The Life-Course of Crime and Disorder at Places: Onset, Persistence, Aggravation, and Desistance

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ABSTRACT

Places, like individuals, experience both stability and changes in the perpetration of crime over time, or the "criminal career" of a place. Life course theory suggests four phases in the criminal career of a place: *onset* of issues; *persistence* of issues; *aggravation* to more serious types of issues; and *desistance* of issues. We apply this framework to how residential parcels (similar to properties) in Boston, MA shifted between profiles of crime and disorder from 2011-2018. 911 dispatches and 311 requests provided six measures of physical disorder, social disorder, and violence for all parcels. K-means clustering placed each parcel into one of six profiles of crime and disorder for each year. Markov chains quantified how properties moved between profiles year-to-year. Stability and change each exhibited characteristic patterns. Onset was relatively infrequent and more often manifested as disorder than violence. Pathways of aggravation led from less serious profiles to a mixture of violence and disorder. Desistance was more likely to occur as de-escalations along these pathways then complete cessation of issues. Persistence and aggravation were more prevalent in neighborhoods with above-average crime, even relative to local expectations. The results offer insights for further research and practice attentive to the life-course of places.

Introduction

In recent years there has been increasing attention to discrete properties as the locus of crime and disorder. Intellectually, research on crime and place and repeat victimization have each revealed that crime and disorder tend to concentrate at a small number of properties (O'Brien 2019; O'Brien and Winship 2017; Farrell and Pease 2001; Johnson et al. 2007; Trickett et al. 1992; Eck, Clarke, and Guerette 2007). Practically, city officials and police departments have adopted policy tools that identify and respond to "problem properties" (Way, Trinh, and Wyatt 2013; LISC 2015; Boston 2011). As we gain a deeper understanding of the nature and types of problematic properties, there remain open questions about how they emerge and evolve over time. Where there has been longitudinal research on the subject, it is generally on the persistence of a particular form of crime or disorder over time. There has been little if any examination of more nuanced trajectories, like a property manifesting different types of problems or alternating between being problematic and generating no issues from year to year, and whether these patterns are systematic and predictable.

The question of how crime and disorder evolve over time at properties is conceptually allied with the well-established subfields of life-course and developmental criminology (Sampson and Laub 1993; Le Blacn and Loeber 1998). Of course, these literatures are crafted around the developmental processes that constitute the stages of a person's life, which means that some of their key tenets may not directly translate to places. Nonetheless, they offer a starting point for articulating a model for the "life course" or "criminal career" of a problematic property (see also Sherman 1995). We present such a

model in the next section, identifying four main phenomena of interest: *onset*, or the initial emergence of crime or disorder; *persistence* of crime and disorder across time; *aggravation*, or escalation in frequency, severity or variation in crime and disorder; and *desistance*, or the diminishment in frequency, severity, or variation in crime and disorder, including cessation of all issues. The model is extensible to places in general, including properties, local institutions, and street segments. Importantly, we use the model to extend current perspectives in two ways. First, to move beyond work that has focused on the quantity of a single type of crime, we specifically examine shifts in the mixture and severity of issues at a place. Second, we consider how the life course dynamics of a place might differ with neighborhood context.

We use our model of the criminal career of a place to guide the analysis of residential parcels (i.e., individual building lots, analytically similar to properties and akin to the colloquial "address") in Boston, MA over an eight-year period; we focus on residential properties in order to guard against the possibility that different land uses experience distinct life course patterns, requiring independent analyses. We first use cluster analysis to classify every parcel in each year according to the quantity of physical disorder, social disorder, and violent crime occurring there. This technique enables an analysis of how properties do or do not shift between profiles of issues over the study period. In particular, we concentrate on whether certain transitions are consistent: does onset often entail certain low-level issues?; are some forms of aggravation more common than others (e.g., from being high in social disorder to being high in violent crime, a la broken windows theory; Wilson and Kelling 1982)?; does desistance follow the same steps as aggravation in reverse, or does it have its own distinct pathway? Before proceeding to

the data and analyses, we first summarize existing work on longitudinal patterns of crime and disorder at various geographic scales of analysis, including addresses, streets, and neighborhoods; we then present the four stages of the life course of properties and associated hypotheses; and then describe the research design we have adopted to examine them.

Evidence for Stability and Change at Places

Existing evidence on the longitudinal patterns of disorder and crime at places have mainly addressed two phenomena: *persistence*, or stability in the frequency or severity of crime and disorder; and *aggravation*, or escalation to issues of greater frequency or severity. The former line of research has consisted primarily of studies on a how a single type of crime or disorder persists at places, especially hotspot streets. The latter line of research has concentrated on how disorder might encourage or lead to crime. There have only been a few studies on aggravation at places, but there is substantial parallel work at the neighborhood or community scale. Although there is reason to believe that there are different criminogenic processes operating at each scale of analysis (Jones and Pridemore 2019), we take this work into consideration given its similar geographic focus.

There has been extensive work on the persistence of a single type of crime or disorder at every geographic scale. Criminologists have long recognized that crime and disorder tend to persist in the same neighborhoods over time (Shaw and McKay 1942/1969; Sampson 2012; Wilson 1987). A parallel line of work on hotspot streets has leveraged group-based trajectories to track how crime concentrate on a small handful of

streets in a city across years and even decades (Groff, Weisburd, and Yang 2010; Weisburd et al. 2004; Weisburd, Groff, and Yang 2012; Braga, Hureau, and Papachristos 2011; Braga, Papachristos, and Hureau 2010). Notably, these studies have illustrated that street segments tend to maintain a characteristic level of crime, be it high, moderate, low, or none. Further, they have demonstrated that high-crime streets are responsible for an overwhelming majority of the crime events of a given type in a city, even when combining data over time. At the property level, researchers on repeat victimization have also shown that certain people and places tend to experience the same type of crime multiple times (Farrell and Pease 2001; Frank, Brantingham, and Farrell 2012; Johnson, Bowers, and Hirschfield 1997; Levy and Tartaro 2010; Reiss 1980), even arguing that the first such event may increase the likelihood of future ones (Johnson 2008). An additional study at the intersection of each of these literatures found that multiple forms of disorder and crime all persisted from year to year at the address, street, and neighborhood levels simultaneously, even when controlling for persistence at the other two levels (O'Brien and Winship 2017).

Research on aggravation in communities and at places has most typically examined whether physical and social disorder led to more serious incidents. The most well-known perspective on disorder leading to crime is broken windows theory, which argues that the prevalence of physical and social disorder in public spaces encourages further delinquency and violent crime (Wilson and Kelling 1982). This has been joined by corollary theories that also argue that disorder can lead to crime, but via other mechanisms. For example, some have argued that certain types of physical disorder create “ecological advantages” that make crime easier to commit (e.g., abandoned buildings offer hiding places for drugs and weapons; St. Jean 2007; Branas et al. 2016). An alternative perspective has been that

private disorder, rather than public disorder, is more likely to lead to violence in a neighborhood. In their presentation of social escalation theory (SET), O'Brien and Sampson (2015) argued that domestic disputes and conflicts between neighbors can become increasingly violent and spill out into public spaces if not defused.

Regardless of the theory, the vast majority of empirical work on how disorder can lead to crime has occurred at the neighborhood level. BWT has been studied at this scale for nearly 40 years through a variety of methodologies, including cross-sectional and longitudinal observational studies (e.g., Sampson and Raudenbush 1999; Taylor 2001) and evaluations of policing interventions that focused on the removal of disorder (see Weisburd et al. 2015 for a review). There are however, a handful of studies that have examined BWT at the more localized scale of streets. Wheeler (2017), for example, found that disorder on a street was predictive of future crime. Braga and Bond (2008) saw similar support for BWT based on a randomized control trial that cleared disorder from target streets in an effort to lower crime. Likewise, SET has only been studied, to our knowledge, at the neighborhood level (O'Brien and Sampson 2015). That said, it draws on a variety of evidence at the individual and household level that would suggest more localized relationships are possible or even likely. For instance, household conflict and community violence can be instigated by the same individuals (Juarros-Basterretxea et al. 2018; Kiss et al. 2015), or the former can feed into stressors or social dynamics that facilitate the latter (Cuartas 2018; Caughy et al. 2012). Research on ecological advantages has been an exception, largely occurring at the street segment level because the theory specifically implicates the ways that a particular piece of disorder, like an abandoned building, can

facilitate crime in the immediate surrounding area (Branas et al. 2016; Furr-Holden et al. 2011).

In addition to work on crime and disorder over time at addresses, streets, and neighborhoods, a small set of studies have also examined how dynamics at each of these scales interact with each other. Specifically, multiple studies have found that the presence of crime throughout a community can reinforce the persistence of crime at places therein. Repeat victimization, for example, is even more likely for people and places in high-crime communities (Trickett, Osborn, and Ellingworth 1995; Bennett 1995; Johnson, Bowers, and Hirschfield 1997). Meanwhile, O'Brien & Winship (2017) found that persistence at an address was greater if its street or tract also had above-average levels of crime. We might, then, expect to see the same reinforced persistence when analyzing the criminal careers of places. It also raises the possibility that reinforcement can make aggravation more likely. A full consideration of the life course of places will require attention to these contextual effects as well.

The existing research on persistence and aggravation lays a strong foundation for a life-course approach to crime and disorder at places. It also suggests that there might be an important interplay between places and their communities. That said, it is incomplete. As we elaborate in the next section, there are other components of the criminal career of a place that have received less, if any, attention.

A Life Course Framework for Places

In an early essay on crime and place, Sherman (1995) compared the "criminal careers" of people and places. As he did then, we argue that life course theory and developmental criminology hold lessons that will allow us to develop a life course framework for examining, understanding, and addressing problematic places. As we do so, it is important to distinguish between the major stages that describe a life course and the processes that underlie them. The stages describe the events from the onset of offending to its termination and everything in between, and they are captured through measures of criminal behavior. Processes, meanwhile, are often prioritized for their ability to explain these stages and the various forms they might take. As we are taking an early step in developing a life course framework for places, we will focus on four stages that describe the criminal career of a place: in addition to *persistence* and *aggravation* we also consider *onset* and *desistance* of crime and disorder. We begin, though, by laying out the types of processes that might be relevant when reasoning about these stages. We acknowledge that we only describe these processes in brief and that future work will need to further develop our understanding of them, a point we return to in the Discussion. After doing so, we present the four stages of a criminal career in the order they would occur—onset, persistence, aggravation, and desistance—and propose hypotheses for each that we will test in the study that follows.

Research on the life course of offending operates on the premise that offending behavior interacts with other social and psychological developmental processes that describe the pathway from youth to adolescence to young adulthood and beyond. LeBlanc and Loeber (1998), for instance, center their summary of developmental criminology on three main processes that are each responsible for one or more stages or transitions

between them. First, *activation* entails the processes that contribute to sustained, accelerated, or diversified offending over time, beginning with the onset of offending. Second, *aggravation* is described as a developmental sequence of escalation from less to more serious forms of offending. Third, *desistance* entails the reduction in the frequency, severity, or variety of offending, including the age of cessation of offending. Though places do not follow the same developmental blueprint as a human being, they might still experience similar stages in their expression of crime and disorder that describe a life course.

Crime and disorder at places are often conceptualized in terms of routine activities theory—that is, the coincidence of potential offenders, victims, and guardians and their purposes for being there (Cohen and Felson 1979). Given that the land use and demographic context of a place are often consistent over time, its routine activities are also often described as being stable. But Sherman (1995) pointed out in his own essay that, if and when these local social dynamics shift, they might precipitate concomitant changes in the quantity or types of crime and disorder. Such shifts might come in various forms, from changes in ownership, residents, visitors, institutional oversight, or otherwise. These could give rise to processes that are analogous to those articulated by Leblanc and Loeber (1998) or others that are better suited to the particularities of places. In turn, they suggest that a place could indeed have a life course with meaningful transitions between stages rather than an unchanging level of crime and disorder. We walk through each of the consequent stages in turn.

Onset

The beginning of a criminal career is the *onset* of crime. For a person, the age of onset matters substantially as it lands during a particular stage in the developmental process. Earlier onset could speak to a greater propensity for long-term offending and, practically speaking, a greater timespan for doing so (Farrington, Loeber, and Van Kammen 1990; Moffitt 1993; Elliott 1984). The age of a place has less meaning in these regards, but it is still a salient moment in which crime and disorder appear at a property where there was none previously, setting the stage for future increases or decreases in issues. Thus, we focus here specifically on the forms that onset tends to take. Onset of crime in youth, for example, typically occurs with a low-level offense as an individual initiates his or her criminal career (Belson 1975; Le Blanc and Frechette 1989). It would seem possible that the same could be true for places, with minor issues, like physical or social disorder, being the first issues to appear.

Onset has been little studied for places. The closest has been work on the trajectories of crime for street segments, though this has been indirect at best. For example, Weisburd et al. (2004) identified a substantial proportion of streets in Seattle, WA with increasing trajectories. In cases when these increases followed periods of no crime, these might have been onsets, however the work did not flag them as such nor analyze their characteristics. As we analyze onset, a major initial question is whether certain profiles of crime and disorder more likely to be observed as the point of onset. We hypothesize that onset entails less severe kinds of issues, like disorder.

Persistence

Following onset, crime and disorder might continue. This is captured in the developmental criminology literature under the term activation. This term, however, is not a perfect fit for our purposes here as it refers to a process that encompasses multiple outcomes, including acceleration in the rate of crime, diversification of crime types, and stabilization of criminal activity into a habit (Leblanc and Loeber 1998). This reflects the understanding that as an offender grows older their offending will have the opportunity to proliferate in one or more ways. That is to say, without a change in one's relative attitude toward offending, there is still an expectation that growth in offending could occur owing to the sociopsychological experience of aging. As places have no such developmental blueprint to drive change in their expression of crime and disorder, the simpler phenomenon of interest is the *persistence* of crime and disorder of the same sort at a place. This stage is different from the others in its relative stability, contrasting with increases or decreases in crime following onset. For this reason, persistence is likely the predominant stage of the criminal career of a place as it implies a stability in underlying routine activities and social dynamics.

A major consideration for persistence is whether stability is uniform across types of crime and disorder, or whether some types of issues are more likely to give way to further shifts in the criminal career of a place. We view this as an open empirical question. In addition, the availability of 8 years of data enables us to examine how durable persistence is. We hypothesize that as a parcel exhibits the same profile of crime and disorder for more

consecutive years, it is increasingly likely to remain that way in the following year, rather than experiencing aggravation or desistance.

Aggravation

Aggravation, in its reference to a sequence of escalation that an offender might pass through, also assumes a developmental process. The literature argues that aggravation might take multiple forms, including increases both in the seriousness of events (Sellin and Wolfgang 1964) and their variety (Blunstein et al. 1986; Hindelang, Hirschi, and Weis 1981). As summarized in the previous section, multiple theories have posited the same for places, with disorder giving way to more serious issues. These theories might be framed as proposing that disorder itself is the factor that instigates aggravation at a place.

In our analysis, we probe three questions. The first is descriptive: how frequently does aggravation actually occur? Second, which of these pathways to severity are most common? This is a novel test of BWT and SET's arguments that public and private disorder, respectively, tend to evolve into more serious events. Third, it is possible that there are different pathways or cycles of aggravation comprising two or more overlapping or entirely distinct profiles of crime and disorder. For example, social disorder reflects interpersonal and behavioral issues that are prone to violence, whereas physical disorder is more often a sign of negligence or impoverishment. The two might then be involved in different pathways of aggravation. Uncovering this would be possible with the extended corpus of data available here.

Desistance

Desistance, or a decrease in the frequency or severity of crime and disorder, is the concluding stage in the crime careers of people or places—and especially critical from the practical perspective of identifying ways to prevent or discourage crime. It need not, however, be an all-or-nothing concept. Kazemanian (2007) points out that, although desistance is often measured in the literature as a complete cessation of crime, it is a more nuanced, dynamic process in which an individual diminishes the severity and frequency of offending. We adopt this same perspective for places. As such, desistance could be the opposite of onset in cases of complete cessation of crime and disorder, but it also could be the mirror-image of aggravation. Similar to offenders, places might gradually experience fewer and less severe forms of crime and disorder. This may follow the same pathway as aggravation in reverse or could entail its own characteristic set of steps.

Desistance has been understudied in places. Research on pathways from disorder to crime, for instance, have never, to our knowledge, examined whether there is a reciprocal downward pathway from crime to disorder. This is explained by both conceptual and methodological limitations. Conceptually, a de-escalation of this sort is not a stipulation of those theories and has not received much attention. Methodologically, studies on the subject have traditionally employed a regression framework that uses counts of events of disorder at one time to predict the likelihood or frequency of crime at a later time. Using such a technique to reveal the presence of disorder—although potentially less disorder—following the cessation of serious crime would be complicated if not convoluted. As such, the question lends itself more to the analysis of trajectories. Nonetheless, research in that

vein has identified decreasing trajectories, but never used them to differentiate between partial and complete desistence. Also, these previous studies have often focused on a single type of crime or disorder, meaning they were unable to identify forms of desistance that entail shifts to lower severity issues.

Given the evidence that desistance more often manifests as a gradual process of de-escalation in offenders, we hypothesize that the same will be true for parcels, with parcels with high-severity issues more often transitioning to lower-severity issues than immediately ceasing to have issues. Indeed, the routine activities that underpin crime and disorder arise from the behaviors of interactions of people. It would thus follow that, just as individuals gradually advance toward cessation, the alteration of routine activities at a place will often have to do the same. Second, we will examine whether the steps involved tend to be a mirror image of aggravation or not. There is no clear to evidence as to whether this would be the case or not, and thus we leave this as an open question to be addressed by the analysis.

In sum, there are four major stages that together describe the life course of crime and disorder at a place, or its criminal career: onset, persistence, aggravation, and desistance. Each of these reflects one or more specific transitions—or the notable lack thereof in the case of persistence—that might be observed empirically. The goal of this study is to probe each of these four stages, guided in part by the questions and hypotheses that we posed in this section. Last, we return to the observation from the previous section that the prevalence of crime throughout a neighborhood might influence the trajectories of crime

and disorder at places therein. Based on this, we also hypothesize that persistence and aggravation will each be bolstered by the social dynamics of the broader neighborhood, thus being greater in high-crime neighborhoods. Further, if desistance proves to be a multipart process, we hypothesize that the realization of complete cessation will be more common in lower crime neighborhoods. These questions will be addressed in a later part of our analysis.

Current Study and Hypotheses

There are two main strategies for studying longitudinal patterns of crime and disorder. One is to use a regression framework (e.g., cross-lag models, hierarchical linear models) to test how one or more types of crime and disorder at a particular scale of analysis predict each other at a later time. For example, does the frequency of physical and social disorder at a place in one year predict the frequency or likelihood of violence at that place in the following year? The alternative is to categorize units of analysis according to their trajectories of crime over time. This typological approach is more common for life course studies (e.g., Nagin and Land 1993), as well as studies of stability at hotspot streets (e.g., Weisburd et al. 2004), in part because it can classify units of analysis according to the timing and shape of the different stages that constitute a criminal career. For instance, are there reliable differences between early-onset and late-onset offenders? This approach has the advantage of treating units of analysis as discrete units with multiple attributes; in contrast, under a regression framework, units of analysis are abstract bundles only understood through the interpretation of variable-centric results.

We are interested here in the criminal careers of individual places; specifically, of all residential parcels (similar to properties or addresses) in Boston, MA for 2011-2018. This suggests a typological approach. That said, most studies on trajectories of places have examined a single type of crime, whereas the questions raised both by life course theory and theories of the escalation of crime also reference shifts in the types or variety of issues at a place. We thus apply our model of the life course of a crime and disorder at a place to examining multiple types of issues across time. This is made possible by using 911 dispatches and 311 service requests generated in the city, which provide six established measures: physical disorder in private and public spaces; social disorder in private and public spaces; and violent crime and prevalence of guns (O'Brien, Sampson, and Winship 2015; O'Brien and Sampson 2015). They are also the same data sets used by the City of Boston's Problem Properties Task Force (PPTF) to investigate properties and to initiate interventions. Despite the semantic and practical focus on the "property," the analysis focuses on "parcels"—identifiable lots that contain one or more properties and are very similar to addresses—because they are the lowest level for reliably attributing events to places (see Methods for more). Also, we note that we limit our attention to residential parcels, thereby excluding commercial, industrial, and exempt parcels. Each form of land use has its own characteristic patterns of routine activities and consequently could exhibit different contours in its life course. This would complicate analyses and interpretations, especially regarding the distinction between residences and other institutions. For this reason we start with residential parcels as the most numerous locations in the city (~80% of parcels) and anticipate that future work should do the same with other types of places.

To study shifts in the types or mixtures of crime and disorder over time, we pursue a two-part analysis. First we create a typology for profiles of crime and disorder for each place in each year. Second, we track how they shift between these profiles, or "states," over time. To illustrate, a property that falls into a "high physical disorder" category in year one might shift into a "high social disorder" category in year two. Operationally, the first stage will consist of a cluster analysis that uses the six measures of disorder and crime to categorize all parcels in each year according to their profile of crime and disorder. The second stage will then use Markov chain analysis to observe when properties transition from one type to another between years, quantifying which transitions are occurring more often than would be likely by chance. It will assess not only year-to-year transitions but also three-year sequences. This will better reveal both the durability of stability, either in the form of persistence or the absence of crime, as well as the shape of multipart transitions, like aggravation and desistance. We are also able to segment these analyses by neighborhoods, allowing us to specifically examine the role of neighborhood crime of reinforcing or exacerbating certain dynamics in the criminal career of places.

Our analytic strategy will allow us to observe onset of issues and their persistence, as well as both aggravation and desistance as the severity of crimes at a place increase or decrease. First, it allows us to reveal aggravation in cases that might have been treated as onset if the incumbent form of crime or disorder was not measured (e.g., an escalation from physical disorder to social disorder in a study that did not measure physical disorder). Second, it enables the identification of desistance that would be difficult to specify with a regression framework. It would require a complicated, if not convoluted, regression model to demonstrate, for example, that the cessation of violence at a property is followed by the

presence of social disorder, especially when that social disorder may have already been present. Here, however, we will be able to observe how often a property exhibiting a profile of crime and disorder characterized by the presence of violence transitions into one with only social disorder. Across these considerations, a final advantage of the strategy is that it highlights the frequency and form of each of our four stages of interest, without over-prioritizing one—most notably, persistence—because it is more common. The Markov chain models instead permit us to independently observe the different forms that each of the stages take and to quantify those forms relative to chance.

A final methodological consideration that must be addressed is the justification of a typological approach for profiles of crime and disorder. There has been much debate about the efficacy of typological approaches to analysis, most notably in an exchange between Daniel Nagin and colleagues and Robert J. Sampson, John H. Laub, and colleagues about the study of life course offending (Eggleston, Laub, and Sampson 2004; Sampson, Laub, and Eggleston 2004; Nagin 2004; Nagin and Tremblay 2005; Sampson and Laub 2005). The debate centered on the tension between methods and theory. The methods used to generate typologies assume that there are typologies to be found in the data. In turn, they will find typologies even if such groupings do not actually exist or have no real-world meaning. A specific concern is that the method would reveal "groups" that are merely a segmentation of a continuous distribution. There are statistical and theoretical reasons to believe that this is not a concern here. Statistically, we are using multiple forms of crime and disorder that are substantially independent of each other at our level of analysis (i.e., do not share strong correlations). Theoretically, returning to routine activities theory (Cohen and Felson 1979), it is unlikely that all problematic places feature the same

expression of crime and disorder. Instead, the specific types of offenders, targets, and guardians that frequent a place and their purposes for being there will determine the types of issues that arise. For instance, a pub with poor management and a rental property with an absentee landlord and delinquent tenants could feasibly generate distinct profiles of crime and disorder. Balancing the limits of these concerns with the overall benefits of the typological approach for revealing shifts in the profile of crime at a place, we conclude that this is an appropriate way to examine the question of the life course of crime and disorder at places.

METHODS

Data sources

The study utilizes two archives of administrative records from the City of Boston for 2011-2018: (1) dispatches made by the 911 system and (2) requests for non-emergency services received by 311. All records include date and time when the issue was registered or received, the location of the violation or event, and a case type categorizing the issue. These archives are also used by Boston's Problem Properties Task Force (PPTF) to identify and investigate properties. The 911 dispatches capture events typically categorized as social disorder and violent crime, whereas the 311 requests capture physical disorder in private and public spaces, respectively.

Geographic Coordination of Data and Unit of Analysis

The analyses focus on land parcels (i.e., lots that contain one or more properties), which are the fundamental unit of the urban landscape and an approximation of the colloquial "address."[1] Land parcels are nested in census tracts. This organization is made possible by the Boston Area Research Initiative's Geographical Infrastructure for Boston (GI; O'Brien et al. 2018). The City of Boston maintains the list of land parcels, but the GI condenses this list slightly by combining distinct land parcels with the same postal address that are sufficiently close to each other as to be indistinguishable in the data.

Between 2011-2018 the City of Boston made 5,356,049 unique 911 dispatches and 1,686,459 requests for service through 311, including the latitude and longitude of the location of each event. We used this information to spatially join to the nearest land parcel. This process was able to attribute 4,978,558 911 reports to an address (93% geocoding rate; 6% of records lacked a lat-long and 1% fell outside city boundaries) and 1,482,040 311 reports were mapped to the nearest known parcel at the time of data entry (others had no relevant geographic information or were mapped to City Hall as a default; 88% geocoding rate). Geocoding rates for the case types used in the study (see Data Measures) were somewhat higher: 98% for 911 dispatches and 92% for 311 requests.

Land use categories were used to limit the analysis to the 81,673 residential parcels in the city (of 98,136 total; see Appendix A Table A1). These include single-family (R1; 41%), two-family (R2; 23%), three-family (R3; 19%), four-family (R4; 0.4%), apartment buildings (seven or more units; 3.3%), condominiums (12%), and condo lobbies (0.04%).

[1] Parcels contain one or more properties (e.g., condo buildings are parcels with a separate property for every unit). However, in official records of events the most granular piece of information is the street address, which does not distinguish between properties within a parcel. For this reason, it is necessary to treat parcels as the most fundamental unit available to analysis.

As noted in the Current Study section, we limited to residential parcels in order to maintain a certain level of homogeneity in routine activities, otherwise a typological analysis would be likely to differentiate primarily on land use. Further, it is possible that questions of life course vary considerably between residential parcels and other land uses, which would complicate this initial study and are more appropriate for further research.

Data measures

We used six measures of physical disorder, social disorder, and violent crime drawn from administrative records (see Appendix A Table A1 for all relevant case types and their frequencies). We drew two indices of physical disorder from 311 requests, as previously developed from 311 data in Boston (O'Brien et al., 2015): *private neglect*, comprised of cases referencing housing issues, uncivil use of private, and problems with big buildings; and *public denigration*, comprised of cases reflecting graffiti and the improper disposal of trash. Measures of social disorder and violent crime were drawn from 911 dispatches (O'Brien & Sampson, 2015). The two indices of social disorder were *public social disorder*, (e.g., panhandlers, public drunkenness), and *private conflict* arising from personal relationships (e.g., landlord-tenant conflicts). The indices of violent crime are *public violence* that did not involve a gun (e.g., fight) and *prevalence of guns*, as indicated by shootings or other incidents involving guns. Over 2011-2018, 12,697 calls for service referred to social disorder, 55,065 referred to private conflict, 62,173 referred to public violence, 12,172 referred to the prevalence of guns, 59,517 referred to private neglect, and 72,671 referred to public denigration. We tabulated events reflecting each of these six types of crime and disorder

at each parcel in each year (see Table 1 for distribution). These are the main measures used in the analyses that follow.

Analysis Plan

Typologies of Properties

We created typologies of residential properties based on their profile of crime and disorder events using K-means clustering. K-means is an unsupervised machine learning technique that categorizes a collection of *n* entities (i.e., parcels in this case) into *k* groups based on a set of variables or "features." *k* must be less than *n* and is pre-determined by analyst. K-means begins with an initial set of *k* means and then categorizes every point in *n* according to the nearest of these means on the pre-established features (by squared Euclidean distance; that is, partitioning space into *k* Voronoi cells). It then adjusts each of the *k* means to be the centroid of the cases now attributed to it and reclassifies all objects in *n* according to these new means. This process continues until convergence (i.e., there is no change in the categorization of any member of *n* in the final iteration). The goal of K-means clustering is to minimize the within-cluster variance (i.e., $\min(\sum_{i=1}^{k} \sum_{x \in S_i} |x - \mu_i|^2)$ where S_i is a member of one of the *k* categories), in turn maximizing variance across clusters, for a given value of *k*. In this case, the features were the six categories of disorder and crime, each normalized before analysis. The units of analysis were parcel-years (i.e., each parcel in each year was treated as an independent event that could take on a different profile of crime and disorder), making for a sample of 653,384 (8 years * 81,673 parcels).

There is no definitive way to determine the optimal number of clusters, but the algorithm generates diagnostics for solutions for every value of *k* up to 10. We used three popular techniques for interpreting this information. First, the "elbow test" involves plotting the total within-cluster variance in a line chart. Because this value decreases monotonically with each increase to *k*, the analyst must visually determine when this decrease plateaus (i.e., the point at which increasing the value of *k* provides minimal returns). In the case that the elbow method does not uncover a clear bend, the silhouette score shows how similar an object is to its own cluster (cohesion) compared to other clusters (separation), and has a range of [-1,1]. Values closer to 1 indicate clusters that are more internally cohesive and separated from neighboring clusters. The silhouette test seeks out an inflection point as *k* increases. Third, Tibshirani's Gap-Statistics compares intra-cluster variation at each value of *k* to the expected amount of variation under a null reference distribution with no actual clustering. It recommends the *k* value where the largest difference in this comparison. With cluster analysis as with other data reduction techniques, the analyst must make certain judgments based on domain knowledge. We provide the details that went into the final determination of the number of clusters in Appendix B.

Trajectories of Problematic Properties

We used Markov Chain models to describe how properties do or do not transition between profiles of crime and disorder from year to year. Markov chains are a random process that consists of: a *state space*, or the set of states that objects might take on (i.e., the

profiles of crime and disorder); a *transition matrix* describing the probabilities of transitions between states; and an initial distribution of states (Gagniuc 2017). Markov chains are characterized by a memoryless property, meaning that a future state depends only on the current state. This is represented mathematically as $P(q_i = a|q_1, q_2, \dots, q_{i-1}) = P(q_i = a|q_{i-1})$, where q_i is the state of object q at timepoint i and a is a specific state in the state space; that is, if the immediately previous state of an object is know, prior states add no additional information for predicting its state at the current time. This logic can also be generalized to chains of size n where the final state is modeled as a function of the preceding n-1 states (i.e., $P(q_i = a|q_1, q_2, \dots, q_{i-1}) = P(q_i = a|q_{i-n}, \dots, q_{i-1})$. The primary product of interest is the transition probability matrix, $A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix}$, where A_{ij} is the probability that an object that begins in state i will transition to state j at the next time point. Markov chain analyses use shifts observed in the data to construct estimates and standard errors for all the values in the transition probability.

We conducted two Markov chain analyses using the markovchain package in R (Spedicato 2017). First, we conducted a traditional Markov chain calculating the probabilities that a parcel with a given profile of crime and disorder in one year exhibited each of the other possible profiles of crime and disorder in the next year (i.e., the transition probability matrix). Second, we conducted a second-order transition probability matrix in which an outcome state was modeled on the states in the previous two years. This required some elaboration by the authors on the tools in the markovchain package. We refer to these two analyses as two-year and three-year Markov chains throughout the analysis.

To better interpret the probability matrices, we re-ran the analyses by randomizing the distribution of parcels across states within each year (i.e., keeping the annual proportions of states but removing their non-random associations within parcels across years). We compared these randomized results with the actual results in two ways. First, we calculated relative odds ratios of the form $OR = \frac{\frac{a_{ij_a}}{(1-a_{ij_a})}}{\frac{a_{ij_e}}{(1-a_{ij_e})}}$ where a_{ij_a} and a_{ij_e} are the probability of transition between states *i* and *j* in the actual and randomized (i.e., expected) data, respectively. This offers an interpretable effect size of a given transition's deviation from expectations. Second, we calculated significance by comparing the magnitude of difference between the actual and expected likelihood of a_{ij} with *t*-tests, using the standard errors generated by the chain analysis.

RESULTS

Descriptive Statistics

Across the eight-years' time span, 59.5% of parcels generated zero instances of crime or disorder as defined by our six main measures. The remaining parcels were almost evenly split between those who experienced only one type of issue (19.9%) and those that had at least one instance of two or more type of issues (20.6%). Only 0.06% experienced issues from all six categories of crime and disorder.

Confining to parcels with two or more type of issues, we found that over half of them included two combinations: 29.0% had a combination of private neglect and public denigration, and 27.7% had a combination of violence and private conflict. Other

combinations included: private conflict and private neglect (16.5%); violence and private neglect (13.1%); private conflict and public denigration (12.8%); violence and public denigration (11.9%); private conflict, private neglect and violence (8.8%); and violence and guns (7.0%). Though potentially informative, these proportions are difficult to interpret on their own as they are subject to the differential frequencies of six categories of crime and disorder.

Cluster Analysis

For the cluster analysis we adopt the parcel-year as our unit of analysis—that is, we treat each parcel as being capable of expressing a different profile of crime and disorder in each year. In order to identify different profiles of crime and disorder across parcels, we applied K-means clustering to the six measures of interest. Using diagnostic tests (see Appendix B), we determined that six was the optimal number of clusters. The six clusters, whose characteristics are described in Table 2, might be organized into three groupings, ordered in terms of their prevalence. This ordering also describes a loose hierarchy in terms of severity that we can leverage to describe processes of aggravation and desistance.

- The vast majority of parcels in each year fell in a grouping with little or no crime or disorder (91.92% of parcel-years). This is by definition the lowest severity condition as there are no major issues.
- Next, ~7.85% of parcel-years fell into one of four "single-issue" groupings. These reflected elevated levels of either private conflict (5.18%), gun-related events (1.4%), private neglect (0.8%), or public denigration (0.47%), but relatively few instances of other types of issues.

When considering severity, we see a division between the two forms of physical disorder on the one side and social disorder and violence on the other, the latter of which is of greater concern. Within these, it is not obvious whether private neglect or public denigration is a more serious concern, but a concentration of gun-related events is more serious than a concentration of private conflict.

- The least common and most severe profile consisted of parcel-years that experienced a mixture of violence, public social disorder, private conflict, and gun-related events—what we might refer to as *violent hubs*—sometimes also accompanied by one or both types of physical disorder (0.24% of parcel-years).

It is worth noting that there are multiple types of residential parcels, which can have implications for the distribution of the profiles of crime and disorder (see Appendix A Tables A2 and A3 for distribution of events and types of parcels across land use categories). When comparing parcels with fewer units (e.g., single-family homes) to those with more (e.g., apartments, condo buildings), the latter were less likely to be placed in the "no major issues" grouping. This could simply be because of the greater number of people living in and visiting a parcel with more units. It could also be associated with the socioeconomic status of individuals living in buildings with more units. Nonetheless, all types of problematic parcels were represented in each category of residential land use.

When analyzing profiles of crime and disorder across years, 35.1% of parcels showed at least one of the problematic profiles in at least one year (i.e., 64.9% had no major issues across the entire timespan). Strikingly, only 7 additional parcels (<0.01%) exhibited the same problematic profile across all eight years. Of the 35.1% that experienced shifts in their profile of crime in disorder, 25.2% expressed two different profiles and 8.2%

parcels exhibited three different profiles over the eight years. The remaining 1.7% exhibited 4 or more profiles states over time. This is preliminary evidence for both substantial amounts of stability and change across parcels, indicating that the four stages of the life course—onset, persistence, aggravation, and desistance—will be visible in meaningful amounts in the data.

Stages of the Life-Course

As described above, in order to analyze the four stages of the life course of a parcel—onset, persistence, aggravation, and desistance—we conducted two sets of Markov chains, each of which is referenced throughout the section. First, analyzed two-year chains, quantifying the likelihood that a parcel would transition from one profile of crime and disorder to another in the following year. These results are reported in Table 3, with transitions that occur more often than expected represented graphically in Figure 1. Second, we analyzed three-year chains that examined the same transition matrices between years two and three, segmented by the parcel's status in the first year. Relevant results from these chains are reported in the text. The full results constitute six separate tables (one for each initial state) that are provided in Appendix C. To better interpret all results, we also compared them to randomized data. We evaluate the likelihood of a given transition relative to expectations under randomization using odds ratios and significance using *t*-tests based on the standard errors of estimates (see Methods for more detail). Last, based on the K-means cluster analysis, we posited a loose hierarchy for the five types of problematic parcel, ordered by severity. At the top were the violent hubs; next, gun-related

events were more serious than private conflict; and then concentrations of physical disorder, be it private neglect or public denigration, were of least severity. We use this hierarchy as we interpret the results, especially the pathways for aggravation and desistence. We limit the foregoing analysis to parcels to exhibited any of these five categories in at least one year (28,637 parcels, or 35%, constituting 229,096 parcel-years).

Onset

As anticipated, onset was not an especially frequent event. Parcels that had not had any noteworthy issues in one year were modestly more likely to remain that way in the next year (79% actual vs. 77% expected; O.R. = 1.12, $p < .001$). Though all forms of onset were lower than expected by chance, some were more likely than others. First, parcels most often experienced onset in the form of many instances of private conflict (14% actual and expected), and they were most likely to do so relative to the prevalence of such parcels in general (relative O.R.s compared to all other forms of onset = 1.09 – 2.42). At the other end of the spectrum, onset was least likely to manifest in violent hubs and also most underrepresented relative to expectations (0.2% actual vs. 0.7% expected; relative O.R.s = 0.41 – 0.53). Onset in the form of parcels with a concentration of gun-related events, private neglect, and public denigration fell between these extremes.

The second question is the extent to which onset portends persistence or is a one-year aberration at a parcel. We see evidence of each in the two-year Markov chain models. 78% of parcels that experienced onset in a single-year transition returned to having no major issues in the third year, which is the exact same proportion of parcels that were non-

problematic across the first two years that remained as such into the third year. That said, these proportions were not the same across types of problematic parcels. Parcels with an onset of incidents of private conflict in year 2 were more likely to have no major issues in year 3 than other parcels with concentrations of private conflict (81% actual vs. 75% of all parcels with such a concentration). Parcels experiencing an onset of gun-related incidents were also nearly as likely as chance to return to a state of no major issues (76% actual vs. 69% overall). Meanwhile, parcels where onset took the form of violent hubs or a concentration of public denigration—and, to a lesser extent, a concentration of private neglect—were considerably less likely to return to a state of no major issues. Nonetheless, all were more likely to do so than the average parcel exhibiting that profile of issues (violent hubs: 46% actual vs. 30% overall; concentration of public denigration: 59% vs. 54% overall; concentration of private neglect: 71% vs. 61% overall). This is to say that while a substantial proportion of parcels continue to generate crime and disorder after onset, they are more likely than chance to return to a no-issue status quo.

Persistence

All forms of problematic parcels were more likely to persist into the following year, as highlighted in Figure 1. This was most marked for violent hubs (32% actual persistence vs. 0.7% expected; O.R. = 64.86, $p < .001$). The two types of parcels featuring a density of physical disorder followed (public denigration: 33% actual persistence vs. 2% expected; O.R. = 25.21, $p < .001$; private neglect: 16% actual persistence vs. 2% expected; O.R. = 8.37, $p < .001$). The least likely to persist, though still above expected, were properties with a

concentration of guns (12% actual persistence vs. 4% expected; O.R. = 3.10, $p < .001$) and private conflict (17% actual persistence vs. 15% expected; O.R. = 1.13, $p < .001$).

Persistence was amplified in the three-year chains: issues that had persisted across two years were even more likely to continue into the third year, relative to the expectations of the two-year chains. To take the strongest case, 12% of parcels with a concentration of gun-related events in year 1 saw the same in year 2. But of that 12% of parcels, 27% persisted into the third year (relative O.R. = 8.66 $p < .001$). The next highest such tendency was for concentrations of private neglect (31% persistence in the 3rd year vs. 16% in the 2nd year; relative O.R. = 20.32 $p < .001$). Notably, the lowest level of persistence in the three-year models was again for parcels with a concentration of private conflict (25% persistence in the 3rd year vs. 17% in the 2nd year; relative O.R. = 1.89 $p < .001$). Overall, this indicates that once a certain type of issue has become established in a place it is increasingly likely to persist.

Aggravation

Of the significant transitions in Table 3 and Figure 1, the most apparent instance of aggravation was that parcels with a concentration of gun-related events or private neglect were more likely than expected to transition into violent hubs in the following year (gun-related events: O.R. = 2.73, $p < .001$; private neglect: O.R. = 2.30, $p < .001$). To put this in practical perspective, only 2% of parcels with a concentration of gun-related events experienced such transitions, but this was relative to 0.6% expected by chance.

Turning to the possibility of lower-scale aggravations, parcels with concentrations of private conflict or either form of physical disorder did not transition to having concentrations of gun-related events any greater than chance. Meanwhile, there were horizontal transitions from concentrations of public denigration to concentrations of private neglect (4% actual vs. 2% expected; O.R. = 2.08, $p < .001$), and, to a lesser extent, in the other direction (2% actual vs. 1% expected; O.R. = 1.52, $p < .01$).

The three-year transition matrices give a further insight into how aggravation evolves. First, based on the two-year results, the only candidate for a three-step pathway was from concentrations of public denigration to concentrations of private neglect to violent hubs. Parcels who experienced the first two steps of this pathways were in fact more likely to become violent hubs in the third year relative to the typical parcel with a concentration of private neglect, but this was non-significant (2.9% actual vs. 0.9% expected; O.R. = 3.41, $p = ns$).

A second major question is whether aggravations are durable. Parcels with concentrations of private neglect or gun-related events that transitioned to violent hubs remained that way less often than parcels that had been violent hubs in year 1, though they were still more likely to persist than by chance (23% for private neglect and 18% for gun-related events vs. 50% for violent hubs in year 1; O.R.s = 3.00 and 3.69 relative to expectations, respectively, p-values < .001). As with the story for onset and persistence seen above, it appears that the longer a place exhibits a particular profile of crime or disorder, the more likely it is to continue to do so; contrastingly, parcels without that history do not exhibit the same level of persistence.

Last, transitions between public denigration and private neglect showed varied trajectories thereafter. On the one hand, parcels that went from concentrations of public denigration to concentrations of private neglect tended to be evenly divided between the two in the following year (19% concentrations of public denigration and 17% concentrations of private neglect), raising the question of how persistent the transition was. On the other hand, parcels going in the other direction tended to continue to have concentrations of public denigration rather than concentrations of private neglect (35% vs. 13%).

Desistance

Last, we turn to desistance, the fourth transition in the criminal career of a place. We focus here on two forms of desistance: complete cessation and the de-escalation to less severe issues. As we anticipated, complete cessation of issues (i.e., transition to having no major issues) was uncommon relative to chance for all types of problematic parcels. This was most prominent for violent hubs (30% actual vs. 77% expected; O.R. = 0.13, *p*-value < .001), but also noteworthy for parcels with concentrations of public denigration (54% actual vs. 78% expected; O.R. = 0.32, *p*-value < .001), private neglect (61% actual vs. 77% expected; O.R. = 0.46, *p*-value < .001), and gun-related events (69% actual vs. 78% expected; O.R. = 0.65, *p*-value < .001). Notably, parcels with a concentration of private conflict were neither more nor less likely than chance to transition to having no major issues in the following year (76% actual vs. 77% expected; O.R. = 0.96, *p*-value = *ns*).

This suggests that where desistance is occurring, especially for violent hubs, there is a more gradual transition to less severe issues. As illustrated in Figure 2, we see that violent hubs tend to step down to having only a concentration of gun-related events (12% actual vs. 4.2% expected; O.R. = 2.98, *p*-value < .001) or private neglect (5.4% actual vs. 2.3% expected; O.R. = 2.42, *p*-value < .001). This is notable being that these profiles of crime and disorder were the ones that tended to escalate into violent hubs. Further, the specific history of escalation was predictive of the pathway for de-escalation. Three-year chains revealed that individual violent hubs were more likely to step down to the profile of issues with which they started: parcels with previous concentrations of gun-related events were more likely to revert to that state than to a concentration of private neglect (return to concentration of gun-related events: 24%, O.R. = 5.44, *p*-value < .001; concentration of private neglect: 8%, O.R. = 2.93, *p*-value = *ns*). The converse was true for parcels with previous concentrations of private neglect (return to concentration of private neglect: 15%, O.R. = 11.78, *p*-value < .01; concentration of gun-related events: 12%, O.R. = 2.13, *p*-value = *ns*). As such, we see that aggravation to and de-escalation from violent hubs tend to be mirror-images of each other. This is also illustrated in Figure 2.

Violent hubs also stepped down to concentrations of private conflict more often than chance (19% actual vs. 15% expected; O.R. = 1.38, *p*-value < .01). This was unexpected given that concentrations of private conflict showed no consistent pathway to violent hubs through escalation. Interestingly, in the last stage of the three-year chains, this transition was overrepresented for violent hubs that in year 1 had had concentrations of private neglect (27% vs. 14% expected, O.R. = 3.07, *p*-value < .05). This suggests an alternate pathway to desistance that does not mirror escalation. It is especially noteworthy because

concentrations of private conflict were the most likely to desist relative to other types of problematic parcels.

The partial de-escalations from violent hubs to other profiles of crime and disorder did not seem to be reliable pathways to cessation of issues, however. For instance, when a violent hub transitioned to having only a concentration of gun-related events in the second year, its third-year states were almost evenly divided between becoming a violent hub (25%), persisting with a concentration of gun-related events (24%), and having no major issues (31%). These values were markedly different from all parcels with a concentration of gun-related events, the majority of which saw cessation in year 2 (69%), fewer of which saw the persistence of gun-related events (12%), and very few of which became violent hubs (1.7%). A similar story was observable for those whose severity de-escalated to concentrations of private neglect: 14% reverted to being violent hubs (vs. 1.6% of all parcels with concentrations of private neglect), 30% persisted with concentrations of private neglect (vs. 16% overall), and 23% had no major issues in the third year (vs. 61% overall). In each of these cases, it is clear that complete cessation was less common for parcels with a history of being violent hubs than others with concentrations of gun-related events or private neglect lacking that history. Further, re-escalation to a violent hub was rather likely.

Violent hubs that stepped down to concentrations of private conflict also were substantially more vulnerable to persistence (21% vs. 17% overall) and re-escalation to violent hubs (12% vs. 0.8%) than similar parcels lacking this history. That said, with 42% of these parcels transitioning to having no major issues in the following year (vs. 76%

overall), they represented a more consistent pathway to complete cessation than the others.

Neighborhood context

To understand how the criminal careers of places differ by neighborhood context, we replicated the analyses, splitting parcels by whether they are in a census tract with above or below the mean level of crime and disorder (quantified as the rate of events across all categories per 1,000 residents; 17,648 and 10,989 parcels, respectively). For the sake of brevity, we focus here on the main findings in the two-year chains, walking through the four transitions of the life course in order. We report these results in Table 4. Notably, we use two types of comparisons to illustrate differences between neighborhoods. First, we present traditional comparisons of the proportion or parcels that experience each transition in each of the two types of neighborhoods. However, these do not account for the different baseline expectations in the two types of neighborhoods owing to the overall prevalence of crime and disorder. To attend to this, we also compare the relative magnitude of the difference with these expected proportions.[2] Across these analyses we

[2] This was accomplished in three steps. We first calculated the *t*-value for the difference between the observed and expected likelihood of a given cell in the probability transition matrix separately for neighborhoods with above- and below-average crime. We then translated these *t*-values to Cohen's *d*, a standardized measure of magnitude, using the equation $2 * \frac{t}{\sqrt{n-2}}$ where *n* was the number of parcels who could have experienced that transition (i.e., for a_{ij}, *n* = # of parcels with initial state of *i*). We also calculated the sampling variance (v) for each *d* value as $v = \frac{1}{n_1} + \frac{1}{n_2} + \frac{d^2}{2*(n_1+n_2)}$. These values then permitted a traditional *z*-score calculation of $z = \frac{d_1 - d_2}{\sqrt{v_1+v_2}}$ that evaluated whether the magnitude of difference from expectations was different between the two contexts.

see consistent evidence that the presence of elevated crime and disorder in the neighborhood reinforce the onset, persistence, and aggravation of issues at a parcel.

Onset was more common in neighborhoods with above-average crime and disorder, as might be expected. Specifically, parcels with no issues in one year were more likely to exhibit concentrations of private conflict (15% vs. 13%), private neglect (1.8% vs. 1.5%), and gun-related events (4.8% vs. 2.2%) in the following year in neighborhoods with above-average crime and disorder relative to neighborhoods with below-average crime and disorder. Interestingly, concentrations of public denigration were more likely to appear in neighborhoods with below-average crime and disorder (2.1% vs. 0.5%). Neighborhood context was not associated with the likelihood of violent hubs appearing at parcels with no major issues in the previous year (both 0.3%), though this might be because onset rarely jumped to violent hubs in general.

It is worth noting that differences in onset across neighborhoods were a product of the greater prevalence of each of these profiles of crime and disorder in higher-crime neighborhoods. Interestingly, once account for the baseline expectations for each profile of crime and disorder in neighborhoods with above- and below-average crime, we find that onset of all types *except* public denigration and violent hubs was more common in neighborhoods with below-average crime (t-values = 3.41 – 4.96, all p-values < .001). This is likely due to the analytic strategy of limiting to parcels that had at least one year of exhibiting noteworthy issues, meaning that transitions from having no issues to one of the other categories were overemphasized in neighborhoods with below-average crime.

Persistence was stronger in neighborhoods with above-average crime and disorder for multiple profiles of crime and disorder: concentrations of private conflict (19% of parcels persisting vs. 12% in below-average crime neighborhoods), private neglect (18% vs. 12%), and gun-related events (14% vs. 5.5%). Each of these differences was significant when accounting for the prevalence of such profiles of crime and disorder in the neighborhood (*t*-values = 2.10 – 7.39, all *p*-values < .05; private conflict, $p < .001$). Thus, not only were these profiles more likely to persist in an absolute sense in neighborhoods with above-average crime and disorder, they were more likely to persist relative to the elevated prevalence of the same profiles of crime and disorder in the neighborhood.

Neighborhoods with both above- and below-average crime and disorder saw aggravation from concentrations of private neglect and gun-related events to violent hubs. Though these tendencies were numerically greater in neighborhoods with above-average crime and disorder for concentrations of gun-related events (1.8% vs. 1.7%; $t = 0.97$, *p*-value = *ns*), and in neighborhoods with above-average crime for concentrations of private neglect, neither was significant (1.7% vs. 1.4%; $t = -0.46$, *p*-value = *ns*).

Horizontal shifts from concentrations of public denigration to concentrations of private neglect were more visible in neighborhoods with above-average crime and disorder (7.1% of parcels with concentrations of public denigration vs. 3.0%). Meanwhile, the opposite was true for shifts in the other direction (1.3% of parcels with a concentration of private neglect shifted to concentrations of public denigration in neighborhoods with above-average crime vs. 3.8% in neighborhoods with below-average crime). These surface-level proportions, however, are more reflective of the greater prevalence of private neglect

in neighborhoods with above-average crime and the correspondingly greater prevalence of public denigration in neighborhoods with below-average crime. In fact, shifts from private neglect to public denigration were *more* likely in neighborhoods with above-average crime relative to expectations ($t = 2.06$, $p < .05$), and the differences in shifts to private neglect were non-significant.

Last, desistance took different pathways in neighborhoods with above- and below-average crime and disorder. The partial step-downs from violent hubs to concentrations of private neglect or gun-related events were somewhat more common in neighborhoods with above-average crime (concentrations of private neglect: 6.2% vs. 3.8%; concentrations of gun-related events: 13% vs. 7.6%). These differences were not significant when compared to baseline expectations, however ($t = 1.05$, -1.45, respectively, p-values = *ns*).

In contrast, full cessation was much more frequent in neighborhoods with below-average crime. For example, 72% of parcels with concentrations of private conflict in neighborhoods with above-average crime and disorder had no major issues in the following year; meanwhile the same was true for 82% of such parcels in neighborhoods with below-average crime and disorder ($t = 5.06$, $p < .001$, for difference relative to local expected proportions). The same values were 69% and 57% for parcels with concentrations of private neglect ($t = 4.59$, $p < .001$), and 79% and 67% for parcels with concentrations of gun-related events ($t = 4.69$, $p < .001$).

DISCUSSION

The results illustrate four main components of the criminal career of a place—in this case problematic parcels in Boston, MA: onset, persistence, aggravation, and desistance. It bears noting that all four components were readily apparent in the data, moving beyond previous research that has primarily concentrated on persistence at places (Weisburd et al. 2004; Weisburd, Morris, and Groff 2009; Weisburd, Groff, and Yang 2012; O'Brien and Winship 2017; Braga, Papachristos, and Hureau 2010; Braga, Hureau, and Papachristos 2011; Trickett, Osborn, and Ellingworth 1995; Johnson et al. 2007; Farrell and Pease 2001). Thanks to the use of Markov chains to track shifts between profiles of crime and disorder, it was possible to identify events that were more likely than chance but that would have been difficult to observe through regression approaches, either because they would be overwhelmed by more common events (e.g., persistence) or were too precise to define and observe. The results lay the groundwork for a more thorough, theoretically-informed research agenda on the life course of problematic places. Before we make suggestions on new directions for this agenda, we first summarize the main characteristics of each of the four components of the life course as observed here.

Onset was less common than might be expected by chance, although this was anticipated given the extended body of work showing that places tend to maintain a characteristic level of crime or disorder over many years (Weisburd et al. 2004; Weisburd, Morris, and Groff 2009; Weisburd, Groff, and Yang 2012; Braga, Papachristos, and Hureau 2010; Braga, Hureau, and Papachristos 2011). Onset at a parcel was most likely to manifest in the form of private conflict and least likely to manifest as a violent hub. This is consistent with the hypothesis that the criminal career of a place was more likely to begin with a less severe, less varied set of issues. Correspondingly, *persistence* was very common, especially

for more serious profiles of crime and disorder. It also exhibited momentum, becoming more likely as a certain type of crime or disorder had been present at that place for longer.

Aggravation and *desistance* largely proved to be opposite sides of the same coin. Concentrations of gun-related events and private neglect were relatively likely to escalate into violent hubs. Also, there was a three-stage pathway for aggravation from public denigration to private neglect to violent hubs. Meanwhile, de-escalation at violent hubs tended to result in concentrations of gun-related events or private neglect in the following year. Further, this de-escalation tended to give way to the form that the property had been before undergoing aggravation. There was also an alternate de-escalation pathway from violent hubs to concentrations of private conflict. Full cessation was uncommon for places that had at one time been violent hubs, though it was approximately equal to chance for concentrations of gun-related events and private conflict that did not have such a history. This implies that places whose routine activities once generated high-severity mixes of crime and disorder have difficulty achieving the complete elimination of issues.

We found considerable evidence for our hypotheses that neighborhood context helps shape the criminal career of a place. Parcels in neighborhoods with above-average crime and disorder were more likely to experience persistence, which is consistent with numerous previous studies on the way high-crime contexts reinforce the potential for repeat offending or victimization for both people and places (Trickett, Osborn, and Ellingworth 1995; Bennett 1995; Johnson, Bowers, and Hirschfield 1997; O'Brien and Winship 2017). Likewise, desistance was less common in neighborhoods with above-average crime, but the full story was a bit more nuanced. De-escalation from violent hubs to

concentrations of other forms of crime and disorder was reasonably common in all types of neighborhoods, but it was the relatively more likely pathway in neighborhoods with above-average crime and disorder. Meanwhile, full cessation was more likely in neighborhoods with below-average crime and disorder, suggesting that a high-crime context might hinder complete cessation.

In the remainder of this section we forward three directions for future research and practice regarding a life course theory of places: the interplay of stability and change; the role of different forms of disorder; and desistance and interventions. It is important to note, however, some limitations of the study and areas that require replication. First, we have conducted the analysis on a single city, Boston, MA. It would be important to do the same in cities in other parts of the United States and the world, especially those with different structures (e.g., 20th century cities with a more spaced-out, suburban design) and demographics. There has been some evidence that persistence in crime concentrations is less stable in some cities, suggesting that the exact dynamics observed might be different as well (Hipp and Kim 2017). Also, we have explicitly conducted this study on residential parcels, which calls for replications on other types of places, including non-residential problematic parcels as well as hotspot streets. Second, the records used here are reported mainly by constituents, meaning they are potentially an incomplete representation of crime and disorder at places in the city. It is well established that neighborhoods can have different propensities for reporting issues (Klinger and Bridges 1997; O'Brien, Sampson, and Winship 2015), and it would be best to replicate this work with other measures of crime, like crime reports or victimization surveys, which feature different forms of bias. Given these considerations, we note that some of the precise results observed here may

differ by locale and application, but the overall story they tell should prove useful in how a research agenda on the life course of problematic places develops.

Stability and Change

As we have already noted, existing work on the criminal careers of places has been dominated by two main lines of inquiry. The first has centered on the stability of crime across time—or what we refer to here as persistence—whether it be at street segments (e.g., Weisburd et al. 2004; Weisburd, Morris, and Groff 2009; Weisburd, Groff, and Yang 2012; Braga, Papachristos, and Hureau 2010; Braga, Hureau, and Papachristos 2011) or properties (e.g., O'Brien and Winship 2017; Trickett, Osborn, and Ellingworth 1995; Johnson et al. 2007; Farrell and Pease 2001). The overarching message has been that places tend to have characteristic levels of crime that rarely change. Importantly, this work rarely if ever has considered the mix of crime and disorder types. The second line of inquiry has involved testing if and how unchecked disorder can encourage or escalate into more serious issues, a form of aggravation posited by broken windows theory (Wilson and Kelling 1982), ecological advantages theory (Branas et al. 2016), and social escalation theory (O'Brien and Sampson 2015). These two lines of work comprise arguments for stability and change, respectively, but they are not necessarily contradictory. It is perfectly possible for the *majority* of places to be stable from year to year but for the presence of certain types of disorder to incline *some* places to experience escalation. Here we see the simultaneity of these processes and their relative prevalence. Further, the results provide evidence for how onset and desistance operate, each of which are largely absent from those

two existing lines of inquiry. Overall, it presents a more thorough illustration of stability and change in crime and disorder at places.

Unsurprisingly, our results captured quite a bit of stability. 64% of parcels never exhibited meaningful amounts of crime or disorder over the eight years. Persistence was the most common state for parcels that did exhibit major issues. But there was change as well, with 35% of parcels shifting their profile of crime and disorder annually, reflecting substantial amounts of onset, aggravation, and desistence. There are three ways of interpreting this change, and each may have its place. The first is that these year-to-year changes might be the expression of within-place variability but without any true shifts to the underlying dynamics or latent potential for generating crime or disorder. From this perspective, "change" is merely measurement error hovering around a characteristic level or mix of crime and disorder, something that has also been observed with individual offenders (Osgood and Schreck 2007; Piquero 2004). There are multiple reasons to think this can at times be the case for the results here: persistence was lower in parcels that recently experienced onset; when escalation to a violent hub was followed by de-escalation, the parcel often returned to the profile of crime and disorder it had experienced previously; de-escalation was often followed by re-aggravation and rarely reached full cessation, especially in neighborhoods with above-average crime. The practical implication is that many year-to-year changes are ephemeral fluctuations wherein the place will likely revert to the previous state in the following year.

Nonetheless, within-place variation need not be dismissed as mere measurement error. For instance, individuals are more likely to offend in various ways when

experiencing stressful conditions than at other times (Slocum, Simpson, and Smith 2005). Whereas a focus on the outcome alone might look like a statistical fluctuation, the timing and influence of underlying contextual factors is still meaningful. The same reasoning might be applied to a problematic parcel experiencing an escalation of crime or disorder. The escalation might be associated with short-term shifts in the underlying routine activities of the place, and the speed and extent to which they re-equilibrate will have major implications for whether the place continues to experience aggravation. Similar considerations would apply to how durable desistance is in the case of a de-escalation. It may be that well-targeted interventions could capitalize on these incremental shifts in local dynamics that might otherwise end up being ephemeral fluctuations.

Third, there is the possibility that some changes are not natural fluctuations but reflect a fundamental shift in the dynamics of a place. The most dramatic example was the 30% of violent hubs that transitioned to having no issues in the following year. Though such parcels were relatively uncommon, 81% of them remained in the no issues group the following year, suggesting complete cessation. These sorts of transformations likely arise from a full reorientation of the local routine activities. This would be analogous to the concept in life course theory of "turning points" (Sampson and Laub 1993; Laub and Sampson 2001). Although turning points are pegged to life transitions that are often part of the developmental process, like marriage, the underlying idea may still be relevant to places. Turning points alter the social context or functioning of the individual, thereby fundamentally altering their proclivity for offending. In the case of places, Eck and colleagues' work on place management suggests one set of explanations (Eck 2018; Eck and Guerette 2012; Eck and Weisburd 1995; Madensen and Eck 2013). If place

management is a critical ingredient to the prevention of crime and disorder, then we might anticipate changes in ownership or other critical personnel (e.g., rental management companies, floor managers or bouncers in a restaurant or bar) could dramatically change social dynamics, which in turn would alter the frequency and mixture of crime and disorder likely at a place. There might also be cases in which management remains the same but the replacement of problematic tenants leads to a change in the amount of crime and disorder. In the most extreme example, the turnover of households in a single-family residence literally supplants one set of social dynamics with another, and the two could be quite different from each other in their criminogenic tendencies. Taking the reasoning one step further, the transformation of one location—say, the opening or closing of a liquor store or bar—may create new dynamics that precipitate shifts in crime and disorder at neighboring properties. Across these and other examples, the key is that a turning point in the social context has altered a place's underlying propensity for crime and disorder.

Roles of Different Types of Disorder

There are numerous theories for the interplay that different types of disorder share with crime, especially how they might lead to more serious issues. These include broken windows theory, which posits that public disorder will encourage more serious forms of delinquency (Wilson and Kelling 1982); social escalation theory, which argues that private conflicts between household members or neighbors can give rise to interpersonal violence (O'Brien and Sampson 2015); and ecological advantages theory, which argues that certain forms of disorder can facilitate crime (e.g., abandoned buildings as a hiding place for contraband; Branas et al 2016, St. Jean 2007). When considering how the results here add

to these perspectives, we note that we used four measures of disorder that capture the two dimensions of physical vs. social disorder and disorder in public vs. private spaces: denigration of public spaces (e.g., graffiti); neglect to private spaces (e.g., dilapidation of homes); public social disorder (e.g., drunkenness); and private conflict and disturbances (e.g., landlord-tenant disputes). The analysis revealed distinct relationships and roles among these measures, though we set aside public social disorder as it is primarily relegated to spaces with commercial land use and we limited our analysis to residential parcels.

First, we saw a division between physical disorder and social disorder, with parcels sometimes experiencing transitions between the two types of physical disorder. Interestingly, only concentrations of private neglect had the tendency to crossover to social disorder, sometimes being part of the escalation to or de-escalation from violent hubs. Second, concentrations of private conflict were distinctly less likely to indicate further issues to come. It was the least persistent profile of crime or disorder, had no clear pathways for aggravation to more serious social issues (e.g., violence), and was the most likely to transition to full cessation. It was also the profile of crime and disorder most often observed at the onset of a parcel's criminal career. This all suggests that, while concentrations of private conflict can of course persist across time, they have the potential to be temporary challenges at otherwise non-problematic parcels and do not necessarily portend aggravation.

The more prominent role of private forms of disorder is most consistent with social escalation and ecological advantages theories, though the precise interpretation is not

entirely clear. Private neglect did have a stronger relationship with social disorder than public denigration, which could reflect the escalation of personal challenges among place managers, residents, or both (i.e., social escalation). It might also be that these forms of disorder are providing safe harbor for certain types of crime (i.e., creating ecological advantages). That said, from the perspective of SET it is curious that private conflict did not reliably undergo any form of aggravation. Meanwhile, the lack of aggravation for parcels with concentrations of public denigration and the overall unimportance of public social disorder provide at best no new support for BWT, and potentially add to the research calling its basic premise into question (O'Brien, Farrell, and Welsh 2018; Sampson and Raudenbush 1999; Weisburd et al. 2015). For both SET and BWT, however, it is important to keep in mind the analytic strategy used here and the implications it might hold. Whereas past studies on these subjects have included events at all places, we limited to places that expressed a distinctive profile of crime and disorder; a non-trivial proportion of places in each year had a small amount of crime or disorder that was insufficient to place it in one of these profiles, thus excluding them from analysis. Further, SET and BWT do not necessarily predict wholesale transitions between types of crime and disorder, and some phenomena that would be consistent with them—for example, a parcel with a large amount of disorder experiencing one or two events of violence in the following year—might not be captured by our approach here.

Interventions and Desistance

Possibly the most practically informative set of findings from the results regarded desistance. Problem properties task forces and similar initiatives tend to utilize

interventions that pursue desistance in the form of complete cessation of crime and disorder. Most often these are rooted in "nuisance laws," which enabled municipalities to take control of properties that are havens of illicit economic activity, like drug dealing, prostitution, and illegal gambling (Way, Trinh, and Wyatt 2013; LISC 2015; Boston 2011). For example, once the City of Boston designates a problem property, it charges the owner for every subsequent police or inspectional visit, thereby incentivizing the elimination of all issues and disturbances. The results here, however, suggest that the true process of desistance is nuanced, paralleling the observation in life course research that cessation is not so much equivalent to desistence as it is the hoped-for endpoint of a gradual de-escalation from a peak of offending (Kazemanian 2007). Just as Ward et al. (1997) have argued that understanding this process will enable the design of more effective interventions for offenders (see also Walker, Bowen, and Brown 2013), problem properties task forces might adopt new techniques that better facilitate de-escalation rather than targeting cessation outright. This would in fact be aligned with the similarly-named problem-oriented approach to policing, in which officers leverage a broad toolbox to flexibly address local challenges (Goldstein 1990). The task at hand, then, is to develop the toolbox for capitalizing on the natural process of desistance.

A reorientation of problem properties interventions could be rooted in adopting distinct short- and long-term goals for the most problematic places. It might be that, in the absence of any major turning points in the residents or owners of a place, the immediate cessation of all issues is overly ambitious. Instead, the routine activities and social dynamics of a stable set of actors will need to be adjusted. Being that it would be difficult to do so overnight, the more reasonable objective would be to gradually lessen severity and

frequency. Cessation would then be a long-term goal made possible by protracted efforts. There is also the consideration of the exacerbating or reinforcing role of the neighborhood, wherein greater patience will be needed for parcels experiencing de-escalation in high-crime neighborhoods.

One issue we do not address in this study that should be a consideration for future research and practice is that of the quantitative lessening of issues. We have exclusively examined the mix of types of issues at a parcel, setting aside the frequency of those events. We have not yet examined whether violent hubs with fewer total events or fewer high-severity events (e.g., those entailing violence) are more likely to experience de-escalation, or if there might be gradual decreases in the frequency of events that mirror the gradual de-escalation in types of events that we concentrate on here. Insights on these processes would be further informative to designing intervention strategies that capitalize on the ways in which desistance naturally proceeds.

Conclusion

We have presented and empirically illustrated a framework for the life course (or criminal careers) of places, comprised of four components: onset, persistence, aggravation, and desistance. Whereas other research has highlighted the predominance of persistence and, to a lesser extent, patterns of aggravation from disorder to crime, the strategies taken here offered a window into all four processes. The results is a richer vantage point on stability and change in disorder and crime at places, with especially actionable insights on desistance as a nuanced, gradual process of de-escalation. The results also added to a growing literature on the interplay between places and communities in driving trajectories

of crime. To be certain, this is but a first step. There is a clear need for replication in other locales, with different types of data, and with other types of "places" (e.g., commercial institutions, hotspot streets); extensions that will further articulate some of the observed phenomena; and applications that translate the results into effective interventions.

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Table 1. Distribution of the six measures of disorder and crime across residential parcels, including the total count of events, mean events per parcel, and the percentage with at least 1 event from 2011-2018.

Measure	Social Disorder	Private Conflict	Violence	Guns	Private Neglect	Public Denig.
Counts	12,697	55,065	62,173	12,072	59,517	72,671
Mean per Parcel	0.16	0.67	0.76	0.15	0.73	0.89
Std. Dev. (parcels)	0.95	1.86	2.85	0.65	2.51	3.04
% parcels w/ 1+ events	9.5%	29.2%	26.2%	9.1%	23.0%	29.0%

Note: Analysis limited to the 81,673 parcels with residential land use classifications.

Table 2. Profiles of crime and disorder generated by K-means cluster analysis, their frequency across parcel-years, and their average expression of six indicators of crime and disorder, including the percentage of parcel-years with one or more events.

Cluster	No. of parcel-yrs.	Social Disorder	Private Conflict	Violence	Guns	Private Neglect	Public Denig.
Violent Hubs	1,559	1.69 (60.23%)	2.08 (62.47%)	6.58 (96.09%)	0.39 (25.59%)	0.78 (31.24%)	0.44 (23.09%)
Public Denigration	3,049	0.09 (7.51%)	0.16 (12.30%)	0.20 (12.96%)	0.02 (2.16%)	0.59 (30.63%)	6.59 (100%)
Private Neglect	5,222	0.07 (6.07%)	0.63 (32.86%)	0.53 (28.63%)	0.05 (4.19%)	4.63 (100%)	0.52 (29.38%)
Guns	9,140	0.08 (6.98%)	0.32 (21.51%)	0.54 (30.01%)	1.22 (100%)	0.21 (12.83%)	0.15 (10.53%)
Private Conflict	33,842	0.05 (4.61%)	1.33 (100%)	0.32 (20.37%)	0.00 (0.31%)	0.16 (12.06%)	0.14 (10.31%)
No Major Issues	600,572	0.01 (1.10%)	0.00 (0.00%)	0.05 (4.23%)	0.00 (0.00%)	0.04 (3.41%)	0.07 (5.49%)

Note: Unit of analysis was 229,096 parcel-years (28,637 parcels * 8 years). Each residential parcel was categorized into one of the six profiles of crime and disorder in each year.

Table 3. Proportion of parcels with each profile of crime and disorder in one year (rows) transitioning to each other profile in the following year (columns), including the odds ratio relative to expectations (those more likely than expected in bold).

	No Issues	*Private Conflict*	*Guns*	*Violent Hubs*	*Private Neglect*	*Public Denigration*
No Major Issues	**.79** (**1.12*****)	.14 (0.98*)	.04 (0.90***)	.002 (0.40***)	.02 (0.76***)	.01 (0.80***)
Private Conflict	.76 (0.95)	**.17** (**1.13*****)	.04 (0.94)	.01 (1.17)	.02 (1.05)	.01 (0.52***)
Guns	.69 (0.65***)	.14 (1.02)	**.12** (**3.10*****)	**.02** (**2.73*****)	.02 (1.03)	.01 (0.42***)
Violent Hubs	.30 (0.13***)	**.19** **(1.38****)**	**.12** **(2.98*****)**	**.32** **(64.86*****)**	**.05** **(2.42*****)**	.02 (1.31)
Private Neglect	.61 (0.46***)	.15 (1.02)	.05 (1.16)	**.02** **(2.30*****)**	**.16** **(8.37*****)**	**.02** **(1.52*)**
Public Denigration	.54 (0.32***)	.07 (0.47***)	.02 (0.39***)	.01 (1.59)	**.04** **(2.08*****)**	**.33** **(25.21*****)**
Approx. Expected Value	*.77*	*.14*	*.04*	*.007*	*.02*	*.01*

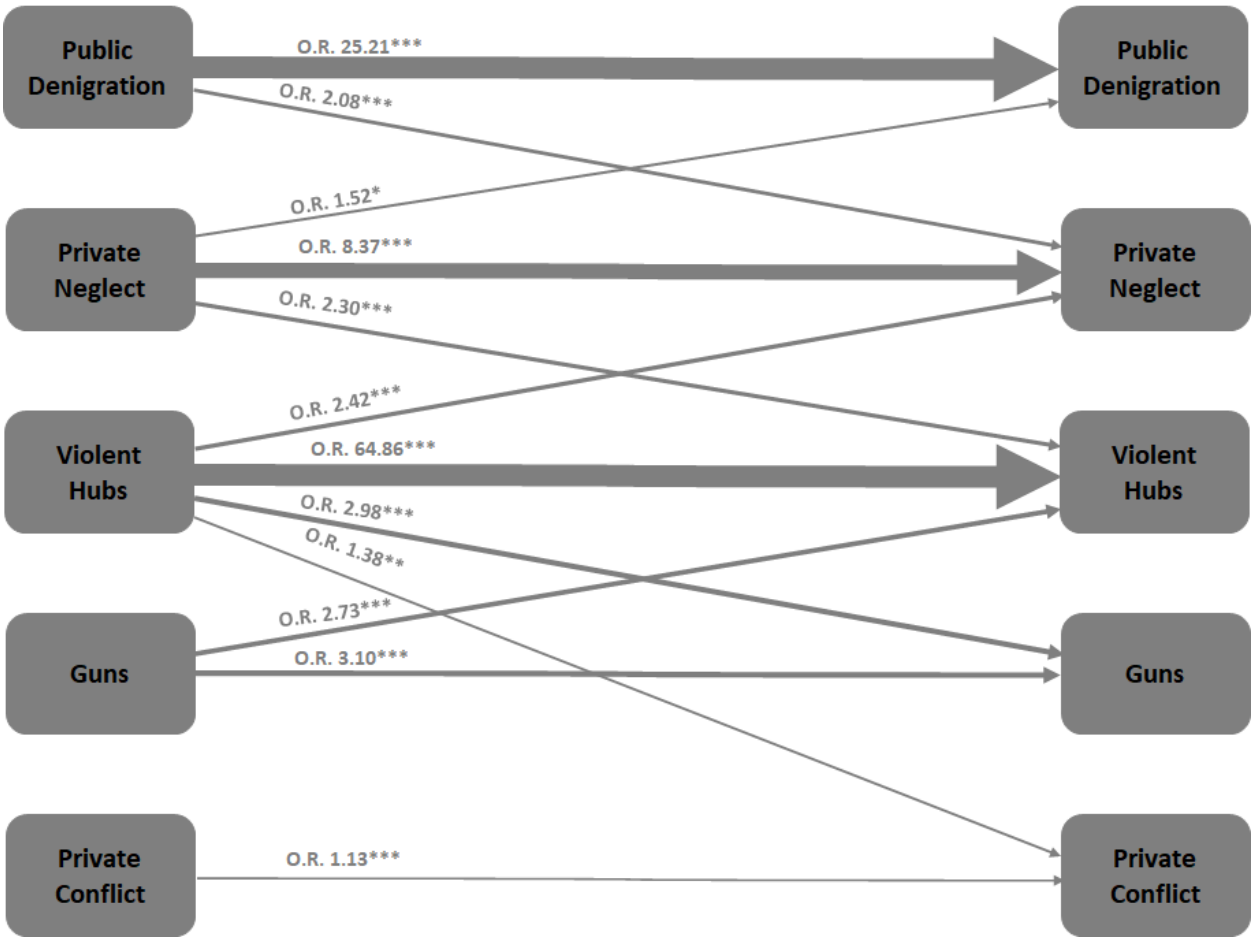
Note: Analysis is of 200,459 year-to-year transitions at parcels (28,637 parcels * 7 two-year chains over an 8-year period). Expectations are established by randomizing the distribution of parcels across states within each year. Odds ratios were calculated as relative to expectation, i.e. $\left(\frac{p_o}{1-p_o}\right)/\left(\frac{p_e}{1-p_e}\right)$. Significance was evaluated through *t*-tests comparing the expected and observed values using the standard errors of their estimates.

Table 4. Proportion of parcels with each profile of crime and disorder in one year (rows) transitioning to each other profile in the following year (columns), including the odds ratio relative to expectations (those more likely than expected in bold), compared between neighborhoods with above- and below-average crime.

Above-Average Crime Neighborhoods						
	No Maj. Issues	*Private Conflict*	*Guns*	*Violent Hubs*	*Private Neglect*	*Public Denigration*
No Major Issues	**.78 (1.15***)**	.15 (0.95***)	.05 (0.88***)	.003 (0.39***)	.02 (0.73***)	.005 (0.82***)
Private Conflict	.72 (0.87**)	**.19 (1.21***)**	.05 (0.94)	.009 (1.20)	.03 (1.10)	.004 (0.69**)
Guns	.67 (0.64***)	.15 (1.01)	**.14 (2.75***)**	**.02 (2.35***)**	.02 (0.92)	.00 (0.61*)
Violent Hubs	.29 (0.14***)	**.20 (1.35*)**	**.14 (2.46***)**	**.30 (60.39***)**	**.06 (2.52***)**	.01 (2.12)
Private Neglect	.57 (0.44***)	.16 (1.04)	.06 (1.14)	**.02 (2.17***)**	**.18 (8.36***)**	**.01 (1.89*)**
Public Denigration	.55 (0.38***)	.10 (0.67**)	.04 (0.63)	.02 (2.09)	**.07 (2.82***)**	**.23 (34.10***)**
Approx. Expected Value	*.75*	*.15*	*.06*	*.01*	*.03*	*.01*
Below-Average Crime Neighborhoods						
	No Maj. Issues	*Private Conflict*	*Guns*	*Violent Hubs*	*Private Neglect*	*Public Denigration*
No Major Issues	.81 (1.15)	.13 (0.95)	.02 (0.88)	.003 (0.39***)	.02 (0.73***)	.02 (0.82***)
Private Conflict	**.82 (0.87*)**	.12 (1.21)	.02 (0.94*)	.007 (1.20)	.02 (1.10)	.01 (0.69***)
Guns	.79 (0.64)	.11 (1.01)	**.06 (2.75***)**	**.02 (2.35**)**	.02 (0.92)	.02 (0.61)
Violent Hubs	.33 (0.14***)	**.18 (1.35*)**	**.08 (2.46***)**	**.36 (60.39***)**	.04 (2.52)	.02 (2.12)
Private Neglect	.69 (0.44**)	.12 (1.04)	.02 (1.14)	**.01 (2.17*)**	**.12 (8.36***)**	.04 (1.89)
Public Denigration	.53 (0.38***)	.05 (0.67***)	.01 (0.63**)	.006 (2.09)	**.03 (2.82*)**	**.37 (34.10***)**
Approx. Expected Value	*.80*	*.13*	*.02*	*.01*	*.02*	*.03*

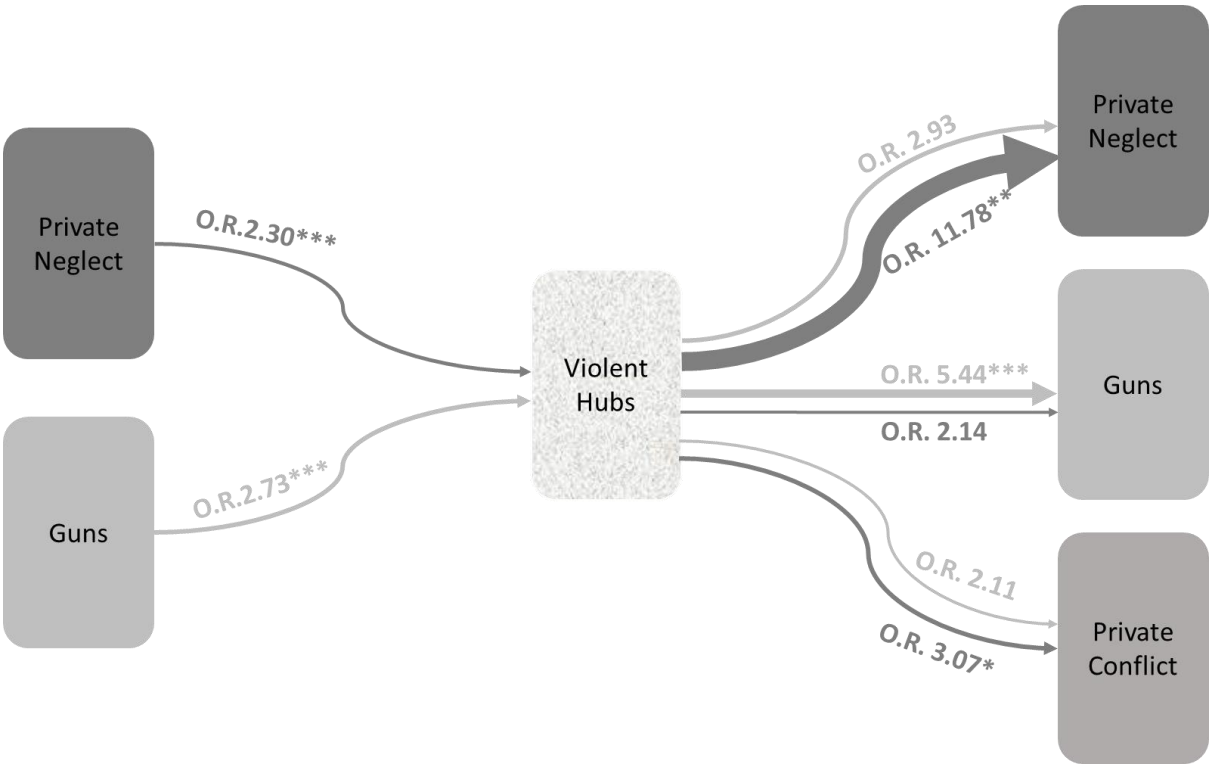
Note: Analysis is of 123,536 year-to-year transitions at parcels (top panel; 17,648 parcels * 7 two-year chains over an 8-year period) and 76,923 year-to-year transitions (bottom panel; 10,989 parcels * 7 two-year chains over an 8-year period). Expected outcomes were established by randomizing the distribution of parcels across states within each year. Odds ratios were calculated as relative to expectation, i.e. $\left(\frac{p_o}{1-p_o}\right)/\left(\frac{p_e}{1-p_e}\right)$. Significance was evaluated through *t*-tests comparing the expected and observed values using the standard errors of their estimates.

Figure 1. Transitions from one profile of crime in disorder to another in the following year that were greater than expected by chance (quantified with odds ratios), based on two-year Markov chains.



Note: Graphical representation of the results of the two-year Markov chains reported in full in Table 3. Lines are proportional to odds ratios with a ceiling at OR = 10 because of outliers. Parcel-years with no major issues were excluded as their transitions to or from all other profiles were not more likely than expected by chance.

Figure 2. Pathways of aggravation to violent hubs and their mirror-image de-escalations, with likelihoods relevant to expectations by chance (quantified with odds ratios), based on three-year Markov chains. Pathways are differentiated by their origination in concentrations of private neglect (dark gray) and gun-related events (light gray).



Note: Graphical representation of results from the three-year Markov chains reported in full in Appendix C. Lines are proportional to odds ratios.

APPENDIX A. CRIME, DISORDER, AND LAND USE

Table A1. Case types composing measures of violence, physical disorder, and social disorder and their frequencies in 2018.

Measure	Type	Frequency
Social disorder (n=1,303)	Drunks causing disturbance	437
	Panhandler	65
	Sex offense/lewd behavior	363
	Vandalism in Progress	438
Private Conflict (n=4,492)	Breaking and entering in progress	1,222
	Landlord/tenant trouble	733
	Vandalism report	1,777
	Violation of restraining order	760
Violence (n=6,296)	Assault and battery in progress	1,217
	Assault and battery report	673
	Armed robbery	125
	Emotionally disturbed person: violent or injured	1,600
	Fight	2,097
	Person with knife	584
Guns (n=1,504)	Assault and battery with deadly weapon	67
	Found gun	46
	Person with a gun	453
	Person shot	181
	Shots fired	757
Private Neglect (n=7,586)	Bed bugs	160
	Breathe Easy	45
	Chronic Dampness/Mold	228
	Poor Ventilation	21
	Squalid Living Conditions	55
	Unsatisfactory Living Conditions	1,917
	Abandoned Building	92
	Illegal Occupancy	252
	Illegal Rooming House	151
	Maintenance - Homeowner	235
	Parking on Front/Back Yards (Illegal Parking)	203

	Poor Conditions of Property	4,073
	Trash on Vacant Lot	153
Public Denigration (n=15,628)	Graffiti Removal	862
	PWD Graffiti	553
	Abandoned Bicycle	518
	Empty Litter Basket	330
	Illegal Dumping	1,441
	Improper Storage of Trash (Barrels)	10,016
	Rodent Activity	1,908

Table A2. Residential land use classifications in Boston, their relative frequencies, and average number of events annually in each of the six categories of crime and disorder per parcel in 2011-2018.

Classification	Use Code	% Res. Parcels	Social Disorder	Private Conflict	Violence	Guns	Private Neglect	Public Denigration
Residential 7 or more Units	A	3.02%	0.09	0.39	0.58	0.08	0.47	0.48
Condominium	CD	10.74%	0.05	0.10	0.12	0.02	0.11	0.30
Condo Main Lobby	CM	0.03%	0.07	0.19	0.63	0.03	0.27	0.05
Residential 1 Family	R1	37.2%	0.01	0.03	0.03	0.01	0.03	0.04
Residential 2 Family	R2	21.03%	0.01	0.08	0.07	0.02	0.08	0.07
Residential 3 Family	R3	16.86%	0.03	0.16	0.17	0.04	0.18	0.14
Residential 4 Family	R4	3.06%	0.04	0.18	0.19	0.03	0.25	0.40
Residential Lot	RL	8.06%	0.01	0.01	0.02	0.01	0.01	0.01

Note: Analysis based on 653,384 parcels years (8 years * 81,673 parcels).

Table A3. Percentage of parcels falling in each of the six categories of parcel for each land use category.

Land Use	**Use Code**	**No. of parcels**	***No Maj. Issues***	***Private Conflict***	***Guns***	***Violent Hubs***	***Private Neglect***	***Public Denigration***
Residential 7 or more Units	A	3.02%	70.68	14.65	4.88	2.68	4.26	2.85
Condominium	CD	10.74%	89.21	6.41	1.40	0.50	0.86	1.62
Condo Main	CM	0.03%	89.42	1.92	0.96	5.29	2.40	0.00
Residential 1 Family	R1	37.2%	96.54	2.46	0.68	0.05	0.19	0.08
Residential 2 Family	R2	21.03%	92.35	5.40	1.34	0.10	0.66	0.15
Residential 3 Family	R3	16.86%	85.23	9.70	2.68	0.28	1.71	0.41
Residential 4 Family	R4	3.06%	82.91	9.71	2.29	0.42	2.25	2.44
Residential Lot	RL	8.06%	98.46	0.79	0.56	0.05	0.12	0.02

APPENDIX B. CLUSTER ANALYSES

We used three diagnostic tests—the elbow, silhouette and Tibshirani's Gap-Statistic—to determine the optimal number of clusters in each of the cluster analyses. We prioritized the elbow test and then informed it with the other two tests as the elbow test captures the minimization of within-cluster variance, which is the explicit purpose of the clustering algorithm.

For the clustering of parcels by their events of crime and disorder, we selected a solution with six clusters. The elbow test saw a steep drop between 5 and 6 clusters (Figure B1). This drop continued through 8 clusters, but we found that these higher levels of *k* created very small groups (10-15 members) that essentially separated less and more severe violent hubs from each other, each with a broad combination of types of issues. This appeared to create a small sub-spectrum of highly problematic places that would go precisely against concerns about inferred typologies. Second, the silhouette test showed the best fit at two clusters, likely because >90% of parcels had no meaningful pattern of issues, separating them out from the rest (Figure B2). The value stayed high and had a local optimum at 6. The gap statistic found the optimal number of clusters to be 9 (Figure B3). Taken together, we stayed with 6 clusters as the maximum defensible number of clusters.

For the clustering of census block groups by their problematic parcels, we selected a solution with five clusters. The elbow test showed a strong drop in within-cluster variance when going from four to five clusters and little improvement thereafter (Figure B5). The silhouette test showed the best fit at two clusters, but this again likely reflected that about 50% of census block groups had very few if any problematic parcels (Figure B6). There was a local optimum, however, at five clusters. Last, the gap statistic suggested six clusters, but with five and seven as nearly as good of fits (Figure B7). Taken together, the consensus was to move forward with five clusters.

Figure B1. Scree plot for elbow test depicting within-class variance for the optimized result for different levels of *k* in the K-means cluster analysis for types of parcels based on their events of crime and disorder.

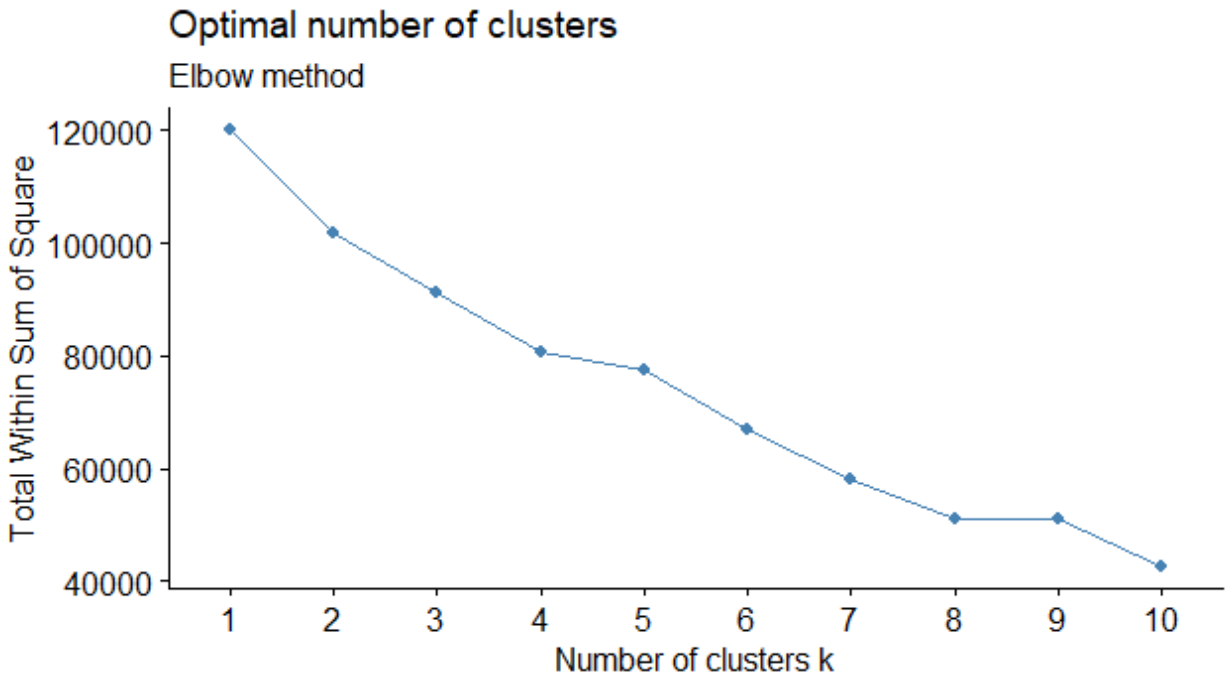


Figure B2. Plot of silhouette values for the distinction between points within and between clusters for the optimized result for different levels of *k* in the K-means cluster analysis for types of parcels based on their events of crime and disorder.

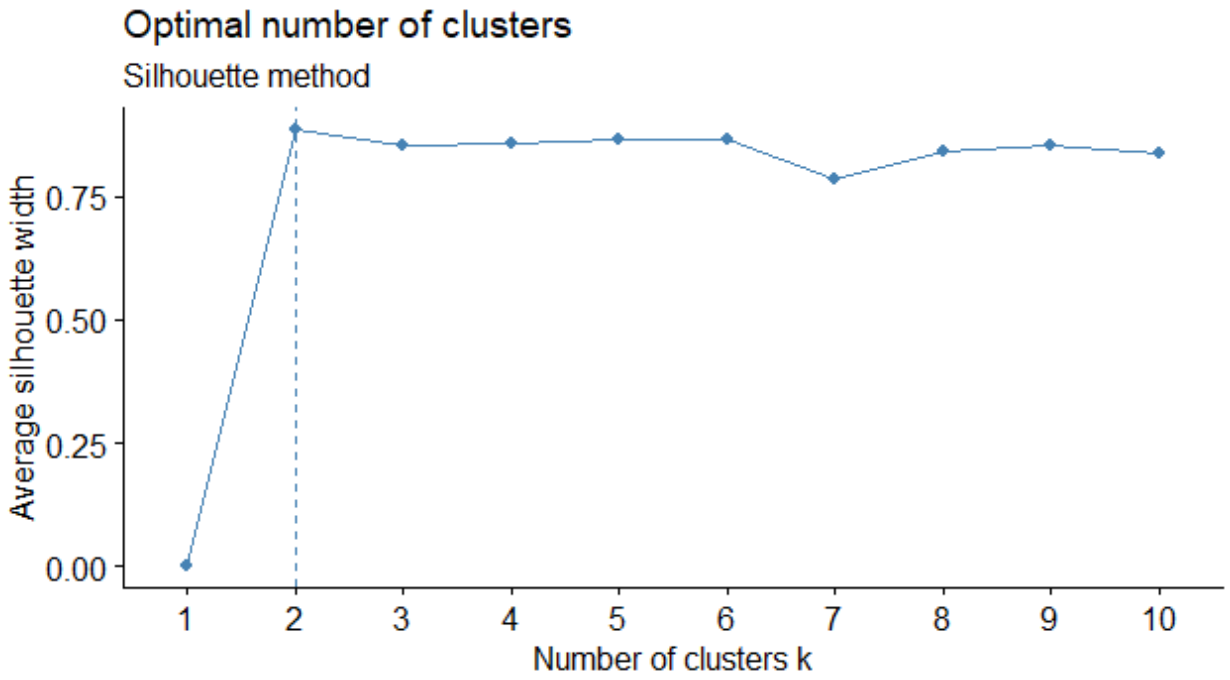


Figure B3. Plot of Tibshirani's Gap-Statistics for the intra-cluster variation relative to expectations in a hypothetical distribution with no clustering for the optimized result for different levels of *k* in the K-means cluster analysis for types of parcels based on their events of crime and disorder.

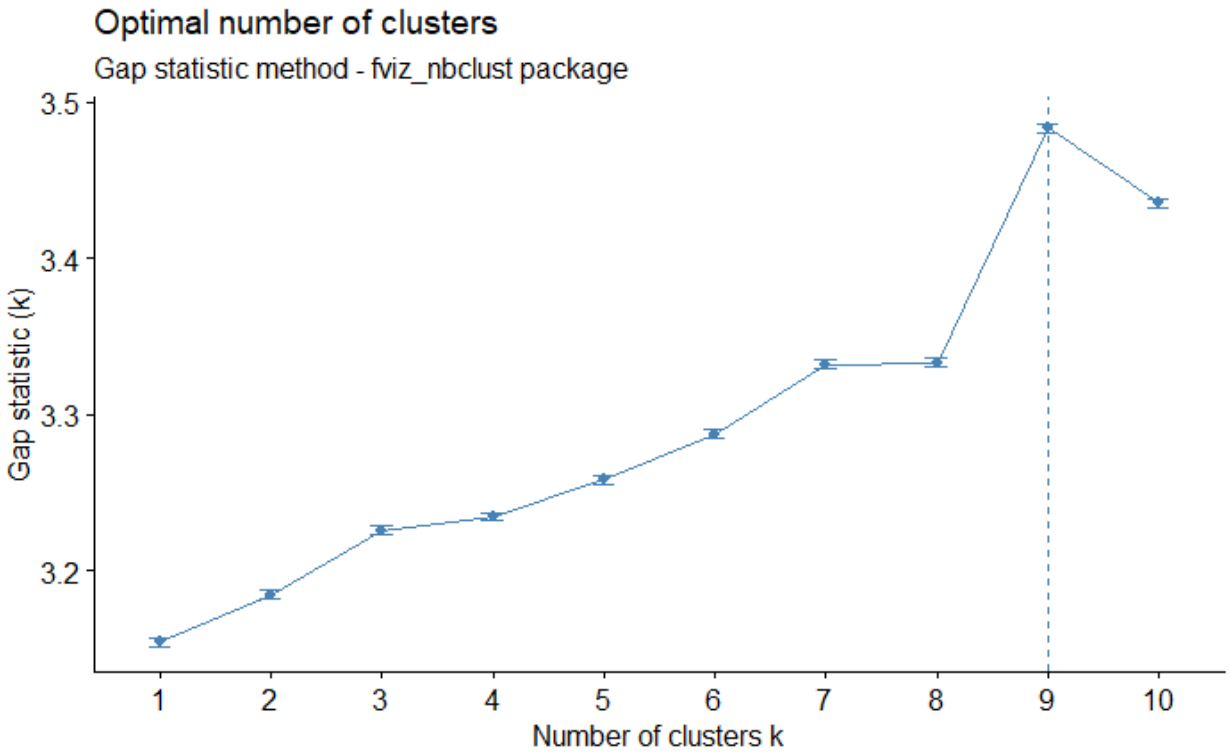


Figure B4. Cluster analysis for parcels grouped along two main dimensions

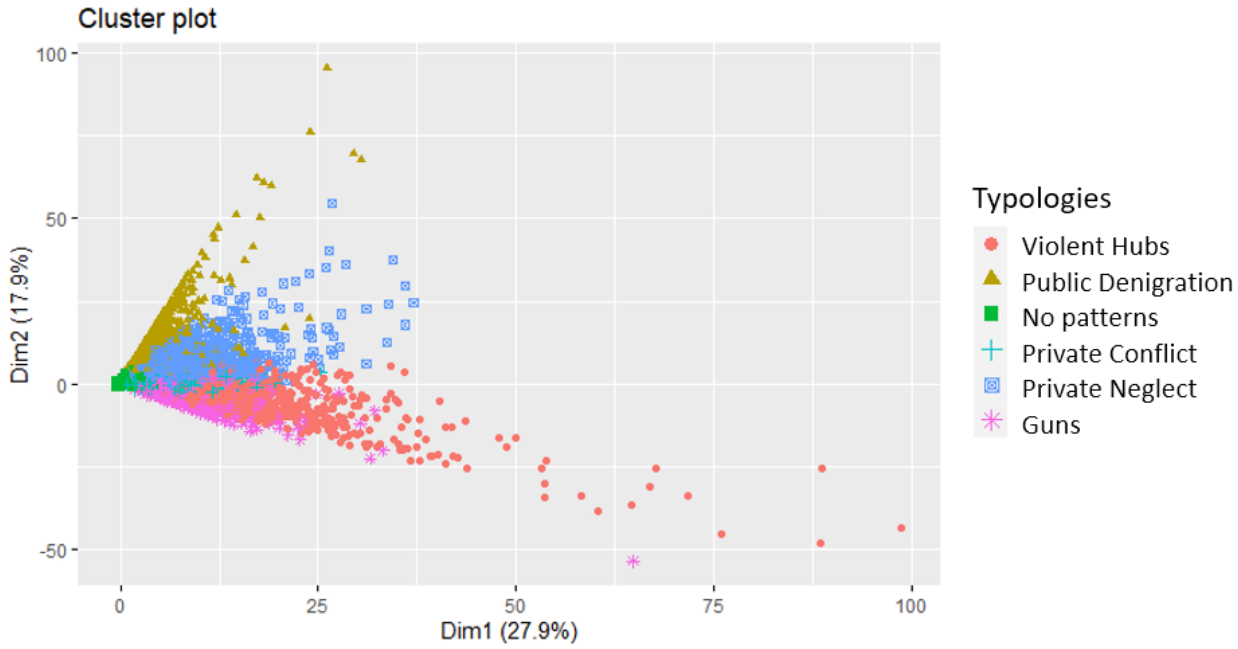


Figure B5. Scree plot for elbow test depicting within-class variance for the optimized result for different levels of *k* in the K-means cluster analysis for types of census block groups based on their problematic parcels.

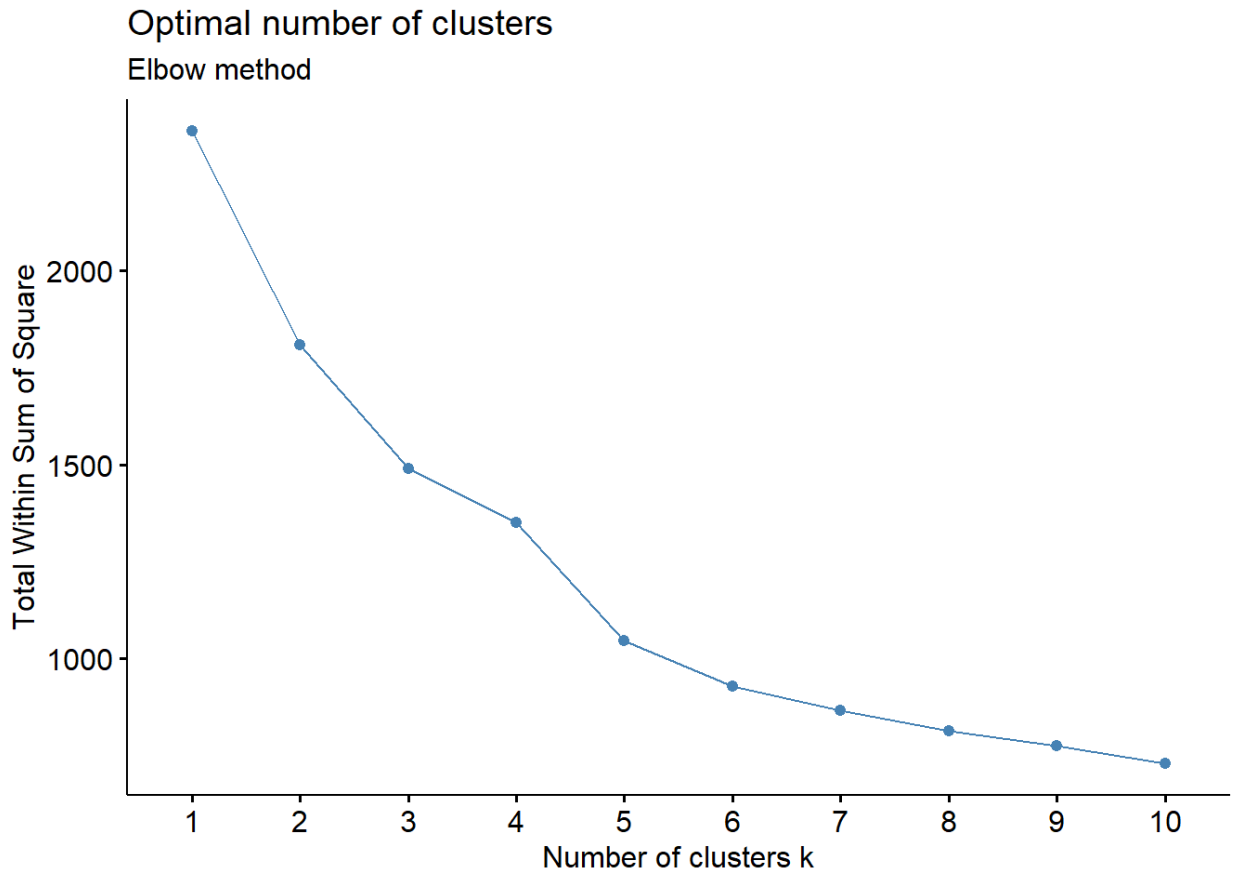


Figure B6. Plot of silhouette values for the distinction between points within and between clusters for the optimized result for different levels of *k* in the K-means cluster analysis for types of census block groups based on their problematic parcels.

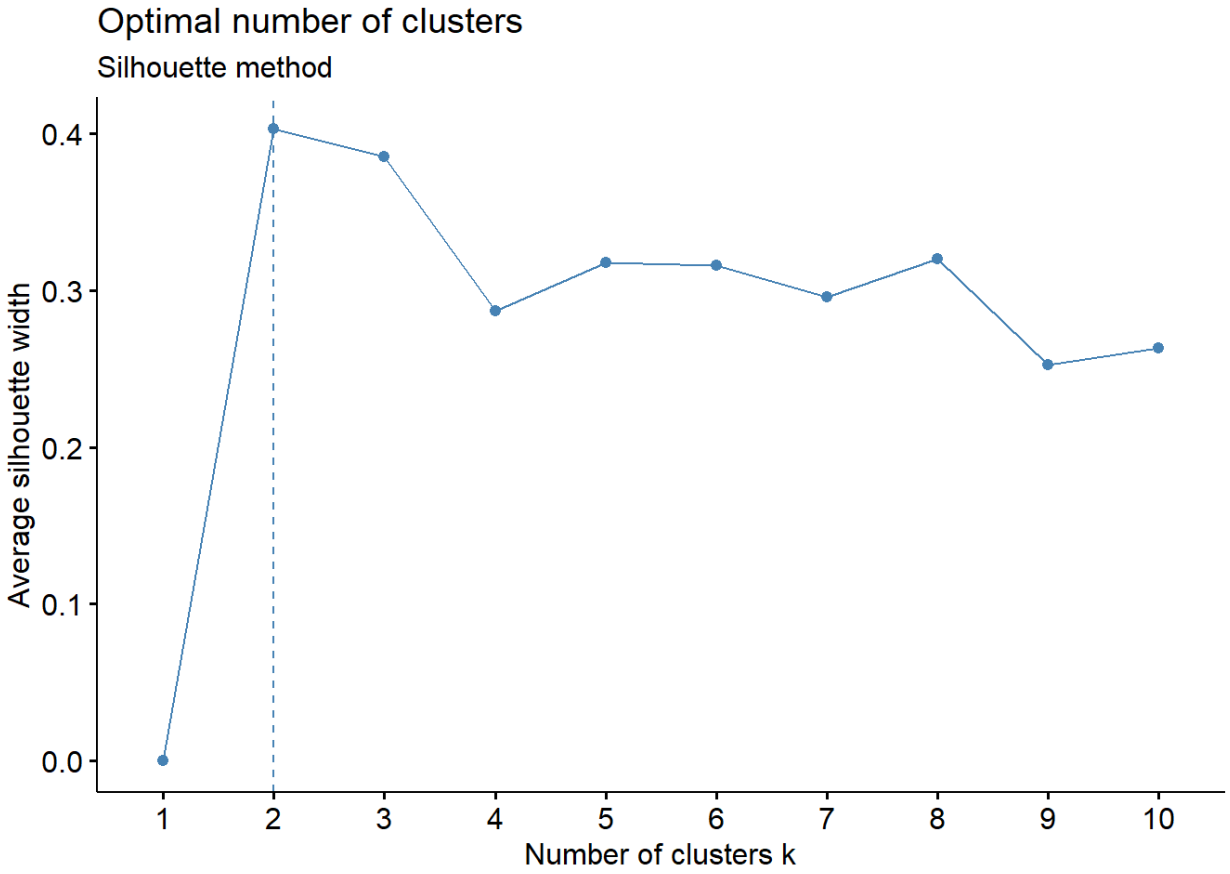
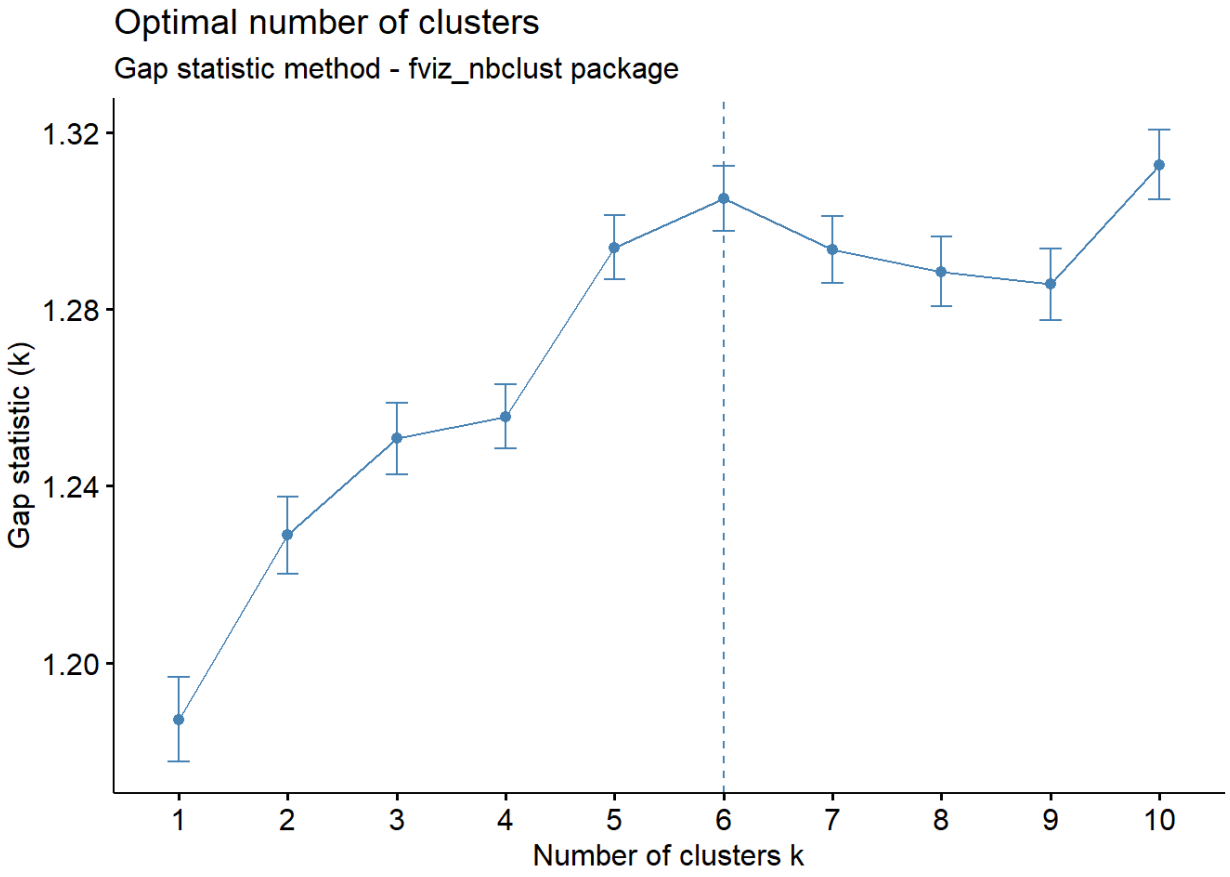


Figure B7. Plot of Tibshirani's Gap-Statistics for the intra-cluster variation relative to expectations in a hypothetical distribution with no clustering for the optimized result for different levels of *k* in the K-means cluster analysis for types census block groups based on their problematic parcels.



APPENDIX C. THREE-YEAR MARKOV CHAIN RESULTS

Table C1. Proportion of parcels with each profile of crime and disorder in year two (rows) transitioning to each other profile in year three (columns), contingent on its profile in year one (panels), including the odds ratio relative to expectations (those more likely than expected in bold).

Profile in Year One: Violent Hub						
	No Issues	*Private Conflict*	*Guns*	*Violent Hubs*	*Private Neglect*	*Public Denigration*
No Issues	.69 (0.62)	.16 (1.20)	.07 (1.66)	**.05 (8.56***)**	.02 (1.10)	.02 (0.95)
Private Conflict	.42 (0.20***)	**.20 (1.77*)**	**.15 (3.58***)**	**.13 (19.99***)**	**.08 (3.76**)**	.02 (1.07)
Guns	.32 (0.15***)	.12 (0.70)	**.24 (6.35***)**	**.24 (23.65***)**	.06 (3.70)	.03 (4.05)
Violent Hubs	.22 (0.09***)	.12 (0.82)	**.09 (2.23**)**	**.50 (142.33***)**	**.05 (2.07*)**	.01 (1.12)
Private Neglect	.25 (0.10**)	.14 (0.90)	**.16 (7.97**)**	**.15 (8.98**)**	**.29 (16.26***)**	.01 (0.93)
Public Denigration	.33 (0.20)	.28 (1.70)	.11 (2.30)	.17 (0.00)	.06 (1.07)	.06 (0.00)
Approx. Expected Value	*.76*	*.15*	*.04*	*.009*	*.03*	*.01*

Profile in Year One: Concentration of Public Denigration						
	No Issues	*Private Conflict*	*Guns*	*Violent Hubs*	*Private Neglect*	*Public Denigration*
No Issues	.76 (0.88)	.07 (0.46***)	.01 (0.30***)	.001 (0.16*)	.02 (1.07)	**.14 (10.39***)**
Private Conflict	.65 (0.49)	.09 (0.68)	.05 (1.06)	.02 (3.97)	.05 (2.07)	**.15 (11.54***)**
Guns	.57 (0.39)	.21 (1.73)	.11 (4.30)	.00 (0.00)	.04 (1.42)	.07 (2.62)
Violent Hubs	.33 (0.13)	.25 (2.72)	.17 (16.60)	.08 (3.18)	.08 (4.27)	.08 (2.06)
Private Neglect	.39 (0.20*)	.20 (1.56)	.03 (0.33)	.03 (3.41)	**.17 (22.12**)**	**.19 (27.28***)**
Public Denigration	.35 (0.17***)	.03 (0.18***)	.005 (0.11***)	.01 (1.65)	.03 (1.30)	**.57 (97.34***)**
Approx. Expected Value	*.78*	*.13*	*.04*	*.01*	*.02*	*.02*

Profile in Year One: No Major Issues						
	No Issues	*Private Conflict*	*Guns*	*Violent Hubs*	*Private Neglect*	*Public Denigration*
No Issues	**.78 (1.10***)**	.14 (0.98)	.04 (0.93***)	.002 (0.33***)	.02 (0.72***)	.01 (0.94)

Private Conflict	**.82 (1.27***)**	.13 (0.94*)	.03 (0.72***)	.004 (0.60***)	.01 (0.67***)	.01 (0.36***)
Guns	.77 (0.97)	.11 (0.77***)	**.09 (2.27***)**	.01 (1.06)	.01 (0.65)	.01 (0.37)
Violent Hubs	.46 (0.25***)	.18 (1.35)	**.12 (2.97***)**	**.22 (40.28***)**	.02 (0.81)	.01 (0.64)
Private Neglect	.71 (0.69**)	.12 (0.88)	.03 (0.83)	.004 (0.58)	**.11 (5.77***)**	.02 (1.11)
Public Denigration	.60 (0.43***)	.06 (0.43***)	.02 (0.36***)	.01 (1.14)	.03 (1.34)	**.28 (22.43***)**
Approx. Expected Value	*.78*	*.14*	*.04*	*.006*	*.02*	*.02*
Profile in Year One: Concentration of Private Conflict						
	No Issues	*Private Conflict*	*Guns*	*Violent Hubs*	*Private Neglect*	*Public Denigration*
No Issues	**.85 (1.61***)**	.10 (0.71***)	.03 (0.63***)	.002 (0.39***)	.01 (0.66***)	.01 (0.37***)
Private Conflict	.64 (0.54***)	**.25 (1.89***)**	**.05 (1.24**)**	**.02 (2.13***)**	**.04 (1.64***)**	.01 (0.64**)
Guns	.57 (0.37***)	**.21 (1.72***)**	**.16 (4.06***)**	**.02 (3.73***)**	**.03 (1.71*)**	.01 (0.35*)
Violent Hubs	.30 (0.12***)	**.29 (2.54***)**	**.12 (2.80**)**	**.19 (32.06***)**	**.08 (4.19**)**	.03 (1.53)
Private Neglect	.55 (0.34***)	**.20 (1.51*)**	**.07 (1.87*)**	.01 (2.20)	**.16 (10.90***)**	.01 (0.61)
Public Denigration	.59 (0.42*)	.11 (0.81)	.01 (0.25*)	.01 (1.25)	**.08 (4.46**)**	**.19 (10.96***)**
Approx. Expected Value	*.77*	*.14*	*.04*	*.006*	*.02*	*.02*
Profile in Year One: Concentration of Private Neglect						
	No Issues	*Private Conflict*	*Guns*	*Violent Hubs*	*Private Neglect*	*Public Denigration*
No Issues	.78 (1.01)	.11 (0.81*)	.04 (0.79)	.01 (0.82)	**.05 (2.43***)**	.02 (1.17)
Private Conflict	.61 (0.45***)	**.21 (1.68**)**	.06 (1.44)	.01 (2.63)	**.09 (4.13***)**	.01 (0.97)
Guns	.48 (0.26***)	**.22 (1.79*)**	**.12 (3.08**)**	**.04 (8.77*)**	**.12 (7.28***)**	.02 (1.10)
Violent Hubs	.20 (0.06***)	**.27 (3.07*)**	.12 (2.13)	**.23 (34.39***)**	**.15 (11.78**)**	.03 (5.97)
Private Neglect	.46 (0.27***)	.13 (0.81)	.04 (0.99)	.02 (2.32)	**.31 (20.32***)**	**.04 (2.88**)**
Public Denigration	.39 (0.22*)	.10 (0.54)	.01 (0.54)	.01 (2.55)	**.13 (5.32*)**	**.35 (24.16***)**

Approx. Expected Value	*.77*	*.14*	*.04*	*.006*	*.02*	*.01*

Profile in Year One: Concentration of Gun-Related Events						
	No Issues	*Private Conflict*	*Guns*	*Violent Hubs*	*Private Neglect*	*Public Denigration*
No Issues	.81 (1.21)	.10 (0.70***)	**.04 (1.59***)**	.004 (0.53*)	.02 (0.72*)	.005 (0.31***)
Private Conflict	.61 (0.44***)	**.20 (1.59***)**	**.11 (3.00***)**	**.02 (2.85*)**	**.04 (1.73*)**	.01 (1.16)
Guns	.53 (0.34***)	.15 (1.06)	**.27 (8.66***)**	**.02 (2.85*)**	.02 (0.72)	.005 (0.41*)
Violent Hubs	.22 (0.09***)	.28 (2.11)	**.24 (5.44***)**	**.18 (19.35***)**	.08 (2.93)	.01 (1.16)
Private Neglect	.41 (0.18***)	.20 (1.92)	**.12 (2.87*)**	**.04 (9.90*)**	**.21 (9.62***)**	.01 (1.13)
Public Denigration	.26 (0.10***)	.13 (0.88)	**.15 (6.83*)**	.02 (3.60)	.09 (2.93)	**.35 (28.86***)**
Approx. Expected Value	*.77*	*.14*	*.04*	*.007*	*.03*	*.01*

Note: Analysis is of 171,822 year-to-year transitions at parcels (28,637 parcels * 6 three-year chains over an 8-year period). Expectations are established by randomizing the distribution of parcels across states within each year. Odds ratios were calculated as relative to expectation, i.e. $\left(\frac{p_o}{1-p_o}\right)/\left(\frac{p_e}{1-p_e}\right)$. Significance was evaluated through *t*-tests comparing the expected and observed values using the standard errors of their estimates.