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Human Mobility and Crime: Theoretical Approaches and Novel Data Collection Strategies

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Abstract

This review outlines approaches to explanations of crime that incorporate the concept of human mobility—or the patterns of movement throughout space of individuals or populations in the context of everyday routines—with a focus on novel strategies for the collection of geographically referenced data on mobility patterns. We identify three approaches to understanding mobility–crime linkages: (*a*) Place and neighborhood approaches characterize local spatial units of analysis of varying size with respect to the intersection in space and time of potential offenders, victims, and guardians; (*b*) person-centered approaches emphasize the spatial trajectories of individuals and person–place interactions that influence crime risk; and (*c*) ecological network approaches consider links between persons or collectivities based on shared activity locations, capturing influences of broader systems of interconnection on spatial- and individual-level variation in crime. We review data collection strategies for the measurement of mobility across these approaches, considering both the challenges and promise of mobility-based research for criminology.

Keywords

human mobility; routine activities; neighborhood; ecological networks; space–time budget

INTRODUCTION

Individual and aggregate patterns of human mobility—or the patterns of movement throughout space of individuals or populations in the context of everyday routines—are implicated in a host of criminological theories. In the characterization of places, for instance, criminal opportunity and neighborhood theories presume the relevance of spatial mobility and associated exposures in the generation of criminality, criminogenic situations, and informal crime regulation (Wilcox et al. 2018). Mobility is also directly implicated in approaches that link the spatial trajectories of individuals with characteristics

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of environments encountered, finding the explanation for crime in the intersection of crime-prone individuals with immediate settings conducive to crime perpetration (Wikström et al. 2012). Recently emerging approaches that examine relations among people or collectivities through shared spatial exposures and their implications for crime consider the concept of mobility as essential to understanding the spatial distribution of crime.

The centrality of mobility across disparate research traditions calls attention to the need for high-quality data sources to effectively advance empirical criminology. This review outlines approaches to the explanation of crime that incorporate mobility with a focus on novel strategies for the direct collection of geographically referenced data on mobility patterns. We structure the review according to the level of analysis emphasized in the criminological theories discussed. First, we consider the substantial research tradition focused on the role of mobility at the place and neighborhood level. We then turn to literature taking a person-oriented approach, emphasizing the contribution of person–place interactions—tracked across individual mobility trajectories—to offending and victimization. Finally, we review emerging efforts to treat person–place interactions relationally, constructing ecological networks of persons tied through places and their implications for crime. Across each approach, we focus on key claims that implicate mobility directly or indirectly. Within each section, we then describe extant methodologies for the collection of spatial mobility data, emphasizing the recent dramatic expansion of geographically referenced data sources and the significant potential and challenges these data present.

Our approach is selective and geared toward productive pathways for future mobility-related research on crime. We call for acknowledgment of the often submerged or neglected assumptions regarding mobility embedded in several prominent criminological theories as well as greater recognition of the complexity of spatial exposure processes as theoretical development continues to evolve (Sampson 2018, Weisburd et al. 2016). Addressing these concerns requires far more precise information on mobility than has conventionally been employed. Research on spatial mobility has only recently begun to employ large-scale, high-resolution data to capture geographic exposures. The relative dearth of mobility-based studies is rooted in the substantial obstacles to the reliable, cost-effective collection of these data. Nevertheless, rapid changes in the size, quality, and availability of crime-relevant mobility data point to exciting potential for criminology.

PLACE, NEIGHBORHOOD, AND MOBILITY

The output of criminological research employing places as units of analysis is voluminous and can be traced to the origins of criminology. We begin by reviewing salient theoretical frameworks for understanding place and neighborhood-based mobility influences on crime, highlighting seminal work in the criminal opportunity and neighborhood effects traditions. We then consider attempts to operationalize mobility within this tradition, largely relying on proxies based on location type. Finally, we consider empirical work attempting to directly measure relevant mobility factors. We highlight three emerging strategies: geographically referenced social-survey reports, in-person systematic social observation and related virtual neighborhood audits (e.g., Google Street View; Bader et al. 2017), and volunteered geographic information (VGI) approaches (e.g., geo-tagged Twitter, Foursquare, etc.).

Place and Neighborhood Approaches: Theoretical Foundations

Writing in the mid-twentieth century, Jane Jacobs (1961) offered a highly influential understanding of the conditions under which urban neighborhoods function effectively to regulate crime, focusing on the role of the built environment and associated patterns of street activity. In Jacobs's view, neighborhoods produce mobility patterns that foster the social control of crime when they supply a pool of regular, residential users of neighborhood space, a concentration of local destinations for activities such as shopping and organizational involvements that evenly distribute street activity across space and time, and a physical layout of streets that ensures frequent contact of street occupants. In turn, eyes on the street function as natural deterrents to potential offenders and a source of bystander intervention in the case of an unfolding crime event. Although Jacobs influenced perspectives focusing on the built environment and crime (Duany et al. 2001), her principal emphasis was the mobility patterns of both residents and strangers within the public space of neighborhoods. Despite the relevance of mobility in her approach, subsequent empirical investigations of Jacobs's model mostly focused on the hypothesized structural and land-use factors thought to influence street activity (Fowler 1987).

Place-based approaches: criminal opportunity and the microplace emphasis.—Jacobs's work informed subsequent research on criminal opportunity factors associated with place (Felson & Boba 2010, Newman 1972, Wilcox & Cullen 2018). Most notably, the emergence of routine activities theory in the late 1970s brought systematic attention to the criminal opportunity implications of historical shifts in patterns of everyday activity in the post-WWII era (Cohen & Felson 1979, Land & Felson 1976). Routine activities theory articulated the preconditions for the occurrence of a crime, focusing on the convergence in time and space of a motivated offender, a suitable target, and the absence of capable guardianship. In this view, potential offenders assess the costs and benefits associated with criminal acts based on immediate environmental conditions. This perspective brought the relevance of mobility—and the ambient social composition of spaces with respect to potential offenders, effective guardians, and human targets—clearly into view, initiating a decades-long project to identify place-based characteristics that tend to inhibit or promote criminal opportunity (Wilcox & Cullen 2018).

The more direct emphasis of routine activities theory and other criminal opportunity approaches on the intersection of potential offenders, guardians, and victims has been accompanied by an increasing interest in understanding spatial variability at small units of analysis, such as street blocks or segments (Smith et al. 2000), street corners (McCord & Ratcliffe 2007), parcels (Kinney et al. 2008), or residential addresses (Eck & Weisburd 2015, Hipp & Williams 2020, Sherman et al. 1989, Smith et al. 2000, Weisburd et al. 2012). Indeed, investigations of crime variance at the microplace level offer evidence that crime exhibits substantial variability at small areal units of analysis, even within conventionally defined neighborhood units such as census tracts (Schnell et al. 2017, Steenbeek & Weisburd 2016). Accordingly, this approach has tended to emphasize crime-relevant mobility-related factors at the microplace level.

An emphasis on microplace characteristics—particularly the size and composition of ambient populations and the availability of attractive physical targets—characterizes several theoretical approaches within the criminal opportunity perspective (see Wilcox & Cullen 2018 for an excellent review). Crime pattern theory, for instance, describes places that concentrate large numbers of strangers in space and time as target-rich crime generators (Brantingham & Brantingham 1995). Crime pattern theory has generated a large body of empirical studies demonstrating that street segment features such as the presence of nonresidential land uses and public transportation nodes are associated with higher crime rates, with the implication that higher traffic places concentrate crime targets (Brantingham et al. 2020, Tillyer et al. 2020). Environmental design theory focuses on physical and design characteristics of spaces that influence potential offender access, promote target-hardening, and facilitate effective guardianship through surveillance and informal social control (Brantingham & Tita 2008, Eck & Madensen-Herold 2018, Eck & Guerette 2012, Jacobs 1961, Newman 1972). Finally, place management theory elaborates the informal social-control process by identifying relevant actors associated with each component in the crime triangle. Guardians monitor potential victims, whereas the presence of handlers (e.g., parents, neighbors, teachers) offers a deterrent to potential offenders and place managers regulate the crime-relevant conditions of sites (Eck 2003, Weisburd et al. 2012). Thus, patterns of mobility leading to the space–time convergence of collectivities varying in criminogenically relevant ways with respect to size and composition are central to the criminal opportunity approach.

Neighborhood approaches: mobility implications.—Neighborhood approaches have emphasized a range of mechanisms in linking structural and compositional factors to crime outcomes. Social processes such as network ties, institutional resources, collective efficacy, subcultural orientations, and social and physical disorder have been considered in a voluminous literature attempting to explain the substantial variation in crime observed across neighborhood contexts, particularly by level of economic disadvantage (Hipp & Williams 2020, Sampson 2012). Although mobility dynamics have been less frequently considered in empirical applications of neighborhood theory, these approaches nevertheless incorporate mobility with varying degrees of explicitness.

Social disorganization theory and its contemporary extensions, most notably systemic (Bursik & Grasmick 1993) and collective efficacy theory (Sampson 2012)—include several mobility-related implications and offer potentially fruitful bases for more sophisticated integration of mobility dynamics. Bursik & Grasmick's (1993) systemic approach highlights the role of parochial networks within the neighborhood—less intimate, secondary ties rooted in, for instance, shared local organizational connections—in shaping neighborhood informal social-control capacity. Face-to-face interaction rooted in parochial network ties implies some level of aggregate, place-based connection maintained through routines.[1] Collective efficacy theory similarly draws on the basic framework of social disorganization theory but emphasizes the emergence of mutual trust and shared expectations for prosocial action in the

[1]The role of social media in the form of online neighboring platforms as an extension of, or substitute for, more traditional face-to-face encounters is an emerging area of research on neighborhood social organization. Empirical research on shared online exposures may yield important insights into neighborhood mobilization capacity to combat crime (Wilcox et al. 2018).

control of neighborhood crime. Although this approach challenges the notion that network ties—particularly private, intimate ties—are sufficient for the emergence of informal social-control capacity, the local institutional and organizational base of neighborhoods is nevertheless seen as contributing to a "web of 'mundane' routine activities that can lubricate collective life" (Sampson 2012, p. 371). Consistent with Jacobs (1961), systemic and collective efficacy theories' emphasis on overlapping organizational involvement and associated weak ties in generating and reinforcing place-based informal social-control norms suggests the utility of measurement approaches that capture everyday shared organizational exposures (Small 2009). Relatedly, systematic differences in the presence of potential guardians in public space no doubt shape the effectiveness of informal social control norms. Thus, both systemic and collective efficacy approaches imply the importance of mobility for the emergence, reinforcement, and effective application of informal social-control norms within urban neighborhoods.

Neighborhood-level social and physical disorder have also been the subject of an extensive literature. Disorder approaches emphasize the role of cues of decline in the environment typically categorized as physical (e.g., vacant buildings, graffiti, trash on the street, etc.) and social (drug and alcohol use in public space, prostitution, groups of teenagers hanging out, etc.). In this view, mobility processes are implicated in the focus on the presence of individuals in public space engaged in activities that signal local social indifference. For potential offenders, disorder cues in public space serve as indicators that "no one cares," exposure to which contributes to the perception that crime will go unchallenged. Potential guardians, in contrast, respond to disorder cues as indicating enhanced likelihood of victimization, encouraging withdrawal from afflicted spaces. However, specific predictions regarding the expected pattern of withdrawal [e.g., into the home (Furstenberg et al. 1999), outside the neighborhood] to be expected among residents of disordered neighborhoods are typically lacking, and data on routine activities and mobility processes that might capture exposure to disorder cues and withdrawal processes are mostly absent from the extant literature.

Cultural approaches have occupied an important place among neighborhood theories of crime, but few have explicitly incorporated mobility factors directly into theoretical models of cultural influence (White & Renk 2012). An exception is Anderson's (1999) *Code of the Street*: *Decency*, *Violence*, *and the Moral Life of the Inner City*, which focuses on cultural orientations among "street" and "decent" occupants of racially segregated, economically distressed neighborhoods. Anderson applies a spatial term—street—to the code reflecting its hypothesized operation in the public space of disadvantaged neighborhoods. The code encourages overt displays of violent inclinations in public spaces as a defensive posture. Even those who maintain a decent (or more conventional) cultural orientation may adopt a potentially violent demeanor to reduce the threat of victimization in neighborhood spaces where the code dominates.

Mobility dynamics are implied in this approach in the extent of exposure to code-governed spaces, with consequences for affiliation with street or decent subcultural orientations. Anderson describes decent households as less tethered to disadvantaged neighborhood spaces and able to access conventional institutions and other mainstream environments

potentially outside the neighborhood. These more variable exposures, in turn, require code-switching to navigate the expectations of both racially and economically isolated spaces as well as those beyond the neighborhood. Extremely disadvantaged residents who remain isolated within the neighborhood (or, presumably, comparably disadvantaged spaces) are most at risk of adopting a street orientation. Anderson also highlights the role of "staging areas" in disadvantaged neighborhoods—hangout locations such as local establishments (bars, carryouts) and businesses frequented by street-oriented people—where the code is hypothesized to be a more influential behavioral guide because of the volatile mix of youth typically present. The concept of the staging area highlights the potential for a more subtle, microplace-level analysis of street code influence in disadvantaged neighborhoods, where high-resolution exposure data may be particularly informative.

Consistent with Anderson's emphasis on both neighborhood-level structural factors and microplace dynamics, emerging research highlights the potential interaction between place and neighborhood characteristics (Hipp & Kim 2017). Wilcox and colleagues (2003, 2018) proposed a multilevel approach to the identification of criminal opportunity, arguing that characteristics of both neighborhoods and the microplaces within them—including mobility-related factors—combine to influence the occurrence of crime. Building on Brantingham & Brantingham (1995), this approach focuses on hypothesized crime generators at the microplace level that concentrate large numbers of people, bringing individuals engaged in everyday routines together with potential offenders. The impact of crime generators at the microplace level, however, is presumed to vary by the criminal opportunity level of the surrounding neighborhood.

This brief review of place and neighborhood approaches highlights the relevance of mobility factors—more or less explicitly acknowledged—across a range of dominant theoretical approaches to place effects on crime. Although the relevance of mobility dynamics for crime is associated most directly with routine activities theory and the criminal opportunity approach more broadly, mobility is clearly implicated in several of the most dominant neighborhood theories as well, calling for data collection strategies that hold the potential to illuminate the operation of these crime-relevant sociospatial processes. We next turn to approaches to the measurement of mobility at the place level in extant research.

Operationalizing Mobility at the Place and Neighborhood Level: Land Use as Determinant or Proxy

Empirical research on mobility-related factors within place and crime research traditions has been dominated by measurement strategies that focus on land-use patterns as a determinant of, or proxy for, crime-relevant human activity patterns. These approaches hinge on assumptions regarding the association between particular area characteristics and the size and temporal flow (e.g., work- or school-related) of ambient populations and their likely composition with respect to potential offenders, guardians, and targets (Rengert & Wasilchick 1985). This approach has yielded important, but equivocal findings, largely focusing on the role of specific land uses or combinations of land uses (e.g., mixed residential and commercial uses) hypothesized to generate crime-relevant dynamics.

Research investigating specific land-use effects on crime mostly emphasizes location types likely to function as crime generators, highlighting the criminogenic effects of nonresidential land uses on the size and composition of ambient populations (Brantingham & Brantingham 1981, Browning et al. 2010, Grubesic & Pridemore 2011, Roncek & LoBosco 1983, Roncek & Maier 1991, Smith et al. 2000, Stucky & Ottensmann 2009). For instance, in a series of papers, Roncek and colleagues (Roncek & Bell 1981, Roncek & Maier 1991, Roncek & Pravatiner 1989) find positive associations between the presence of bars and taverns on city blocks and crime levels and argue that bars tend to bring large numbers of people together with limited guardianship in and around such establishments (see also Grubesic & Pridemore 2011). Kubrin & Hipp (2016) focused specifically on the category of fringe banking locations, finding that check-cashing services and payday lenders are positively associated with crime rates in the immediate vicinity of these locations. Bernasco & Block (2010) find that a range of place types such as fast-food restaurants, liquor stores, grocery stores, general merchandise stores, gas stations, laundromats, pawnshops, and check-cashing services tend to function as crime generators, leading to higher rates of robbery. Tillyer et al. (2020) found evidence that several place types are positively associated with violent, property, and drug crime at the microplace (census block) level, including banks and credit unions, fast-food restaurants, gas stations, grocery stores, hotels, bars and liquor stores, and convenience stores. Schools have also been a focus of extensive investigation due to their role in concentrating youth—a population combining higher risk of both offending and victimization and posing guardianship challenges (Roncek & Faggiani 1985, LaGrange 2016).

Beyond specific land-use types, several studies have examined the link between concentrated commerce or mixed commercial and residential land use in generating crime. Commercial concentration may increase street traffic and attract visitors from outside the neighborhood who complicate informal social-control efforts (e.g., by interfering with the ability to distinguish locals from outsiders) (Gardiner 1978, Greenberg & Rohe 1984, Taylor 1988, Wilcox et al. 2004). Stucky & Ottensmann (2009), for instance, found that both high-density residential land use (8 or more units per acre) and the percentage of commercial activity measured in small areas (1,000 × 1,000 ft grid cells) are positively associated with violent crime (see also Taylor et al. 1995,Wikstrom 1991). However, these effects are moderated by the socioeconomic disadvantage level of the surrounding neighborhood context (with more pronounced positive effects on crime as disadvantage increases).

Drawing on Jacobs's (1961) expectations regarding the beneficial effect of diverse land uses on crime-deterring street activity, some studies have focused on the guardianship potential of land-use combinations. For instance, Corcoran et al. (2018) developed a typology of social conduits—land uses thought to promote local interaction (Hipp et al. 2014). They find evidence that, at the neighborhood level, land uses hypothesized to foster routinized interactions among frequent users—or anchoring conduits—are associated with more frequent neighbor networking, enhanced social cohesion, and stronger attachments to place. Places associated with chance interactions among local residents increase networking but not other forms of integration. Furthermore, land-use diversity—or the colocation of residential and commercial land uses—is positively associated with cohesion.

Consistent with both criminogenic and protective hypotheses regarding the influence of mixed land use, Browning et al. (2010) found evidence of a nonlinear association between a measure of neighborhood commercial and residential density and both assault and homicide. Increased neighborhood commercial and residential density is positively associated with crime at low levels but exerts a protective effect at high levels. Sampson & Raudenbush (1999) used a measure of mixed land uses drawn from the Project on Human Development in Chicago Neighborhoods (PHDCN) Systematic Social Observation data (see Systematic Social Observation below). Measuring mixed land use as the percentage of block faces within a census tract that combine commercial and residential land uses, they find no association with crime rates.

Thus, although evidence on the criminogenic effect of some specific land-use categories (e.g., bars, schools) is relatively consistent, conclusions regarding the impact of land uses across studies remain mixed. The indeterminate nature of this literature is likely partially rooted in the lack of direct measurement of mobility factors thought to channel the effects of land use on crime. Assumptions regarding the size and composition of ambient populations associated with particular land-use types or combinations may be erroneous or highly variable and dependent on unmeasured features of the immediate setting. Furthermore, as noted by Stucky & Ottensmann (2009) and Wilcox (Wilcox & Cullen 2018, Wilcox et al. 2018), the mobility features of places are likely to vary by larger neighborhood contexts. Although extant multilevel approaches to land-use effects (nesting places within neighborhoods) offer important advances over average effect approaches, multilevel strategies may compound measurement error by using proxies for mobility processes at both the microplace and neighborhood levels. Finally, a focus on land uses absent mobility information inevitably conflates the effects of ambient population size and criminogenic composition. Variation in the association between population size and composition across contexts may lead to incomplete characterizations of the criminogenic potential of particular land uses. For instance, offsetting effects of ambient population size and composition may yield negligible observed land-use associations with crime while obscuring potentially important mobility-related influences on crime.

In sum, the vast majority of research implicating mobility in the explanation of crime has used a proxy-based empirical strategy, largely focused on land-use characteristics. In an interesting parallel to the operational history of social disorganization research, a key intervening process hypothesized to explain the link between presumably mobility-relevant structural and built environment characteristics of place and crime has remained empirically elusive for much of the research inspired by this approach. Yet exceptions to this tendency have emerged in recent literature facilitated by new data collection modalities and methods.

Operationalizing Mobility at the Place and Neighborhood Level: Measuring Mobility Directly

Over the past two decades, three approaches have emerged allowing for more direct measurement of place-relevant mobility: geographically referenced social-survey reports, in-person systematic social observation and related virtual neighborhood audits (e.g., Google Street View), and VGI approaches (e.g., geo-tagged Twitter, Foursquare, Facebook, etc.).

Geographically referenced social-survey reports.—Despite a move toward alternative data resources, social surveys remain a dominant source of information for the study of crime, particularly investigations of criminality. Social surveys are less frequently used to identify crime-relevant characteristics of places, with few survey designs collecting geographically referenced data directly from respondents [although see the discussion of travel surveys in Operationalizing Ecological Networks below (Felson & Boivin 2015)]. The typical lack of information on mobility and exposure in social surveys used in criminological research has contributed to the widespread practice of relying on administratively defined residential neighborhood boundaries (employing respondents' street addresses) to proxy sociospatial environments (Browning & Soller 2014, Matthews & Yang 2013, Sperling 2012).

Among the few large-scale social surveys with respondent-provided routine activity information is the Los Angeles Family and Neighborhood Survey (L.A.FANS), a representative study of more than 3,000 households in 65 Los Angeles neighborhoods conducted from 2000–2008. The instrument included a structured location generator, i.e., adult respondents were prompted to provide the geographic locations of several regular destinations for routine activities, including grocery stores, healthcare providers, workplaces, schools and childcare, religious services, relatives' homes, and places other than home where their child spends the night. These data have been used, for example, to operationalize activity spaces—or the subset of all locations with which an individual has direct contact as a result of his or her day-to-day activities—independent of immediate residential neighborhoods (Jones & Pebley 2014, Sastry et al. 2002, Sharp et al. 2015, Sharp & Warner 2018) and aggregated to measure shared routine activity locations among neighborhood residents (Browning et al. 2017a,b; see Operationalizing Ecological Networks for additional discussion of these approaches to mobility data). A similar structured location generator approach to measuring urban residents' routine activities was adopted in the Adolescent Health and Development in Context (AHDC) study (Boettner et al. 2019).

Social survey–based location data offer several advantages for the analysis of mobility. Notably, surveys provide investigators control over questionnaire content, allowing for the construction of measures that are more directly tailored to hypothesis tests. The role of mobility and associated activities and place-based perceptions across criminological theories is typically very difficult, if not impossible, to address using administrative or other secondary sources. Second, rich background information provided by survey respondents often allows researchers to understand the demographic, socioeconomic, and other factors that contribute to within-neighborhood differences in mobility-related outcomes [see also Leverentz (2020) for an example of a qualitative, interview-based approach to data collection on activity spaces]. Finally, survey sampling methods are designed to produce samples that can be used to generate inferences to a known population of individuals.

Survey approaches also present several challenges for the collection of mobility data. First, the cost of fielding social surveys, particularly in the context of declining response rates, can be prohibitive (Czajka & Beyler 2016, Ghandour et al. 2018). Although other studies have asked respondents to report the coordinates of their routine activities and, less often, crime-relevant mobility-related processes at these locations (Basta et al. 2010, Hirsch et

al. 2016, Pratt et al. 2019, Tompsett et al. 2016), the sample sizes of typical studies have been small, complicating inferences regarding mobility and crime. Second, perceptions of mobility processes at locations based on survey interview responses may yield unreliable or biased reports regarding characteristics of spaces due to variation in respondents' levels of familiarity with locations or other unknown factors. The burden associated with responding to often demanding and lengthy modules on activity locations may also be high. Finally, the locations reported on via social surveys may not be a representative sample of the population of all locations in a region. Instead, certain types of locations, perhaps in ways related to crime potential, may be more likely to be reported. This phenomenon, known as informative sampling in the spatial statistics literature, can compromise inferences on areal averages or spatial smoothing. Thus, although social surveys are a useful tool for the measurement of place and neighborhood-based mobility, the obstacles presented by this approach call attention to other, more efficient and cost-effective ways of capturing place-based mobility characteristics.

Systematic social observation.—The systematic social observation (SSO) methodology was developed by Reiss (1971) as a method of observing behavior and other social phenomena in situ. Specifically, social observation occurs systematically when "observation and recording are done according to explicit procedures which permit replication and...rules are followed which permit the use of the logic of scientific inference" (Mastrofski et al. 2010; Reiss 1971, p. 4). The method has been applied in the Project on Human Development in Chicago Neighborhoods (Earls et al. 2007, Sampson & Raudenbush 1999), the 2000–2002 Chicago Community Adult Health Study (Clarke et al. 2008), and the L.A.FANS to characterize units varying in size, from the block face to the neighborhood (see also Mazerolle et al. 1998; Perkins et al. 1992; Taylor et al. 1984, 1985).

For the PHDCN SSO, staff drove sport utility vehicles down more than 22,000 block faces between 7:00 am and 7:00 pm, videotaping and coding each for the presence of adults, children, groups of teenagers, land-use and physical characteristics, and individuals engaged in disorder-related activities (Earls et al. 2007, Sampson & Raudenbush 1999). The PHDCN-SSO data have been used to capture social and physical disorder objectively (Sampson & Raudenbush 1999, 2004), with measures of social disorder cues including, for example, the presence of people on the street engaged in loitering, public drinking, prostitution, and gang activity. Sampson & Raudenbush (1999) employed the PHDCN-SSO data to conduct the first large-scale investigation of the impact of objectively observed social disorder cues on crime, finding no direct effect of their neighborhood-level measure after adjusting for the effect of collective efficacy.

In one of the few efforts to empirically explore Jacobs's model of street control using actual street-activity data, Browning & Jackson (2013) used the PHDCN-SSO data to directly measure the presence of adults on streets to capture their deterrent potential. The authors constructed a street block measure indicating the presence of one or more adults on either side of the street, adjusting for time of day. Nesting streets within census tracts in a multilevel model, the measure yields an estimated percentage of street blocks at the neighborhood level with any presence of adults. Consistent with the expectations of Jacobs's model, the authors found a nonlinear relationship between the presence of active streets

and violence. At low prevalence, increases in the expected percentage of active streets are positively associated with crime—indicating the possible presence of potential victims without sufficient street-level monitoring capacity. Beyond a threshold, however, increases in active streets are negatively associated with violence.

The SSO-based measurement approach to evaluating neighborhood characteristics utilized in the PHDCN represented a major step forward in our understanding of the criminogenic role of place. Still, the approach is quite demanding and costly to implement. This is best evidenced by the fact that few studies employ comprehensive SSO measures. Since the collection of the L.A.FANS and the Chicago Community Adult Health Study, no other large-scale social survey has included an SSO as a supplementary method at a comparable level of sophistication (Jones et al. 2011, Sastry et al. 2006). A notable qualitative extension of the methodology—the SSO video ethnography—was developed by St. Jean (2007) and implemented in a study of microplace characteristics that shape ecological vulnerability to crime.

In response to concerns regarding the costs of large-scale quantitative SSO-based data collection efforts, some have called for the use of virtual neighborhood audit approaches to systematic social observation. Specifically, researchers have begun to draw on Google Street View as a more cost-effective data source with which to capture urban social processes such as physical disorder, commercial activity, and the presence of people in public places (Bader et al. 2017, Odgers et al. 2012). Google Street View draws on mobile photography technology to provide users with interactive and clear images of city streets around the world. In a recent study comparing virtual and in-person approaches to measuring urban disorder, the virtual approach took only three percent of the time it took to perform in-person evaluations (Mooney et al. 2017). Furthermore, disorder based on the two approaches is well correlated, underscoring that virtual audits offer feasible, cost-effective alternatives to more conventional approaches.

Although virtual audits overcome significant challenges of conventional approaches to SSO, there remain clear drawbacks to reliance on street-view data in capturing urban social processes such as street-activity data (Bader et al. 2017, Mooney et al. 2017). First, Google data are foremost of proprietary value. The incentives to ensuring high-quality, up-to-date street-view data on the neighborhoods criminologists are most concerned with are unclear, calling into question the reliability of Google-based virtual audits for neighborhood research. Second, although the results of in-person and virtual assessments of neighborhood physical disorder are correlated, mobility-related social features of spaces may be more difficult to assess based on purely visual cues (Mooney et al. 2017).

More broadly, though, traditional and virtual SSO approaches remain limited in their ability to capture social processes over time, both between and within days (Felson & Poulsen 2003). To this end, the reliance on daytime assessment in SSO approaches likely does not generalize to social processes occurring in the evenings and early mornings, or more generally to times when residents are typically at home and when certain commercial areas may see more or less social activity. These shortcomings have led to an interest in very large,

often social media–based data sources that allow for richer characterizations of mobility dynamics across time and space.

Volunteered geographic information.—In response to demand for higher quality location- and time-specific mobility data, several recent studies have capitalized on newly available sources of VGI—or information on geographic location provided voluntarily by individuals, typically through sources such as smartphone social media applications with geocoding features like Twitter, Waze, or Foursquare (Palmer et al. 2013). These data sources are typically significantly larger than investigator-initiated data collection efforts. Wilcox et al. (2018) examined the moderating impact of vehicular traffic at the neighborhood level on the criminogenic effect of location types at the microplace level (within neighborhood, e.g., pawnshops, payday lenders, and check-cashing services). They found differential criminogenic effects of place types when situated in neighborhoods (block groups) characterized by higher levels of concentrated disadvantage and vehicular traffic and lower levels of civic engagement. The authors constructed a measure of vehicular traffic using Department of Transportation curated data reported by users of the Waze mobile navigation app (crowdsourced information on traffic incidents and jams) aggregated to the block-group level. To the extent that the size of the user community is sufficient, these data represent a useful, national-level resource for capturing spatial variation in vehicular concentration but likely offer insufficient resolution to measure spaces smaller than the block group. Furthermore, measures of vehicular traffic do not capture the concentration of individuals on foot in public space—the more direct mobility-based indicator of potential victims and offenders.

Use of Twitter-derived geolocated data has also been proposed in efforts to enhance estimates of crime rates and measures of the population at risk (Kounadi et al. 2018; Malleson & Andresen 2015a, 2016). For example, Malleson & Andresen (2015b) found that the density of geocoded tweets over the course of the day aligns with shifts in the concentration of crime, improving crime rate estimation based solely on residential population. At the level of census blocks, Hipp and colleagues (2019) drew on geocoded tweets to measure ambient populations in Southern California, examining the relevance of this measure to crime in two-hour time segments for each day of the week and over the course of eight months. They find that these day- and time-specific measures of ambient populations add considerably to estimates of block-level crime during various time points, above and beyond what is explained by conventional commuting data.

In addition to data from Twitter users, crime researchers have also begun to draw on data from Foursquare and Foursquare Swarm apps—local search-and-discovery tools that allow users to alert others to their current position and planned destinations (Kadar et al. 2016, Kadar & Pletikosa 2018, Rosés Brüngger et al. 2017, Rosés et al. 2018). Further information can be obtained about the venues that users report from, such as location types, quality of goods and services, and hours of service. As with data from Twitter, Foursquare data can be aggregated to refined time segments and used to understand the relevance of patterns of routine activities over the course of a day to the occurrence of crime.

The accessibility of these novel sources of aggregate mobility data no doubt provides criminologists with significant opportunities, but questions regarding representativeness remain. To this end, investigations of representativeness and selection among mobile-phone users are limited—especially with regard to offending and victimization outcomes of central interest to criminology—but some validating evidence is offered by Lenormand and colleagues (Lenormand et al. 2014). Specifically, they compare Twitter, mobile-phone, and census sources of mobility data in Barcelona and Madrid, Spain. They find that reports of mobility activity measured using the three data sources are largely comparable across time of day and days of the week, endorsing their aggregate use (see the section titled Ecological Network Approaches for additional discussion of selection-based concerns regarding VGI-derived sources of mobility data).

Criminological research has increasingly embraced emerging data resources for the direct measurement of mobility characteristics of places. These efforts have yielded new insight into social processes that have largely been measured by proxy in previous research. Although survey-based and systematic social observation approaches to capturing mobility processes represent rigorous, investigator-controlled methods for measuring mobility, they are typically costly and tend to yield “small” data on more limited geographies. Newly emerging resources such as virtual audit and VGI represent promising new data resources for the measurement of mobility but offer investigators more limited information regarding the data generating process and the associated potential for bias. We next turn to more recent approaches that attempt to anchor investigations of mobility on individuals rather than places.

PERSON-CENTERED APPROACHES TO MOBILITY AND CRIME

An alternative approach to crime-related mobility focuses on individual-level trajectories of spatial exposure in the course of routines. We refer to this strategy as person-oriented in the sense that the mobile individual is the unit of analysis; places encountered are tracked through exposure trajectories allowing for investigation of person–place interactions as key precursors to crime events. Person-centered approaches have been employed in the investigation of the spatial dynamics of victimization [lifestyle routine activities theory (Hindelang et al. 1978)] and offending [e.g., situational action theory (SAT) (Wikström et al. 2012)] and opportunity-based decision-making (Brantingham & Brantingham 1993). To date, however, no person-centered approach has anchored an empirical investigation of mobility patterns on potential guardians. We briefly review mobility-relevant aspects of person-centered theoretical approaches and then turn to the data collection methodologies in this literature with a focus on traditional and recall-aided space–time budgets.

Person-Centered Approaches: Theoretical Foundations

Although all place-based approaches to understanding crime are explicitly spatial, only a subset of individual-level theories has incorporated space into theoretical models of crime. Accordingly, we focus attention on individual-level approaches that directly engage the concept of mobility. Specifically, we consider lifestyle routine activities, criminal decision-making, and situational action theories.

The macrolevel focus of routine activities theory as originally offered by Cohen & Felson (1979) spurred interest in how profiles of individual-level routines—or lifestyles—differentially incurred victimization risk (Hindelang et al. 1978). Hindelang and colleagues articulated an exposure-based model of everyday routines where "variations in lifestyles are related differentially to probabilities of being in particular places at particular times and coming into contact with persons who have particular characteristics" (Hindelang et al. 1978, p. 245). Lifestyles encompass routines such as work, school, and time at home and are usefully decomposed into functional and leisure-oriented activities. Role-based expectations, structural constraints on lifestyle options (e.g., due to economic circumstances and place of residence), and attitudinal and skill-based adaptations to these conditions shape the contours of everyday routine activity profiles relevant for victimization risk.

Hindelang et al. (1978) offered a series of propositions rooted in lifestyle theory that bear directly on space–time exposure patterns. Among their key expectations is that persons spending more time outside the home, in public space, at night, and around potential offenders will have higher probabilities of victimization. Sharing demographic and other characteristics with typical offenders is associated with shared lifestyle patterns and increased risk. In this view, the relatively high likelihood of victimization among young, single men, for instance, would be a function of lifestyles that place them in closer proximity to potential offenders who share these demographic characteristics. Research in the lifestyle tradition has employed a variety of proxies to capture lifestyle factors that increase the likelihood of exposure to places and people that heighten victimization risk. For instance, Turanovic et al. (2018) used residence in concentrated disadvantage neighborhoods and involvement in risky activities (offending, substance use) to capture risky exposures but did not measure place-based exposures directly.

Theories of offending have also taken a person-centered approach, focusing on activity patterns and routine exposures that heighten the risk of criminal perpetration. Brantingham & Brantingham (1981, 1993, 1999) describe the decision-making process as driven by opportunities anchored in potential offenders' everyday exposures. In this view, routine travel paths, marked by key nodes such as home, school, workplace, shopping locations, and leisure destinations are connected by linking travel paths, the combination of which describes an individual's activity space. The area made visually accessible by an activity space pattern is the awareness space in which perceptions of suitable targets and guardianship potential are rationally assessed for criminal opportunities. The decision-making process involves identifying general areas thought to be more conducive to offending and then selecting specific places within these areas to commit crimes (Bernasco & Block 2009; Brantingham & Brantingham 1993, 1995; Clarke & Cornish 1985). The everyday spatial trajectory of the offender is thus central to crime pattern theory.

Among the most well-developed person-centered theoretical approaches to crime emphasizing mobility is Wikstrom and colleagues' SAT. SAT combines insights from routine activities theory with a focus on individual criminal propensity and place-based informal social-control capacity (collective efficacy) to capture the constellation of person–environment factors that yield a high risk of offending. In this view, mobility patterns of potential offenders—who vary in morality and self-control—yield differential exposure

to criminogenic settings. Low morality and self-control combine with environmental temptations and/or provocations and minimal place-based collective efficacy to shape the perception–choice process that yields crime as an outcome. Conceptualizing and measuring youth activity fields are central to this approach (Wikström et al. 2010). Proponents of SAT have employed sophisticated methods for measurement of mobility and associated exposures, to which we now turn.

Operationalizing Mobility at the Person Level

Several approaches have been used to measure crime-relevant person-based mobility and associated exposures. We consider traditional space–time budgets eliciting self-reported mobility trajectories over specified time periods, use of GPS[2] measurement alone to capture spatial exposures, and geographically explicit ecological momentary assessment (GEMA) (combining GPS and EMA). Finally, we review the more recent use of automated, recall-aided space–time budget methods that combine GEMA with space–time budget interviews to measure and clean location data (Boettner et al. 2019, Sugie 2018a).

Traditional space–time budget method.—The space–time budget is a methodology designed to capture human activities in spatial and temporal contexts (Hägerstrand 1970, Yu & Shaw 2011). The approach has a long history in geography (Golledge & Stimson 1987) and has been adapted to the study of crime in the ambitious Peterborough Adolescent and Young Adult Relationship Study (PADS+). PADS+ combines conventional individual-, family-, and community-level survey methods with a space–time budget in which the 716 participant youth retrospectively report on their activities for each hour of the day, over the course of four days (two weekend days and the two most recent weekdays). Youth are asked to report, for each hour of the day, where they were, the function of this place (e.g., workplace, school, park), who they were with, and the main activity in which they were participating (including criminal activity). This innovative adaptation of the space–time budget methodology to the measurement of routine activities and criminal behavior has yielded a wealth of insights into the situational determinants of crime, with findings generally supportive of SAT expectations. Space–time budget-based contributions include not only studies based on the PADS+ data (Hardie 2019; Wikstrom & Butterworth 2013; Wikström & Loeber 2000; Wikström et al. 2010, 2018) but also additional research drawing on the PADS+ space–time budget design (Bernasco et al. 2013, de Jong et al. 2019, Hoeben et al. 2014, Menting et al. 2019, Vandeviver & Bernasco 2019, Weerman et al. 2015).

The space–time budget method yields rich information about the mobility trajectories—including stable destinations and travel paths—of respondents. When combined with crime-relevant exposure and event data, the method allows for exploration of the situational circumstances of offending and victimization in unprecedented detail. Yet concerns have also been raised about the approach. First, recalling sequences of spatial exposures may be difficult, particularly when respondents include youth who may struggle to recover their step-by-step spatial trajectory several days removed from its occurrence. For this

[2]We use the term GPS to capture technologies that are exclusively GPS-based as well as those that use, e.g., smartphone-based location tracking incorporating both GPS and cell tower triangulation.

reason, Wikstrom and colleagues chose to collect information from youth respondents using hour blocks of time under the assumption that higher-resolution temporal units would tax recall and add inordinate length to the interview (Wikstrom & Butterworth 2013, Wikström et al. 2012). Consequently, mobility dynamics that occur over shorter windows—which may nevertheless be important from the standpoint of criminogenic exposures—may be obscured. Recalling situational characteristics of crimes perpetrated over the study period may be additionally compromised if youth experience intoxication during the offending event. Furthermore, given cognitive limitations on the capacity to recover activities beyond a relatively recent temporal window, space–time budgets cannot capture longer-term exposure patterns in detail. Finally, social desirability factors may lead to omission or other forms of bias in the reporting of location exposures when space–time budgets are interviewer administered.

GPS-based measurement.—The limitations of traditional recall approaches to collecting space–time budget data have led to increasing incorporation of technology-aided data collection approaches. A rapidly expanding method employs GPS data to capture mobility trajectories with enhanced precision. For example, using GPS data collected from 11 participants followed over the course of two weeks, Theall et al. (2018) found that even remote exposure to non-neighborhood alcohol outlets is associated with one's own drug and alcohol consumption and internalized anger. Explicitly examining racial differences in youths' daily exposure to violent crime, Browning et al. (2017c) drew on the GPS data of 878 youth from the AHDC study, finding that activity space characteristics beyond residential neighborhoods explain a substantial proportion of the variation in exposure to violent crime, indicating the importance of non-neighborhood exposures.

Geographically explicit ecological momentary assessment.—The results of studies considering retrospective time diary reports as well as in-the-moment exposures call attention to questions regarding how objective and subjective exposures independently and jointly contribute to criminal and delinquent involvement. Tothisend, Byrnes et al. (2017) utilized GPS-enabled smartphones in tandem with EMA reports (or GEMA) (Kirchner & Shiffman 2016)] to examine how objective and subjective exposures shape adolescent alcohol use and delinquent behavior. They found objectively measured exposure to highly disadvantaged neighborhoods and alcohol outlets to be associated with alcohol use, whereas only respondents' subjective neighborhood perceptions were associated with problem behavior. This finding underscores the importance of measuring not only objective measurement of capable guardians and suitable targets but also variation in likely perpetrators' individual perceptions of these features.

In addition to more directly measuring real-time subjective assessments and mobility patterns, GEMA approaches have also been used to capture the experiences of traditionally hard-to-reach groups (Sugie 2018a). Specifically, Sugie and colleagues (Sugie 2018b, Sugie & Lens 2017) draw on three months of data from the Newark Smartphone Reentry Project (NSRP) to understand accessibility to employment opportunities and subsequent activity patterns among men exiting prison. Sugie (2018a) further assessed the feasibility of these

GPS and EMA data collection approaches with high-risk participants, finding evidence of substantial advantages over traditional survey and interview-based approaches.

Finally, Browning and colleagues combined GEMA and interview-based approaches in an effort to generate more accurate mobility data on youth from the AHDC study. In this recall-aided interactive space–time budget approach (Boettner et al. 2019), youth and their caregivers were administered an entrance survey during which geographic and other information on typical locations visited was collected from both respondents. These specific locations were then incorporated into EMA surveys administered five times a day (randomly within time blocks) over a week. Youth were asked whether they were currently at any of the typical locations provided on the entrance survey at each EMA. Youth were also tracked continuously using smartphone GPS over this week-long period. Finally, GPS data were processed through a binning algorithm that decomposed spatial trajectories into stationary and mobile periods and provided estimates of the specific locations visited. These estimates were based on both the entrance survey typical location data and Google Maps locations proximate to the centroid of point clusters generated during stationary periods. A dedicated software application displayed spatial trajectories based on GPS data along with EMA responses to aid recall regarding the locations visited. During the space–time budget interview, youth were prompted to corroborate or correct location estimates provided by the software and add information for each location on activities and network partner presence.

The use of GPS and EMA responses to aid recall regarding mobility trajectories offers the potential for more precise and unbiased information on exposure patterns by comparison with traditional recall-based approaches. However, reliance on GPS data to inform spatial trajectories risks building measurement error into the space–time budget data (e.g., due to the inaccuracy of the GPS data or if the respondent is physically separated from the phone). Although the approach reduces the cognitive burden associated with recall during the space–time budget interview, the total respondent burden is increased with the addition of multiple days of smartphone data collection. A principal concern is the potentially considerable cost associated with fielding studies that combine GPS, EMA, and face-to-face space–time budget interviews. Costs increase when specific location data are fed forward from baseline survey interviews through EMA and space–time budget instruments, requiring demanding instrument programming.

Despite hurdles associated with use of traditional and automated space–time budget data collection approaches, these methods yield incomparably rich information on the crime-relevant mobility and exposure patterns of individuals. An important direction for future methods development will be the design of integrated and entirely smartphone-based GPS, EMA, and space–time budget data collection. A potentially feasible approach would be to employ machine learning techniques to adaptively refine routine location inferences combined with minimally invasive, respondent-driven data cleaning.

ECOLOGICAL NETWORK APPROACHES

Advancements in the conceptualization and measurement of crime-relevant mobility in place- and person-oriented approaches have yielded important insights into criminogenic

sociospatial processes. Yet the tendency of these approaches to focus on features of a single place or neighborhood context or the situational person–place link downplays the embeddedness of people and places in broader systems of location interconnection based on mobility flows. Similarly, individuals occupy positions within the network of persons and places linked through routine exposure. The structural context of places through mobility flows and persons through shared routines may have a variety of implications for understanding place effects on crime. Although many place-based approaches acknowledge the relevance of spatial or neighborhood embeddedness (Weisburd et al. 2012), research on mobility-based embeddedness remains incipient.

Ecological Network Approaches: Theoretical Foundations

Place embeddedness has been a concern in both neighborhood and microplace studies in the focus on proximate area influences. Research emerging in the late 1990s brought attention to the potentially problematic focus on atomized neighborhood units in the conventional neighborhood effects design (Goodchild 2009). Studies of neighborhoods often drew on populations of neighborhoods within a single city, inducing dependence among contiguous or proximate neighborhoods, particularly in analyses of highly spatially clustered outcomes such as crime. Several studies addressed this concern through explicitly theorizing and modeling spatial dependence, incorporating the expectation that mobility across inevitably porous neighborhood boundaries may independently contribute to focal neighborhood crime outcomes (Morenoff et al. 2001). Yet, as with the typical proxy approach employed in research on space, analyses of neighborhood spatial dependence are built on an assumed—but not measured—distance decay approach to inter-neighborhood mobility. Findings from this literature have offered powerful indirect evidence of spatial spillover processes (Groff 2007a,b; Brantingham & Tita 2008), but lack direct evidence of mobility processes that could capture actual cross-boundary exposures.

Absent data on interplace mobility, conventional neighborhood spatial dependence approaches obscure heterogeneity in dependence among proximate areas as well as inter-neighborhood ties that may be driven by other processes such as race/ethnic homophily or organizational resource-seeking behavior. Shifting attention to ties across places based on actual exposures regardless of proximity uncovers the actual ecological network—the structure of ties between persons through shared routines and places through shared mobility flows. The content and structure of ecological network ties may independently influence crime above and beyond conventional place-specific covariates. For instance, economically disadvantaged and racially segregated neighborhoods characterized by high levels of everyday mobility to similarly disadvantaged neighborhoods may experience elevated crime rates over comparable neighborhoods with less isolated ecological network ties (Wang et al. 2018). Lack of social and economic resources in extra-neighborhood exposure spaces combined with the potential for reinforcement of crime-tolerant orientations (e.g., legal cynicism, street codes) may compound the disadvantages of internally segregated and economically deprived neighborhoods. Attention to the potentially complex structural characteristics of ecological networks may also shed light on the diffusion and reinforcement of crime-tolerant or crime-inhibiting social processes. The ecological network approach,

however, presents unique challenges with respect to data resources necessary for estimation of network characteristics.

Operationalizing Ecological Networks

The emerging literature on econetwork mobility has relied on both social-survey data and VGI, showing substantial promise for understanding the embedded nature of crime. Several studies have examined relationships between characteristics of ecological networks and crime-relevant outcomes using geographically referenced survey reports. An emerging literature has investigated inter-neighborhood mobility flows using commuting data. For instance, Hipp & Kim (2019) used Southern California commuting data to investigate how street-segment-aggregated mobility flows shape crime across hours of the day and days of the week. They find that robberies are especially likely at street segments with fewer total routine employees and late in the evening but that these same street segments become most prone to robberies during weekend evenings.

Drawing on twelve years of Origin-Destination Employment Statistics commuting data in the Longitudinal Employer Household Dynamics survey (LEHD) linked to Chicago neighborhoods, Graif et al. (2017) examined how neighborhood violent crime rates shape inter-neighborhood ecological networks (Abowd et al. 2005). Specifically, they find that levels of neighborhood violent crime are associated with fewer neighborhood-level network ties to other communities. Additionally, communities with similar levels of violent crime are at an increased likelihood of forming commuting ties. In other work drawing on LEHD data in Chicago, Graif et al. (2019) found that high levels of disadvantage in inter-neighborhood commuting networks are associated with higher local crime rates. Taken together, these studies demonstrate the great potential for spatial commuting data to inform our understanding of how econetwork mobility dynamics interact with place to shape crime.

Other approaches have attempted to capture mobility patterns beyond those associated with commuting. For instance, Felson & Boivin (2015) drew on municipal transportation data from a large city in Eastern Canada, finding that daily inflows to census tracts explain a major portion of the variation in tract-level crime. Boivin & Felson (2018) further examined tract-level predictors of crimes committed by visitors as well as residents, finding visitor inflows and local recreation activity opportunities to be especially relevant for both offender groups.

Using structured location generator data from the L.A.FANS, Browning et al. (2017a) examined the relevance of neighborhood-level econetworks—persons tied through locations (either inside or outside the neighborhood)—to neighborhood social organization outcomes, including collective efficacy, intergenerational closure, and social network interaction. They find that neighborhood econetwork intensity—the average degree to which two households within a neighborhood are characterized by ties through multiple locations—as well as econetwork extensity—the average proportion of households in the neighborhood to which a given household is tied through any location—independently predict change in neighborhood-level collective efficacy and intergenerational closure. Constructing neighborhood econetworks based on travel survey and simulation data for the Columbus, OH, area, Browning et al. (2017b) examined associations between

neighborhood–econetwork structure and crime and found that ecological network intensity is negatively associated with neighborhood crime rates. More recent work using AHDC activity locations extends ecological networks to the concept of ecological communities, or clusters of individuals based on shared activity patterns (Xi et al. 2019) rather than shared residential location.

Travel survey and location generator data collected in L.A.FANS and AHDC can generate useful information on typical routine activity patterns but at the significant cost of sample size (Phillips et al. 2019). This drawback is particularly problematic in the context of econetwork estimation, where sampling from the network may yield biased estimates of network structural characteristics (Browning et al. 2017a). These issues call attention to the potential benefits of big data on routine activities in the form of VGI (Goodchild 2007). For instance, Wang and colleagues (2018) aggregated geo-tagged Twitter data from the 50 largest US metro areas over an 18-month period to investigate the extent to which the everyday mobility patterns of Twitter users extend beyond their residential neighborhood. Calling into question the assumption that residential neighborhoods represent a principal or encompassing exposure space for urban residents, they find that residents of highly disadvantaged neighborhoods Tweet often from areas beyond their immediate residential neighborhoods. Furthermore, they observe a powerful association between residential neighborhood composition and characteristics of non-neighborhood destinations, indicating that residential segregation extends to the isolation of non-neighborhood exposures as well.

Using this same data set, Sampson & Levy (2020) further demonstrated that city-level residential racial segregation is negatively associated with city-level equitable mobility—or the extent to which residents of each neighborhood in a city equally travel to all other neighborhoods in the city (Phillips et al. 2019). Additionally, among cities in which residents' travels outside their residential neighborhoods tend to be concentrated in few receiving neighborhoods (high levels of mobility concentration), higher city-level equitable mobility is associated with lower city-level homicide rates.

Geographically referenced cell phone data have also been leveraged for econetwork estimation. Building on the Columbus, OH, analyses conducted by Browning et al. (2017b), Saxon (2019) used smartphone-based GPS data drawn from a range of applications that collect location data. Specifically, more than 600 million GPS locations were recorded for 279,000 smartphone users using several dozen applications over the course of a month. These data were aggregated by LiveRamp and provided by Carto. Home neighborhoods were defined as the census tract of the modal location for respondents between 12:00 am and 6:00 am in an approach similar to that of Wang et al. (2018), and transit locations—defined as points within 10 meters of roadways—were excluded from analyses. The results of the study corroborate the conclusion that higher neighborhood econetwork integration is associated with lower levels of property and violent crime. Econetworks have also been measured with GPS data provided by major mobile-phone service providers in China. Specifically, Song et al. (2019) drew on GPS data linked to police records and census data, finding that the degree to which a receiving neighborhood is connected to the neighborhood of a convicted offender through aggregate mobility patterns is associated with the offender committing crimes in that receiving neighborhood.

The studies described above recognize the potential lack of representativeness of individuals who volunteer their geographic information and explore weighting strategies to address generalizability concerns. As demographic variables are typically not available for volunteered mobility data, additional analyses are needed to infer weighting variables from context clues in posted text or meta-data (e.g., profile images[3]) (McCormick et al. 2017). Even if complete demographic information were available from individuals volunteering geographic information on their mobility, there are still significant barriers to the generalization of findings of person-based mobility analyses. Generalization is challenged by the fact that little is known about the representativeness of geo-tagged locations with respect to the geographic distribution of routine activities of the individuals. On the one hand, it is plausible that users are more likely to share their location directly, or indirectly via tagging, when in socially desirable or nonroutine places. That is, the more atypical or unexpected, the more likely an observation. On the other hand, individuals may not be inclined to provide data when in unknown and potentially threatening situations. This lack of representativeness—from the perspective of individuals' routines—presents a unique form of spatially referenced censoring that, if ignored in empirical analyses, has the potential to produce biased inferences. To increase confidence in findings from volunteered geographic data, more detailed investigations into the generalizability of volunteered mobility data through validation with respect to observed spatial trajectories are necessary.

CONCLUSION

Two overarching objectives have motivated our discussion. First, we sought to demonstrate the relevance of the concept of human mobility for not only theoretical approaches to crime that directly and centrally implicate it as a key factor in the generation of crime but also a wide range of approaches not typically thought to emphasize mobility. The literature focused on criminology of place—particularly criminal opportunity approaches that highlight microplace dynamics—has theorized the situational relevance of mobility for crime in various approaches to the nexus of potential offenders, guardians, and victims. Although the neighborhood literature has generally not emphasized mobility, we argue that the dominant neighborhood theories of crime nevertheless indirectly implicate mobility-related factors. In addition, the more recent development of innovative person-centered and ecological network approaches highlights the emerging theoretical centrality of the mobility concept in criminology.

Our second objective was to review approaches to the measurement of mobility, including both dominant proxy-based strategies and novel methods for the direct measurement of mobility. Place and neighborhood approaches have largely employed land-use characteristics as indirect measures of mobility-related processes, relying on assumptions regarding the size and composition of populations associated with particular combinations of land-use types. This strategy has yielded an impressive and informative body of findings, but uncertainties regarding the likely complex association of land use with mobility may have contributed to the equivocal results of this literature.

[3]McCormick et al. (2017) propose a data-processing technique for inferring demographic information from Twitter users using images.

Acknowledging the wide-ranging theoretical import of mobility as well as the rapidly expanding availability of new data collection and measurement strategies, we call for broader incorporation of mobility measures in empirical research on crime. Creative adaptations of established approaches, including social surveys and in-person systematic social observation as well as new resources such as virtual audits and VGI, provide researchers with an unprecedented range of measurement options. Although these data present several logistical, financial, and methodological challenges, their potential for expanding knowledge presents an exciting opportunity for criminology going forward.

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