, but those path points (i.e. before the sunrise) were not used in the daytime analysis (when the violent victimization occurred during daytime). Finally, when comparing performance measures, we categorized the situational factors into two subgroups that were, respectively, consistent with the routine activities and social disorganization perspective.

All analyses were performed using Stata (Version 15.1; StataCorp 1985–2017). Given our careful data collection procedure, missing values were a minor issue and affected three variables [i.e. *neighborhood institutional resources* ($<1\%$), *substance use* ($<2\%$), and *unstructured activities*[16] ($\approx 18\%$)]. Because we had information on subjects' step-by-step movement through activity space over the course of a day, we interpolated missing values for these variables. As robustness checks, we also performed the analyses using listwise deletion and multiple imputation by chained equations (mi impute chained; number of imputations = 20). The same substantive results were obtained. As another robustness check, we assessed how precipitation affected our results. Regression coefficients and performance measures barely changed after adjusting for precipitation; we presented results from the more parsimonious model.

Moreover, we provided E-values (a sensitivity analysis technique) to assess how robust an association is to potential unmeasured or uncontrolled confounding. The E-value represents the minimum strength of association (in our case, odds ratios) that an unmeasured confounder would need to have with both the treatment and outcome to fully explain away

[15] The Huber/White/sandwich estimator of variance adjusted for clustering or intra-subject correlation when multiple data points were included for the same participant.

[16] Missing values were assigned to path points with ambiguous answers to the activity field in our GIS-assisted interview for the *unstructured activities* variable because it was unclear if activities in those settings were structured or not. The most frequent reasons for missing were "none" or an unqualified single-word phrase such as "sitting, standing, walking, running or driving".

a specific treatment and outcome association, conditional on the measured covariates (Vander Weele and Ding 2017).

Results

Descriptive Statistics

Table 1 reports descriptive statistics of the situational variables included in the daytime analysis; 140 subjects were assaulted during daytime (i.e. 140 designated victimization or injury points) with a total of 5063 daytime prior or control points. Specifically, the second to fifth columns report information at the victimization points only, and the sixth to ninth columns show information across all daytime prior or control points. For instance, 53.6% of the subjects were with friends at the victimization point during daytime, whereas across all daytime prior or control points, the subjects were with friends 42.6% of the time.[17] Table 1 also shows that violent assault occurred at varying levels of environmental risk during daytime. For instance, assault could occur at a location with relatively low or high opportunities for crime (e.g. a range from − 1.83 to 2.11).

Similarly, Table 2 reports descriptive statistics of the situational variables included in the nighttime analysis; 158 subjects were assaulted during nighttime (i.e. 158 designated victimization or injury points) with a total of 3493 nighttime prior or control points. For instance, 51.9% of the subjects were engaging in unstructured activities at the victimization point during nighttime, whereas across all nighttime prior or control points, the subjects were involved in unstructured activities 43.3% of the time. Table 2 also indicates that violent assault occurred at varying levels of environmental risk during nighttime. For instance, assault could occur at a location with very low or relatively high collective efficacy (e.g. a range from − 5.35 to 1.22). It is worth noting that the comparisons in Tables 1 and 2 were crude and before matching within the same subject (see Appendix Fig. 4 for additional information on within-subject variation).

Relationships Between Situational Factors and Violent Victimization

Table 3 shows the results from multivariate conditional logistic regression models comparing subjects' level of exposure to situational risk factors during the 10 min preceding the assault relative to their own level of exposure at each 10-min interval earlier in the day. We present point estimates of the parameters and significance levels, robust standard errors, and odds ratios. E-values for statistically significant relationships are presented in Table 8 in "Appendix".

During daytime, consistent with the routine activities perspective, the presence of friends (odds ratio = 2.48), absence of adult guardians (odds ratio = 4.72), being at an outdoor/public space (odds ratio = 10.88), and engaging in unstructured activities (odds ratio = 2.97) led to statistically significant higher risks of violent victimization.[18] From a

[17] The rates of weapon carrying and substance use in our sample were relatively low partially because some people under police guard were excluded from the study.

[18] Due to the very low rate of weapon carrying at the victimization point during daytime, the regression coefficient could not be estimated.

social disorganization perspective, environmental institutional resources (odds ratio = 0.39) and collective efficacy (odds ratio = 0.35) reduced the likelihood of violent assault during daytime, whereas environmental opportunities for crime (odds ratio = 1.96) increased the risk of violent victimization.

During nighttime, the presence of friends actually decreased the risk of violent victimization (odds ratio = 0.35). Lacking adult guardianship (odds ratio = 12.87) and being at an outdoor/public space (odds ratio = 14.48) remained significant predictors of assault at night, though engaging in unstructured activities was only marginally significant ($p < 0.06$; odds ratio = 2.21). This is consistent with previous research suggesting that being at an outdoor/public space without guardianship in dark appears particularly risky (Averdijk and Bernasco 2015). On the other hand, environmental institutional resources and collective efficacy were no longer statistically significant predictors of violent assault at night. Yet, environmental opportunities for crime (odds ratio = 2.38) and household gun ownership (odds ratio = 1.60) increased the risk of violent assault at night.

Performance Measures of the Situational Approach to Violent Victimization

While understanding how situational variables were associated with the risk of being assaulted is important, we are also interested in the predictive performance of the situational approach. Table 4 presents estimates of McFadden's pseudo R^2, McFadden's adjusted pseudo R^2, and Cragg and Uhler's pseudo R^2. During both daytime and nighttime, situational factors derived from the routine activities perspective exhibited good overall predictive performance, whereas environmental characteristics performed less well as situational triggers. For instance, the McFadden's pseudo R^2 for the model only including individual risk activities equals 0.182 and 0.171, respectively, during daytime and nighttime; adding environmental characteristics only increases the pseudo R^2 to 0.202 and 0.199, respectively.[19] Overall, the pseudo-R^2 values in the combined models suggest that the situational approach to violence reached a relatively high degree of statistic fit.

Discussion

At the core, criminological explanations of victimization are situational—certain lifestyles (Hindelang et al. 1978) and routine activities (Cohen and Felson 1979) bring appealing targets for crime into proximity with would-be offenders. Since its origination in the late 1970 s, the situational approach to violent victimization has been subject to much examination. The results have largely confirmed its empirical validity and practical relevance in crime and violence prevention efforts. Despite significant progress, this study further enhanced our understanding of the situational approach to violence.

First, how situational elements function as proximal predictors or *triggers* of violence is understudied. Although victims of assault are found more likely to be involved in risk activities than non-victims at the person-level (i.e. between-individual comparisons),[20]

[19] McFadden's pseudo R^2 values tend to be considerably lower than the R^2 values commonly obtained in ordinary least squares regression; values of 0.2–0.4 are indicative of excellent model fits (Domencich and McFadden 1975; McFadden 1979).

[20] For example, using a case–control study design, we can examine why some individuals are more likely to be violently assaulted during routine activities and in risky behavioral-settings than others.

revealing whether violence erupts during specific, often fleeting moments when situational risks are present is causally more meaningful and germane to the situational framework (i.e. within-individual comparisons). Along this line of collecting situationally-relevant data, Wikstrom and colleagues (Wikström et al. 2010, 2012) collected *hourly* information about youths' activities during four recent days.

However, the chosen time unit of 1 h is not specific enough to establish the duration of activities that have a shorter time span or detect secondary activities. This is true of youth violent incidents, which rarely take up an entire hour, or drug and alcohol use, which may be secondary activities (Hoeben et al. 2014; Wikström et al. 2012). To investigate whether *triggers* encountered while carrying out daily routines act to initiate violence in real time, situational-level data at an even higher temporal resolution than 1 h are needed. Our innovative GIS-assisted interviews addressed such limitation by adopting a continuous-narrative approach. Rather than asking subjects to complete time diaries with fixed intervals, we heard young people's stories and then binned the narrative data and mapped data into sequential 10-min segments.

We found that during both daytime and nighttime, being outdoors at a public space significantly increased the odds of being assaulted compared to staying indoors, and the effect sizes are large. Public outdoor spaces are likely to increase an individual's physical visibility and accessibility to potential offenders and decrease guardianship by diffusing the responsibility of supervision. The absence of capable guardians and engaging in unstructured activities also served as situational triggers of violent victimization both at day and night (marginally significant at night; $p < 0.06$). Turning aside from planned, organized to unstructured activities often results in impulsive/careless or risky behaviors, which, in turn, lead to crime and victimization among young people. Had these youths remained within sight of "authority figures", adult family members or other responsible handlers would intervene when they observe the unfolding of crime and violence.

Interestingly, the presence of friends had differential impact on violent victimization during daytime versus nighttime. Hanging out with friends only during the day increased the risk of violent assault. This is consistent with the argument that peers encouraged impulsive/careless, "rowdy" behaviors and diffused the responsibility of delinquent, aggressive acts (Warr 2002). Such provocative effects may be particularly strong when the surroundings are considered relatively safe and under control (Dong et al. 2017). Conversely, being with friends at night decreased the likelihood of being assaulted. Rather than provoking violence, the presence of a friend can deter potential assailants, reduce target suitability, and thus provide protection and guardianship against victimization when the surroundings are considered relatively unsafe (e.g. at night in disadvantaged neighborhoods). It is worth mentioning that although risk factors identified in the current study may not necessarily differ from some of those identified in previous studies (but not stratified by daytime and nighttime; e.g. Sampson and Lauritsen 1994; Lauritsen and Rezey 2018), situational *triggers* represent a more accurate way of conceptualizing and understanding proximal predictors of violence than previous research did.

In addition, prior research on situational explanations of victimization did not adequately account for environmental or contextual characteristics in microgeographic behavior-settings. In our study, social disorganization characteristics functioned differently as situational triggers of violence during the day versus night. During daytime, higher levels of environmental institutional resources and collective efficacy protected youth from violent victimization, and, not surprisingly, environmental opportunities for crime led to a higher likelihood of violent assault. These findings are consistent with prior research on the role of

Table 1 Descriptive statistics of study subjects' risk activities and environmental characteristics over the course of being assaulted (daytime)

Variables	Victimization points ($N=140$)				Points before victimization ($N=5063$)			
	Mean or proportion	SD	Min	Max	Mean or proportion	SD	Min	Max
Violent victimization	1.000	–	–	–	0.000	–	–	–
Presence of friends	0.536	–	0	1	0.426	–	0	1
Absence of adult guardians	0.907	–	0	1	0.747	–	0	1
Outdoor/public space	0.771	–	0	1	0.417	–	0	1
Unstructured activities	0.300	–	0	1	0.148	–	0	1
Weapon carrying	0.007	–	0	1	0.004	–	0	1
Substance use	0.021	–	0	1	0.028	–	0	1
Environmental socioeconomic status	−0.209	0.560	−1.307	1.948	−0.152	0.612	−1.274	3.405
Environmental institutional resources	0.015	0.652	−0.575	2.109	0.054	0.702	−0.575	3.188
Environmental collective efficacy	−0.099	0.549	−1.499	0.978	−0.053	0.578	−2.190	1.097
Environmental opportunities for crime	0.234	0.739	−1.826	2.114	0.208	0.778	−1.925	3.199
Environmental gun ownership	0.095	0.830	−1.682	1.842	0.174	0.927	−1.899	3.660

SD standard deviation (omitted for binary variables)

Table 2 Descriptive statistics of study subjects' risk activities and environmental characteristics over the course of being assaulted (nighttime)

Variables	Victimization points ($N=158$)				Points before victimization ($N=3493$)			
	Mean or proportion	SD	Min	Max	Mean or proportion	SD	Min	Max
Violent victimization	1.000	–	–	–	0.000	–	–	–
Presence of friends	0.405	–	0	1	0.386	–	0	1
Absence of adult guardians	0.930	–	0	1	0.735	–	0	1
Outdoor/public space	0.892	–	0	1	0.569	–	0	1
Unstructured activities	0.519	–	0	1	0.433	–	0	1
Weapon carrying	0.032	–	0	1	0.024	–	0	1
Substance use	0.108	–	0	1	0.182	–	0	1
Environmental socioeconomic status	−0.120	0.963	−1.090	7.272	−0.041	0.907	−1.326	6.545
Environmental institutional resources	0.104	0.746	−0.575	2.194	0.066	0.754	−0.575	2.445
Environmental collective efficacy	−0.045	0.714	−5.350	1.223	−0.086	0.888	−7.924	1.519
Environmental opportunities for crime	0.269	0.713	−1.518	1.848	0.085	0.769	−2.022	2.983
Environmental gun ownership	0.068	0.970	−2.273	2.544	0.013	1.089	−2.693	3.311

SD standard deviation (omitted for binary variables)

social disorganization characteristics on violence at the area- or neighborhood-level. However, during nighttime, environmental institutional resources and collective efficacy were not significant predictors of violent victimization, though environmental opportunities for crime remained a significant predictor. In addition, household gun ownership in microgeographic behavior-settings became a significant predictor of violent assault at night.

It is not surprising that being exposed to alcohol outlets, vacant properties, and disorderly and violent conduct along a subject's activity path both at day and night enhances the risk of being assaulted (Branas et al. 2009b, 2011; Han et al. 2016; Morrison et al. 2016). Yet, the non-significant effects of environmental institutional resources and collective efficacy on violent victimization at night need explanation. We suspect that in an opportunity or situational sense, the theoretically expected protective effects of environmental institutional resources and collective efficacy would only emerge when ordinary citizens are present and perform conventional duties and activities on the street. During nighttime, fewer people are on the street and they may be less likely (either less willing or less capable) to engage in informal social control and intervene when seeing or hearing violent incidents. This may also partially explain why the prevalence of gun ownership in the surrounding environment only triggers violent assault at night when other protective mechanisms may have been de-activated.

It is important to bear in mind that our findings only speak to the *situational* impact of social disorganization characteristics (i.e. as "triggers") on violence. It is likely that data on a fine temporal scale, such as the 10-min data segments, cannot capture full contextual effects on violence. Research has implied that neighborhood influences on human behavior take place in a gradual and continuing manner (e.g. Sampson 2012a; Sharkey 2008; Wodtke et al. 2011). Additionally, while some scholars have argued that behavior-settings or micro-geographic units function as "small-scale social systems" or "microcommunity" (e.g. Taylor 1997; Weisburd et al. 2014; Wikström et al. 2010), environmental risk factors originated from macro-level analysis may not directly apply to finer geographic scales. Sampson (2013), for instance, cautioned that smaller units, such as micro places, are not necessarily better than larger units (e.g. Census block groups) in understanding social disorganization processes. Yet, it is logically compatible to ask whether those propositions from the original social disorganization perspective and collective efficacy theory apply to criminal behavior of individuals too (Sampson 2012b).

Moreover, we observed that, from an opportunity or situational perspective, examining individuals' risk activities had a higher likelihood of predicting violent victimization than knowing the surrounding conditions along their daily activity trajectories. Yet, it is useful to remember that while environmental characteristics may explain relatively little of individual violence, especially at precise time points (e.g. as situational triggers), they can shape the health and well-being of whole populations because everyone is exposed to environments all the time[21] (Rose 1992).

Our findings have important policy implications for preventing youth violence in an urban context. While it is difficult to change routine activities of high-risk adolescents and young adults, building networks of social support can be a valuable first step. Cullen (1994) introduced the "social support paradigm" in criminology by explicating that expressive and instrumental support received from conformist sources (e.g. parents, teachers or conventional peers) can create a nurturing environment that provides acceptance and

[21] Small risks applied to large populations often have greater population level impacts than large risks applied to small populations. In some ways, environments are the consummate small risk.

Table 3 Results of conditional logistic regressions comparing study subjects' levels of exposure to situational elements at the time of being assaulted relative to times preceding the assault stratified by daytime versus nighttime

Variables	Daytime			Nighttime		
	b	RSE	OR	b	RSE	OR
Presence of friends	0.906*	0.443	2.475	−1.050**	0.379	0.350
Absence of adult guardians	1.551*	0.746	4.717	2.555**	0.801	12.870
Outdoor/public space	2.387***	0.367	10.879	2.673***	0.488	14.476
Unstructured activities	1.090**	0.416	2.974	0.792	0.416	2.207
Weapon carrying	–	–	–	1.878	2.708	6.537
Substance use	−1.766	0.928	0.171	−0.511	0.518	0.600
Environmental socioeconomic status	0.230	0.366	1.259	−0.133	0.261	0.875
Environmental institutional resources	−0.944*	0.403	0.389	0.265	0.255	1.303
Environmental collective efficacy	−1.058*	0.443	0.347	0.010	0.210	1.010
Environmental opportunities for crime	0.671*	0.280	1.957	0.867**	0.258	2.381
Environmental gun ownership	−0.477	0.259	0.620	0.470*	0.230	1.600

RSE robust standard error, *OR* odds ratio

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, two-tailed tests

self-worth, supply physical and human capital needed to refrain from violence and enhance prosocial modeling, and help realize formal and informal social control efforts (Dong and Krohn 2016). Through coordinate efforts from multiple social institutions (e.g. family, school, social services and community organizations), we can keep youth from having lots of unstructured time with friends who are violence-prone in unregulated public places engaging in risky behaviors.

In addition, Felson (2002) referred to "designing out crime" by making structural changes to the built environment. Strategies like converting vacant lots to green spaces and remediating abandoned buildings and houses have been found to reduce community violence (Branas and MacDonald 2014; Garvin et al. 2013; Kondo et al. 2016). These changes encourage residents to go outside and take advantage of public spaces, thus increasing informal social control of prior unsupervised areas of neighborhoods and build social cohesion and mutual trust. Yet, our findings also indicate that such strategies may be less effective during nighttime. Thus, formal social controls (e.g. law enforcement) need to detect, respond to, and prevent crimes by considering temporal variation in people's daily routines. From a situational crime prevention perspective, we need to increase the risk and effort required of youth to harm their opponent, reduce the rewards of committing violence, reduce the provocations for violence, and remove excuses for violence (Clarke 1995).

Limitations and Future Research

Despite the many strengths of this study, there are limitations. First, we were only able to study subjects who survived an assault. Not including decedents in the sample could pose selection bias. However, we know of no literature or clinical evidence suggesting that a disparity exists systematically between urban violent assault victims who live versus die

through the same attacking mechanism.[22] Although some studies enrolled deceased cases and interviewed a family member proxy, that approach was not valid for collecting the detailed activity path data we sought and that enabled the novel insights we have reported here. It is worth mentioning that although we made substantial efforts to recruit every patient who satisfied our inclusion criteria during the screening process, the participation rate was 54%. Nonparticipation bias should also be considered.

Second, in order to examine statistically rare outcomes like violent assault, subjects' daily activity paths were measured retrospectively and thus subject to recall or social desirability bias. Yet, finding a high prevalence of socially undesirable behaviors from the intake questionnaire suggested that subjects were not underreporting (Wiebe et al. 2016). The primary aim of the STARS was to investigate whether going about daily activities and spending time around alcohol outlets, vacant properties, and other environmental features related to the risk of violent assault. Yet we made no mention of these during the mapping exercise. We simply asked subjects to trace the route they travelled through their day. Thus, the respondents should have felt that little if any stigma would be attached to describing the route they travelled to the interviewer. Face validity of the activity path data has also been established in previous studies using these same data.[23]

Third, although we measured situational risk factors thought relevant by theory, perhaps unobserved time-varying covariates (e.g. the fluctuating emotional state) contribute uniquely to the risk of violent victimization. Given the well-documented relationship between offending and victimization (e.g. Berg 2011; Lauritsen et al. 1991), we should ideally include a measure of subjects' offending behavior in the regression models. However, because study participants were interviewed shortly after a serious victimization event, directly inquiring about delinquent or offending behavior may impede their recovery (especially psychologically) as well as lead to untruthful answers. As a result, we did not explicitly ask them to report their delinquent or offending behavior at each path point. The reported E-values (i.e. sensitivity analysis) partially addressed the limitation and indicated that our observed relationships are robust to unmeasured or uncontrolled confounding (but to a varying degree).[24]

Fourth, future research may adopt a similar, continuous-narrative data collection strategy and explore using more refined indicators of the way in which victims spend their time prior to violent assault, especially while in public. While our data are fine-grained in a spatio-temporal sense, more nuanced measures of individual activities (beyond unstructured activities) and surrounding conditions can further contribute to the literature. As Pratt et al. (2014) stated, "it is not simply going outside of the house that matters, but it is instead the differential risks associated with what one is actually doing outside—such as planting flowers in a garden versus selling drugs on a street corner—that influence one's susceptibility to victimization". For instance, Ruiter and Bernasco (2018) incorporated a list of 48 predefined categories of activities for each timeslot in their smartphone time use

[22] Zimring (1968), for instance, reported that "the attack data do not reveal substantial differences between fatal attacks using particular weapon forms and serious area, non-fatal attacks involving the same weapon" (p. 736).

[23] It is worth noting that the activities of the day of the assault are not the only activities that matter to one's risk for victimization. Yet, what the participants did yesterday and before was all fixed within subjects and consistent within subjects over the 24-h period when we monitored them.

[24] Given the strong situational relation between victimization and offending reported by prior research (e.g., Averdijk and Bernasco 2015), the E-values do not guarantee that victims' own role in prior conflict did not play a significant role in leading up to their victimization.

Table 4 Overall performance measures using a space–time situational approach stratified by daytime versus nighttime

Models	McFadden's R^2	McFadden's adjusted R^2	Cragg and Uhler's R^2
Daytime			
Individual risk activities	0.182	0.169	0.712
Environmental characteristics	0.020	0.010	0.129
Combined	0.202	0.179	0.749
Nighttime			
Individual risk activities	0.171	0.158	0.634
Environmental characteristics	0.030	0.019	0.162
Combined	0.199	0.174	0.689

application. In addition, future research should explore the interactions between individuals' risk activities and environmental characteristics in behavior-settings. While Averdijk and Bernasco (2015) found little evidence that the combination (or multiplicative interaction terms) of individual risk activities provides a better explanation of victimization than the sum of the separate effects, the surrounding environment may moderate the impact of risk activities on the likelihood of victimization.

Finally, our investigation was restricted to one type of victimization among males (violent assault that needs treatment in emergency departments), and a major city (Philadelphia, PA) in the United States. Replication studies should examine whether our findings apply to females, to other types of crime and victimization, and to other cities or contexts.

Conclusion

Through a novel space–time modeling approach, we demonstrated the value of documenting how individuals navigate their daily activity space and examined the role of real-time situations and environments on the risk of violent victimization. Subjects' risk activities were confirmed as proximal triggers of violent assault on a high-resolution temporal scale, instead of constituents of individual characteristics. For the first time, social disorganization characteristics were operationalized within this high-resolution situational framework, and we observed time-dependent effects of these characteristics on assault at the momentary-level. We also revealed that investigating individuals' risk activities led to a higher likelihood of predicting violent victimization than knowing the surrounding conditions along their daily activity trajectories, and that when combined, situational predictors reached a relatively high degree of statistic fit.

The current study has also raised some broader issues of importance to criminologists. Understanding induction or hazard period associated with etiological factors of crime and violence is both a theoretically and practically important task, particularly from an opportunity or situational perspective. Accurate and useful explanations of crime and violence need to elucidate which factors influence what type of crime after being exposed for how long and to how much. Relatedly, the study calls for additional research on how the surrounding environment along individuals' routine activities affect their victimization risk. Besides functioning as triggers of violent victimization, social disorganization

characteristics should determine how people organize their daily activities and routines in the first place. Addressing questions like these will help tackle the problem of integrating micro- and macro-levels of explanation (Matsueda 2017).

As members of the public health and criminal justice disciplines often work collaboratively with marginalized populations (e.g. violent injury patients are also crime victims or drug addicts also tend to commit drug offenses), we are responding to a call for "epidemiological criminology"—a new paradigm that links theories, methods and practices of public health with those of their criminal justice counterparts to enhance public safety (Akers and Lanier 2009).

Appendix

See Figs. 1, 2, 3, 4 and Tables 5, 6, 7, 8.

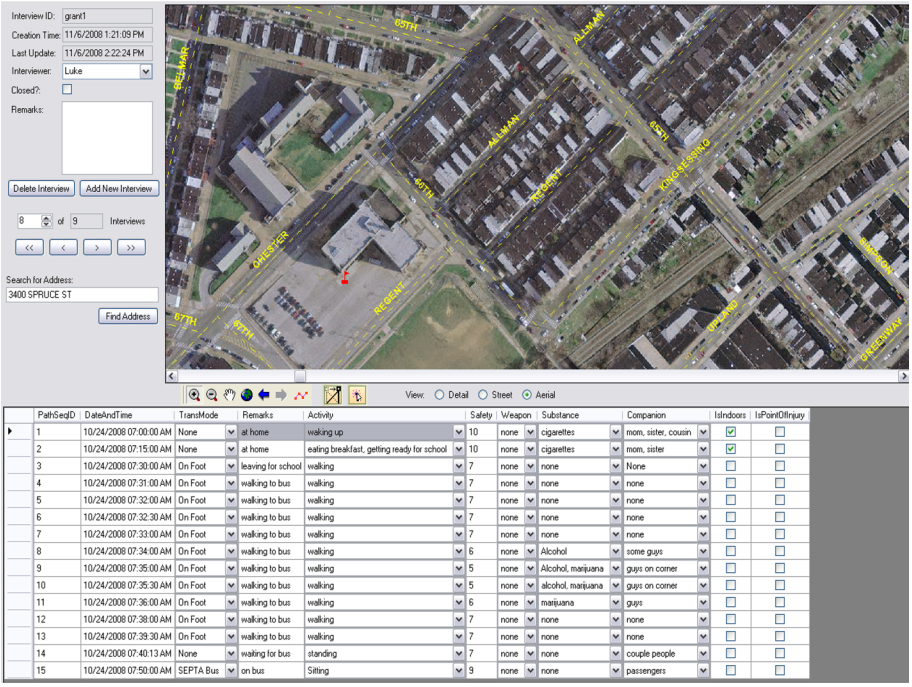

Fig. 1 A screenshot of the data collection application as it appeared on the screen of a laptop computer. *Note* Data are hypothetical since individuals' location-specific data are never shown for confidentiality reasons

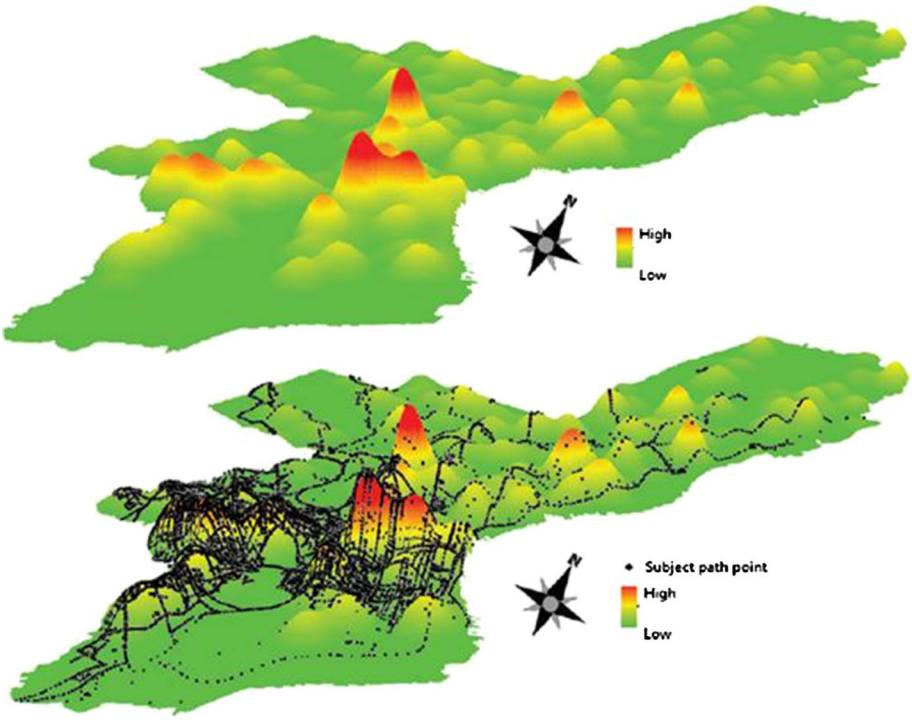

Fig. 2 An illustration of how activity path data were appended to geographic data layers based on latitude and longitude coordinates of subjects' activities. Raster surface layer of the level of a risk factor in the urban landscape as demonstrated using off-premise alcohol outlets (top). Raster surface layer of the urban landscape overlaid with path points marking locations of the daily activities of 298 study subjects (bottom)

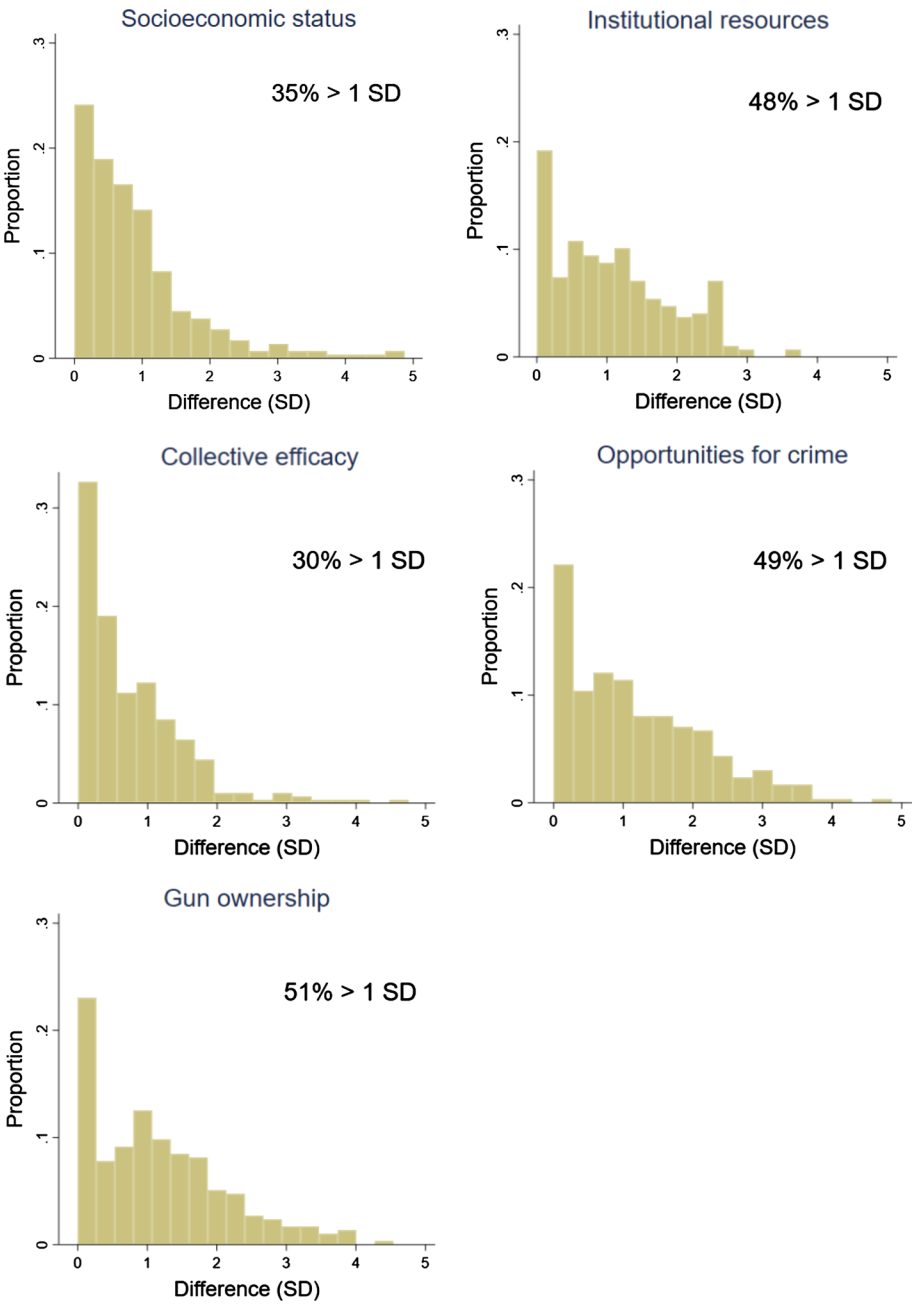

Fig. 3 Differences, in standard deviation units, between the maximum and minimum level of exposure to features of the environment experienced by subjects during daily activities. The number in each figure is the proportion of subjects who experienced a highest level of exposure to a variable that was at least one standard deviation greater than the lowest level of exposure to the variable

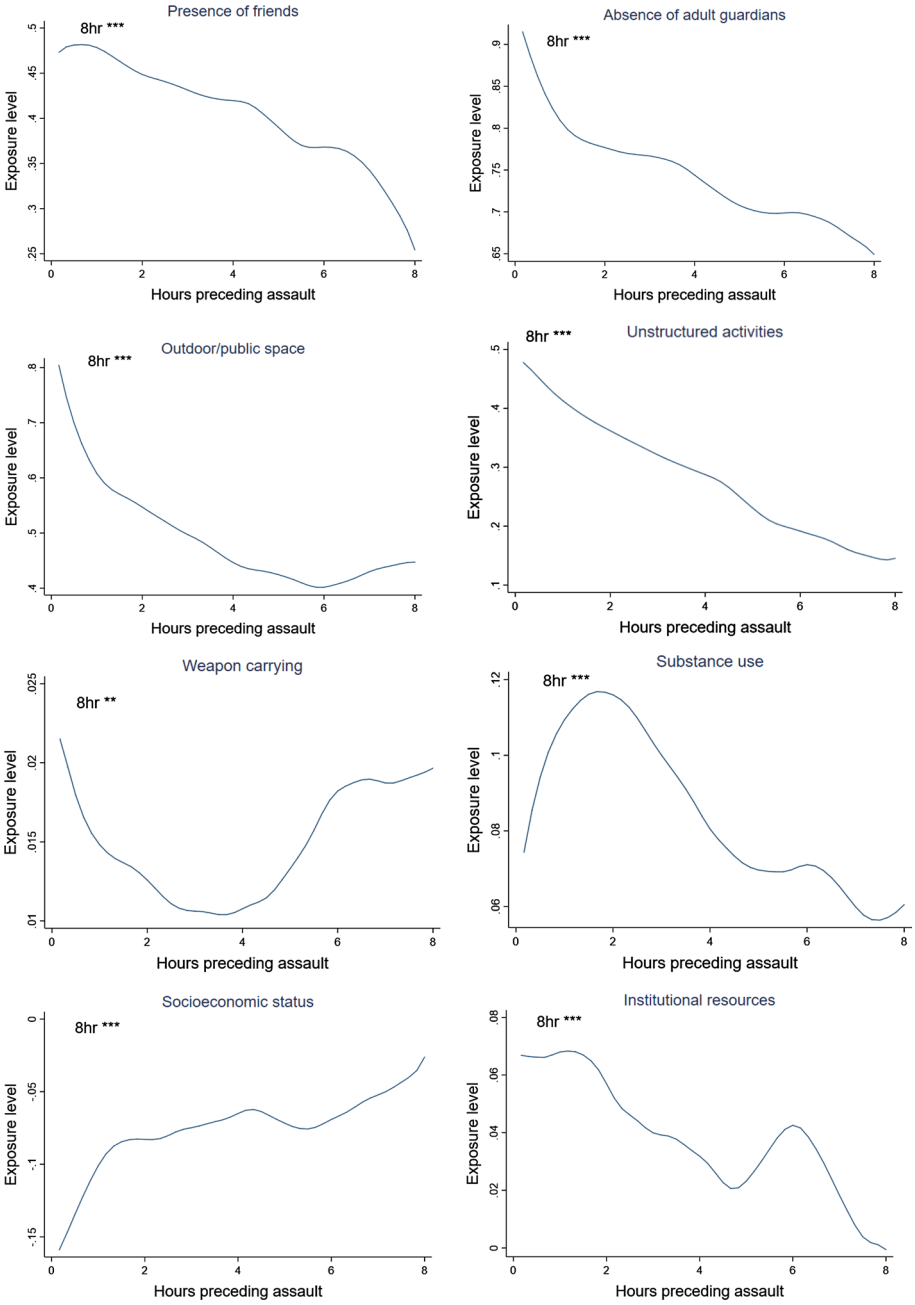

Fig. 4 Mean levels of exposure to 11 situational variables experienced by study subjects during 10-min window over the 8 h preceding and including the time of assault (left-most point in each graph). We applied a Theil–Sen estimator to the series of points for each variable, which tested the null hypothesis that the average slope over the 8-h period was zero. The result is reported in the upper left corner of each plot: *$p < 0.05$; ** $p < 0.01$; ***$p < 0.001$; n/s non-significant

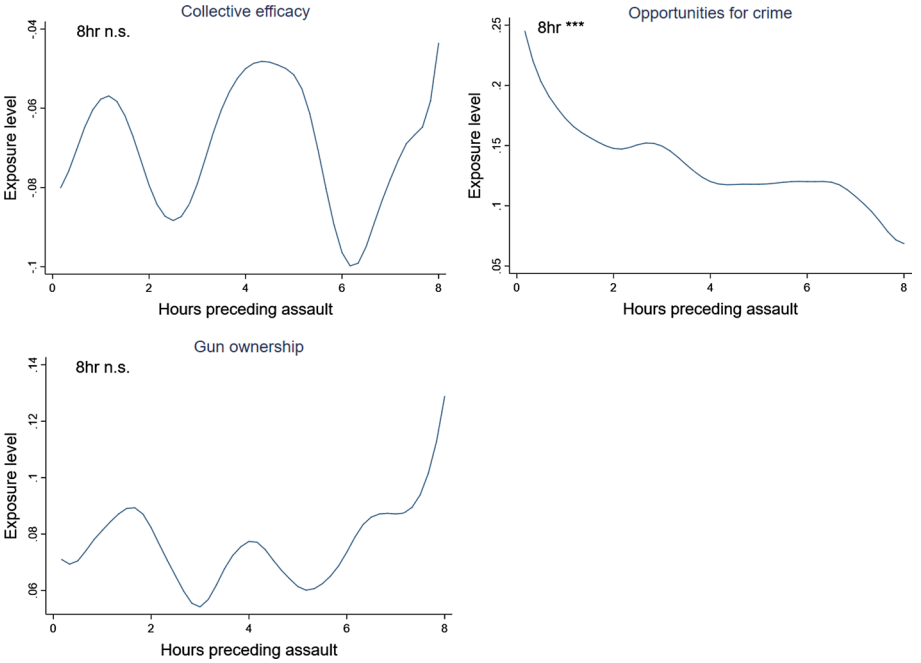

Fig. 4 (continued)

Table 5 Characteristics of violent assault victims

Characteristic	Violent assault victims ($N=298$)
Age, median	18
Male (%)	100
Race (%)	
African American	91
Caucasian	5
Other	4
Grades received in school (%)	
As and Bs	25
Bs and Cs	49
Cs and Ds	19
Ds and Fs	7
Changed route because of safety (%)	
Daily	25
Weekly	22
Monthly	20
Never	33
Ever chose path based on safety (%)	73
Ever been in a fist fight (%)	95
Ever been jumped (%)	66
Ever been part of a gang (%)	9
Ever been in jail or prison (%)	50
Ever been on juvenile probation (%)	35
Ever been shot (%)	9
Ever carried a weapon (%)	35
Ever carried a gun (%)	20
Could get a gun (%)	44
Ever sold drugs (%)	22
Ever tried marijuana (%)	49

Table 6 Source, coding, and format of data used to create surface layers representing environmental exposures in Philadelphia, PA

Description	Source	Unit	Coding	Calculation
Median household income	Geolytics	BG		Raster-IDW
Per capita income	Geolytics	BG		Raster-IDW
Population with at least some college education	Geolytics	BG		Raster-IDW
Number of African Americans per 1000 persons	Geolytics	BG		Raster-IDW
Number of unemployed per 1000 persons age 16+	Geolytics	BG		Raster-IDW
Fire stations	City of Philadelphia	Point		Raster-KD
Police stations	City of Philadelphia	Point		Raster-KD
Please tell me if you strongly agree, agree, disagree, or strongly disagree with the following statement: I feel that I belong and am a part of my neighborhood.	PHMC	CT	Proportion reporting strongly agree or agree	Raster-IDW
Have people in your neighborhood ever worked together to improve the neighborhood?	PHMC	CT	Proportion yes	Raster-IDW
Using the following scale, please rate how likely people in your neighborhood are willing to help their neighbors with routine activities such as picking up their trash cans, or helping to shovel snow. Would you say that most people in your neighborhood are always, often, sometimes, rarely, or never willing to help their neighbors?	PHMC	CT	Proportion reporting always or often	Raster-IDW
How many local groups or organizations in your neighborhood do you currently participate in such as social, political, religious, school-related, or athletic organizations?	PHMC	CT	# of organizations	Raster-IDW
Please tell me if you strongly agree, agree, disagree, or strongly disagree with the following statement: Most people in my neighborhood can be trusted	PHMC	CT	Proportion reporting strongly agree or agree	Raster-IDW
Alcohol outlet	Revenue	Point		Raster-KD
Disorderly conduct (PPD)	NIS	Point		Raster-KD
Narcotics arrests (PPD)	NIS	Point		Raster-KD
Vacant properties	NIS	Point		Raster-KD
Vandalism (PPD)	NIS	Point		Raster-KD
Thinking about the past year, have you been subject to any kind of physical violence?	PHMC	CT	Proportion yes	Raster-IDW
Are there any firearms, such as handguns, shotguns, or rifles in or around your home?	PHMC	CT	Proportion yes	Raster-IDW

PHMC Philadelphia Health Management Corporation's Southeastern Pennsylvania Household Health Survey (mean number of respondents per census tract is approximately 130), *NIS* Philadelphia Neighborhood Information System at the University of Pennsylvania Cartographic Modeling Lab, *PPD* Philadelphia Police Department, *CT* census tract, *BG* census block group, *IDW* inverse distance weighting, *KD* kernel density

Table 7 Within-subject correlation between levels of exposure to environmental characteristics that were present in the locations where subjects lived and (a) mean levels of exposure experienced during daily activities and (b) at the victimization points

	(a) Home and mean-level	(b) Home and victimization point
Environmental socioeconomic status	0.48	0.27
Environmental institutional resources	0.65	0.46
Environmental collective efficacy	0.79	0.64
Environmental opportunities for crime	0.66	0.59
Environmental gun ownership	0.74	0.63

Table 8 Sensitivity analysis (E-values) for statistically significant odds ratios

Variables	Daytime		Nighttime	
	OR	E-values	OR	E-values
Presence of friends	2.475	4.386	0.350	5.161
Absence of adult guardians	4.717	8.904	12.870	25.230
Outdoor/public space	10.879	21.246	14.476	28.443
Unstructured activities	2.974	5.397	–	–
Weapon carrying	–	–	–	–
Substance use	–	–	–	–
Environmental socioeconomic status	–	–	–	–
Environmental institutional resources	0.389	4.580	–	–
Environmental collective efficacy	0.347	5.211	–	–
Environmental opportunities for crime	1.957	3.326	2.381	4.194
Environmental gun ownership	–	–	1.600	2.580

The E-value represents the minimum strength of association (in our case, odds ratios) that an unmeasured confounder would need to have with both the treatment and outcome to fully explain away a specific treatment and outcome association, conditional on the measured covariates

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