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Calling the police as an interdependent security game

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ABSTRACT
Calling to report crime represents public cooperation with the police. When rational individuals are predicted to report (and when not) is still poorly understood. We study an interdependent security game under threat of a costly event that can only occur once or is perceived as so costly that the threat of the event occurring more than once is (in foresight) perceived as no more costly than the event occurring only once. Our analysis suggests how the interactions among the benefits, costs and neighborhood effects of police response might affect reporting. When there is spatial contagion of crime, rational individuals may choose to report when more of their neighbors report. When there is spatial contagion of deterrence, the relationship is reversed.

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1. Introduction

The current state of public-police cooperation contains many contradictions. On the one hand, there is justified concern that to call the police is to invite harm to oneself and one's community (Brunson & Wade, 2019; Friedman, 2021; Gillooly, 2020; Kurlychek & Johnson, 2019; Lanfear et al., 2018). On the other hand, decades of crime victimization surveys show that the communities bearing the brunt of heavy-handed policing actually call the police the most (Baumer & Lauritsen, 2010; Langton et al., 2012; Lantz et al., 2022; Schaible & Hughes, 2012; Xie & Baumer, 2019). The contradictions underscore the complexities involved in the co-production of public safety. The police are uniquely dependent upon the public to report crime. Arguably, the police would be oblivious to most crime if it was not brought to their attention by a member of the public (Bottomley & Coleman, 1981; Klinger & Bridges, 1997; Reiss, 1971). At the same time, the public remains dependent upon police to respond to, solve and prevent many types of crime (Braga et al., 2019; Lum et al., 2022; Lawrence W; Sherman & Eck, 2003). Police have access to unique resources that may be required to

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rectify certain types of problems (Cook et al., 2019). Police also have special powers under the law that may help deter future crime (Chalfin & McCrary, 2017; G. O. Mohler et al., 2015; Lawrence W.; Sherman et al., 1989). But public dependence on the police does not guarantee that an individual will call when they are victimized. Indeed, in a typical year less than 50% of violent and property crime known from victimization surveys is reported to the police (Morgan & Truman, 2019).

When individuals choose to call the police and when they choose to remain silent is still poorly understood (Bowles et al., 2009; Lantz et al., 2022; Sola & Kubrin, 2023). Here, we turn to game theory to provide theoretical insights into how interactions between stochastic crime patterns (Brantingham et al., 2020; G. O. Mohler et al., 2011), the costs of reporting crime (Greenberg & Beach, 2004), and the direct and indirect deterrence effects of police response (Bowers et al., 2011; Koper, 1995; Lawrence W; Sherman, 1990) may alter the decision to report one's own victimization. We extend the *interdependent security game* studied by Kearns and Ortiz (2003) to consider how the decisions of neighbors to call the police may alter not only the transfer of exogenous risk, but also the nature of the endogenous risk faced by a decision maker. Specifically, we model the case where neighbors' calls to the police disrupt the "diffusion of harm," an exogenous source of risk often recognized as "near repeat" crimes where one event statistically triggers another event in close spatial or social proximity (Papachristos et al., 2015; Short et al., 2009; Townsley et al., 2003). We then model the case where neighbors' calls to the police extend a blanket of deterrence over a decision maker producing a so-called "diffusion of crime control benefits" (Clarke & Weisburd, 1994; Telep et al., 2014; Weisburd et al., 2006). We frame the diffusion of benefits as the suppression of endogenous risk that underlies "exact repeat" victimization where a prior crime statistically triggers another crime against the same person or place (Farrell & Pease, 1993). We find that the modulation of exogenous and endogenous risks by neighbors plays a critical role in the individual-level decision.

The model offers theoretical insights that are new to criminology. In particular, under the assumptions specified by our model, rational self-interested individuals are expected to call the police only if the costs of doing so are substantially smaller – often an order of magnitude smaller – than the costs of crime. The model also suggests that deterrence effects might sometimes encourage more members of the community to call the police, but at other times encourage them to remain silent. Indeed, a so-called "diffusion of benefits" might push the system to resemble a "public goods game" where individuals prefer their neighbors to bear the cost of calling the police, while avoiding those costs themselves.

2. An interdependent security game

We leverage the interdependent security game (IDS) framework of Kearns and Ortiz (2003) to study the decisions involved in calling the police (see also Kunreuther & Heal, 2002, 2003). Kearns and Ortiz considered a network of airlines where each airline must adopt a policy whether to screen passenger bags at the start of a travel. The Kearns and Ortiz (2003) model applies to situations where an airline perceives multiple airliner crashes as no worse than a single airliner crash. For cases where, for example, an airline perceives 2 n-person death-toll airliner crashes as worse (or more costly) than a single n-person death-toll airliner crash, the Kearns and Ortiz model does not apply. In the Kearns and Ortiz (2003) model, a focal airline can choose to screen bags at some cost and thereby reduce or eliminate the risk that a bag they take on contains a bomb. A focal airline can choose to screen bags at some cost and thereby reduce or eliminate the risk that a bag they take on contains a bomb. However, a focal airline is not able to control the screening behavior of other carriers in the network. Thus, a focal airline's security is dependent in part upon the screening choices made by other airlines, not just their own decision to screen bags. If no other airline screens the bags they take on, then the screening the focal airline does may do little to stop the transfer of risk from other carriers.

3. The diffusion of harm

Here, we recast Kearns and Ortiz's (2003) model in criminological terms, adopting many of the same simplifying assumptions. We replace the screening decisions of airlines with the decision individuals may make to call the police when they are victimized. We replace the risk of a bomb slipping through unscreened with the future risk of crime. While people are known to call the police about an array of crime and non-crime events (e.g., Langton et al., 2012; Xie & Baumer, 2019), the following is most intuitively understood as a model of individual choice in relation to residential burglary risks. Specifically, we assume that the individual decision maker chooses to call the police based at least in part upon the potential for police to deter the occurrence of a future crime, while also evaluating any costs they might bear as a result of the police response. Like Kearns and Ortiz (2003) and Kunreuther and Heal (2003), we assume that individuals are concerned only with the occurrence of a single future crime, without accounting for the marginal impact of additional incidents beyond that one event. That is, we treat the choice as a one-shot game involving rational self-interested actors concerned only with the immediate future. We believe that where the risk of the crime is relatively low, but also sufficiently traumatic (e.g., violent crime, burglary), there is limited perception of incidents beyond the next immediate crime. Our formulation deals with this first-order effect. Our adoption of this assumption has implications for the set of cases to which our analysis applies and the set of cases to which it does not apply. Our analysis applies to situations in which each actor has just been burglarized and perceives being burglarized again as highly costly, but no less costly than being burglarized two or more times in the future. That is, it applies when being burglarized twice (in total – once already and once in the future) is perceived as worse than being burglarized just the one time that already happened, but being burglarized three times in total (once already and twice in the future) is perceived as no worse than being burglarized twice in total (once already and once in the future). Our analysis does not apply to situations in which an individual whose home has just been burglarized imagines that being burglarized two more times in the future would be worse than being burglarized only one more time would be.

Given these assumptions, the recast interdependent security game is (Kearns & Ortiz, 2003):

$$M_i(\vec{a}) = a_iC_i + (1 - a_i)p_iL_i + (1 - (1 - a_i)p_i)\left[1 - \prod_{i \neq j}^{n}\left(1 - \left(1 - a_j\right)q_{ji}\right)\right]L_i \tag{1}$$

where M_i is the overall cost to individual i of taking the action a_i while her neighbors $j \neq i$ take their own actions a_j. Let $a_i = 1$ correspond to the action that individual i calls the police to report a crime, while $a_i = 0$ corresponds to not calling. It is also possible to model continuous decisions (i.e., $0 < a_i < 1$) (Kearns & Ortiz, 2003), which in the present context might represent variation in call priority from non-emergency to emergency response.

The first two terms on the right-hand side describe the direct effects on individual i. If she calls the police, she pays a "reporting cost" C_i. But calling the police also produces a deterrence effect that prevents her being the victim of a *new* crime. Specifically, let p_i be the probability that individual i is the victim of a new crime and note that $(1 - a_i)p_iL_i = 0$ when $a_i = 1$. If i does not call the police, she does not pay the cost of an encounter with the police, since $a_iC_i = 0$ when $a_i = 0$, but she may then be the victim of a new crime (i.e., a crime in addition to the one that they chose *not* to call about). Let L_i be the cost of that new victimization if it occurs. We treat p_i as the instantaneous probability of an "exact repeat," which is a term used by criminologists to describe a specific person or place ("exact") that is victimized for a second time ("repeat"), usually in short succession, after a first victimization event (Farrell & Pease, 1993; Johnson, 2008; G. O. Mohler et al., 2011; Polvi et al., 1991). Exact repeats are contagious in the sense that the second event has a detectable statistical dependency upon the first event (i.e., non-Poisson) (Loeffler & Flaxman, 2018; G. O. Mohler et al., 2011; Short et al., 2009). Statistical dependence between crime events is thought to arise through offender learning, or a drive for retribution in the case of violent crime, which makes known victims more attractive than unknown victims (Brantingham et al., 2020; Farrell & Pease, 1993; Tseloni & Pease, 2003). The parameter L_i may be thought of as the harm experienced by individual i from the *new* crime. The first two terms of Eq. (1) thus represent the expected cost to individual i that directly results from her calling or not calling the police when victimized.

The third term in Eq. (1) describes the impact on i of the actions taken (or not taken) by i's neighbors. The parameter q_{ji} is the probability that the risk from a *past* crime at neighbor j is results in a *new* crime experienced by individual i. This is consistent with the idea of "near repeat" victimization where a crime committed against one person or place produces contagious spread of crime based on social or spatial proximity (Johnson, 2008; Papachristos et al., 2015; Farrell & Pease, 1993, 1790; Short et al., 2009; Townsley et al., 2003). The contagion is visible as a second victimization close by ("near") and in quick temporal succession to the first ("repeat") (Loeffler & Flaxman, 2018; G. Mohler et al., 2021). Thus, the risk of "near repeat" victimization is the risk faced by individual i (i.e., the decision maker) that they could be the victim of a crime statistically traced to a prior victimization of a neighbor j (Short et al., 2009). Stochastic declustering methods allow for the classification of individual crimes based on the contagious branching process that generated them (G. O. Mohler et al., 2011; Park et al., 2021; Zhuang & Mateu, 2018). Thus, in both theory and practice, it is possible to say probabilistically that a burglary at house i, for example, was either an endogenous exact repeat or an exogenous near repeat, even though the outcome (e.g., theft of property) is functionally the same. The distinction motivates the partitioning of risk into an endogenous p_i and exogenous sources q_{ji}.

In the present model, we assume that this risk spreads only from neighbors that do not themselves report a crime (i.e., $a_j = 0$). In other words, any neighbor who does *not* call the police shares some of the resulting future risk of victimization with i, which would appear as a near repeat. The source of the risk is therefore exogenous to i. By contrast, any neighbor who calls the police blocks the transfer of this exogenous risk. We treat q_{ji} as being dependent only on the characteristics of j, which makes the "near repeat" transfer of exogenous risk from j to i distinct from the processes that drive endogenous exact repeats at i. The cost of a crime arising from a near repeat is also L_i. Intuitively, i incurs the same cost for a burglary regardless of whether it is an exogenous exact repeat or endogenous near repeat. Importantly, the use of subscripts means that the costs of calling the police, the costs of crime as well as the risk of exact and near repeat crime can vary across individuals. Thus, it is possible that the near repeat risk q_{ji} might differ quite precisely among the various neighbors of i.

3.1. Analyzing the diffusion of harm

It is useful to map out the strategic alternatives described by Eq. (1) for a simple case. Consider a focal individual i, who either calls the police $a_i = 1$ or does not $a_i = 0$, along with just three neighbors $j \neq i$, one of whom calls the police $a_j = 1$ and two of whom do not $a_j = 0$. When i chooses not to call the police, then $a_i = 0$. Eq. (1) reduces to:

$$M_i(0) = p_i L_i + (1 - p_i)\left[1 - (1)\left(1 - q_{ji}\right)\left(1 - q_{ji}\right)\right] L_i \tag{2}$$

where the product has been written out in expanded form to make clear the computation for all three neighbors. Assume now that the "near-repeat" probability q_{ji} is the same for all neighbors, allowing us to write q_i for the near repeat transfer of risk to i. In this case, we can further simplify Eq. (2) to read:

$$M_i(0) = p_i L_i + (1 - p_i)\left(1 - (1 - q_i)^{n-k-1}\right) L_i \tag{3}$$

where n is the total number of agents including i, $n - 1$ is the total number of neighbors j, and k is the number of neighbors who call the police. Thus, $n - k - 1$ is the number of neighbors who do not call the police. Referring back to the simple case in Eq. (2), there are $n = 4$ individuals in total, including the focal individual i. The $k = 1$ neighbor who calls is represented by the value (1) in the product, while the $n - k - 1 = 2$ neighbors who do not call are represented by the values $\left(1 - q_{ji}\right)\left(1 - q_{ji}\right)$ in the product.

Using the same simplification, the case where individual i chooses to call the police is then:

$$M_i(1) = C_i + \left(1 - (1 - q_i)^{n-k-1}\right) L_i \tag{4}$$

Given Eqs. (3) and (4) we can ask when i's preference is *not* to call the police. Since both C_i and L_i are negative, both choices produce harm and inductively we know that i's preference will follow whichever strategy produces the *least* amount of harm. The preference to not call the police therefore occurs when $M_i(0) > M_i(1)$. With a little algebra, i prefers to not call whenever:

$$p_i (1 - q_i)^{n-k-1} < \frac{C_i}{L_i}. \tag{5}$$

This result points to a number of intuitive observations. First, since both $0 \leq p_i \leq 1$ and $0 \leq q_i \leq 1$, the left-hand side Eq. (5) will always be ≤ 1. Thus, it is guaranteed that i will *never* call the police if the cost of calling the police is as high or higher than the cost of a future crime; since $C_i, L_i < 0$, then $C_i/L_i \geq 1$ whenever $C_i \leq L_i$. It is a sensible preference to forego calling the police if doing so produces more harm than simply enduring a new crime in silence. Intuitively, you are not likely to call the police if someone steals your pen, but are likely if someone beats you up. Even the mundane cost of taking the time to complete a police report is more than the value of the pen you lost.

Note, now, how the number of neighbors k who call the police impacts i's preference. If all neighbors call the police (i.e., $k = n - 1$), then $\left(1 - q_{ji}\right)^0 = 1$ and Eq. (5) reduces to:

$$p_i < \frac{C_i}{L_i} \tag{6}$$

Here, i's preference is tied only to the probability of an exact repeat p_i, which is endogenously related to the characteristics of i. The lower this probability, the less forgiving i should be of the harm caused by calling the police. For example, if the probability of an exact repeat crime is $p_i = 0.05$, then the cost of calling the police has to be at least *twenty-times smaller* than the cost of the crime to warrant calling. If the cost of calling the police is only ten-times smaller than the cost of the crime, then i will prefer to remain silent. The same result obtains if there is no diffusion of harm from neighbors (i.e., $q_i = 0$).

Figure 1 maps out i's preference for calling or not calling the police as a function of key parameters in Eq. (5). Figure 1a shows the impact of variation in the cost of calling the police C_i against variation in the cost of victimization L_i. In general, i prefers to call the police only when the cost of calling is very low relative to the cost of crime. For example, when the cost of victimization is $L_i = -2.0$ (arbitrary units), then i will prefer to call the police only if the cost

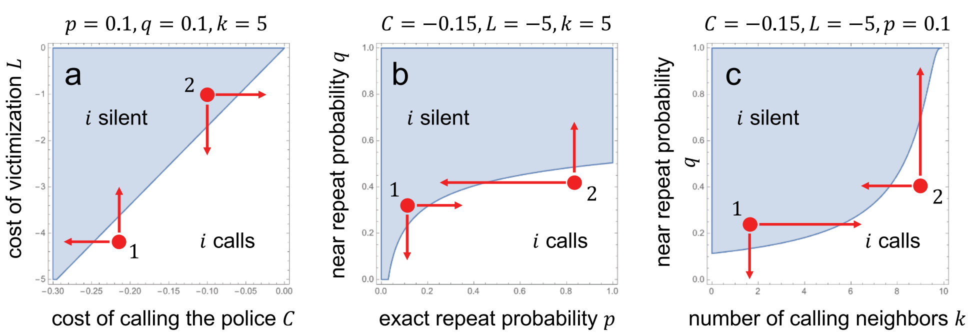

Figure 1. Parameter regions where i prefers to call the police (white) or to remain silent (blue). (a) Preferences as the cost of calling C_i and the cost of victimization L_i vary. (b) Preferences as the probability of exact repeat p_i and near repeat q_i. (c) Preferences as the near repeat probability q_i and number of neighbors k who call vary. Other parameters are held constant at values specified in the figure. The model assumes that i has ten neighbors. Points 1 and 2 in each panel are provided to guide the eye in evaluating how changes in key parameters may lead individual i to switch her preference.

of calling is no greater than $C_i = -0.118$, holding other parameters constant at $p_i = 0.1$, $q_i = 0.1$, $k = 5$ and $n = 10$. In other words, the cost of calling the police must be an order of magnitude less than the cost of victimization for i to prefer calling. If i currently prefers to call the police (see Point 1 in Figure 1a), they might switch their preference to remaining silent if the cost of calling the police increases (i.e., C_i becomes more negative), or if the cost of victimization decreases (i.e., L_i becomes less negative). By contrast, if i currently prefers silence (see Point 2 in Figure 1a), they might switch their preference if the cost of calling the police decreases (i.e., C_i becomes *less* negative), or if the cost of victimization increases (i.e., L_i becomes *more* negative).

Figure 1b shows the impact of variation in the probability of exact repeat p_i and near repeat q_i victimization risk, holding L_i, C_i, n and k constant, in a region where p_i and q_i matter. In general, individual i prefers to call the police across all values of the exact repeat probability p_i as long as the near repeat probability q_i is relatively low. For example, if $p_i = 0.1$, then i will prefer to call as long as $q_i < 0.214$. For an individual i that currently prefers to remain silent when victimized (see Point 1 in Figure 1b), they might switch their preference to calling the police if the probability of an exact repeat victimization increases (i.e., $p_i \rightarrow 1$), or if the probability of near repeat victimization decreases (i.e., $q_i \rightarrow 0$). In other words, if the balance of risk shifts from exogenous sources to an endogenous source, i may start preferring to call the police. By contrast, if i currently prefers to call the police (see Point 2 in Figure 1b), they might switch to remaining silent if the probability of exact repeat victimization decreases (i.e., $p_i \rightarrow 0$), or if the probability of near repeat victimization increases (i.e., $q_i \rightarrow 1$). In other words, i may switch to not calling the police if the balance of risk shifts to exogenous sources from an endogenous source. This result might appear counter-intuitive if you focus only on the sunk cost of past victimization. Rather, Figure 1b suggests that the *future* deterrent value i receives directly from calling the police about a *past* crime can be swamped by *future* exogenous risk of near repeat crime. It makes little sense to call the police to mitigate your endogenous risk if the exogenous risk ensures you will still be a victim (Kearns & Ortiz, 2003).

Finally, Figure 1c shows the impact of variation in the probability of near repeat victimization q_i against the number of neighbors willing to call the police k, holding other parameters constant in a region where q_i and k matter. For an individual i who currently prefers to remain silent when victimized (see Point 1 in Figure 1c), she might switch her preference if the probability of near repeat victimization decreases (i.e., $q_i \rightarrow 0$), or the number of neighbors who call to report their own victimization increases (i.e., $k \rightarrow n$). By contrast, if i currently prefers to call the police (see Point 2 in Figure 1c), she might switch her preference to remaining silent if the probability of near repeat victimization increases (i.e., $q_i \rightarrow 1$), or the number of neighbors who call the police decreases (i.e., $k \rightarrow 0$). Reporting preferences in this case appear to be tied to the balance between endogenous and exogenous sources of future victimization. If the near repeat probability q_i decreases or the number of reporting neighbors increases k, the endogenous risk of exact repeat victimization becomes more salient to *i*'s decision-making. The intuition here is comparable to the findings from Kearns and Ortiz (2003) where the endogenous risk is all that remains for airline *i* to consider (i.e., bags that *i* is the first to take on) if the exogenous risk is eliminated by all other airlines *j* choosing to screen bags.

4. The diffusion of benefits

Eq. (1) and only captures the diffusion of harm. Specifically, a neighbor's willingness to call the police only benefits individual *i* by blocking the transfer of exogenous risk that leads to a near repeat crime. Neighbors' actions have no impact on the endogenous risk that drives exact repeat crimes. However, the criminological literature is fairly clear on the point that the presence of police at a given location not only suppresses crime at that specific location, but also reduces the likelihood of crime in nearby places *without police having to go there*. This is the so-called "diffusion of crime control benefits" (Bowers et al., 2011; Clarke & Weisburd, 1994; Weisburd et al., 2006), or "diffusion of benefits" for short. It is not clear that this form of non-local deterrence involves diffusion in any formal mechanical sense. Nevertheless, we retain the language to remain consistent with the existing literature on the subject.

It is possible that what is recognized as the diffusion of benefits is in part the result of the suppression of the diffusion of harm (i.e., near repeats) (Weisburd et al., 2006). Here we make a subtle but important assumption, however, that links the diffusion of benefits explicitly to the endogenous risk of victimization facing individual *i*. Given an ability to classify individual crimes as arising from endogenous or exogenous sources of risk (see above), we also suppose that deterrence can be partitioned into an effect that suppresses endogenous risk as different from an effect that suppresses an exogenous risk. Our examining the diffusion of harm above assumed that a call to the police by neighbor *j* deters a near repeat from *j*, which is the same as saying that the call suppresses the exogenous risk faced by *i* originating from *j*. Here, we assume that the diffusion of benefits is a separate mechanism that may deter an exact repeat, which is the same as saying that a call to the police by neighbor *j* suppresses some of the endogenous risk faced by *i*.

We can account for the diffusion of benefits with a small modification to Eq. (1). Assume that there is some probability r_{ji} that a call to the police by neighbor *j* deters an exact repeat at *i*. Then $\left(1 - r_{ji}\right)$ is the probability that *j*'s call to the police *fails* to deter an exact repeat. To model the deterrent effect of multiple neighbors who can either call the police or remain silent, we write:

$$M_i(\vec{a}) = a_iC_i + (1-a_i)p_i\left[\prod_{i\neq j}^{n}\left(1-a_jr_{ji}\right)\right]L_i + (1-(1-a_i)p_i)\left[1-\prod_{j\neq i}^{n}\left(1-\left(1-a_j\right)q_{ji}\right)\right]L_i \tag{7}$$

The new product within the second term in Eq. (7) can be simplified using the same logic from above. To wit, assume that i has only three neighbors, one of who calls the police and two who do not. The product in question expands to $\left(1-(1)r_{ij}\right)\left(1-(0)r_{ij}\right)\left(1-(0)r_{ij}\right)$. If we assume that the deterrent effect r_{ij} is the same across all neighbors, then the expanded product simplifies to $(1-r_i)^k$, where k is the number of neighbors who call the police. For k total neighbors who call the police, the simplified expression can be interpreted as the probability that neighbor $j=1$'s call fails to deter an exact repeat *and* neighbor $j=2$'s call fails to deter an exact repeat, …, *and* neighbor $j=k$'s call fails to deter an exact repeat. The actions of the $n-k-1$ neighbors who *do not* call the police are not included because their non-action cannot deter an "exact repeat."

Eq. (3) can now be modified to proscribe when i prefers to *not* call the police given both the diffusion of benefits and diffusion of harm:

$$M_i(0) = p_i(1-r_i)^kL_i + (1-p_i)\left(1-(1-q_i)^{n-k-1}\right)L_i \tag{8}$$

Eq. (4) does not change because i's choice to report provides perfect deterrence against an exact repeat.

4.1. Analyzing the diffusion of benefits

The *Diffusion of Harm* analysis showed that the more neighbors who call the police, the more i also prefers to call. The reason was that the balance of risk shifts from exogenous near repeats to endogenous exact repeats if enough neighbors call. Since neighbors' actions do not deter exact repeats, individual i needs to call to receive any deterrence for this source of risk.

The situation described in Eq. (7) may be quite different since the actions of i's neighbors now impact her own endogenous risk. To show how this might work, we look again at the condition where $M(0) > M(1)$ is true, using Eqs. (8) and (4). After some algebra, individual i prefers to not call the police whenever:

$$p_i\left[(1-q_i)^{n-k-1} + (1-r_i)^k - 1\right] < \frac{C_i}{L_i} \tag{9}$$

Although Eq. (9) is more complicated than for the diffusion of harm alone, the conclusions are very similar under most conditions. Indeed, individual i's decision to call or remain silent is qualitatively identical to that shown in Figure 1, under variation in the costs of calling the police and cost of victimization, the relationship between exact repeat and near repeat probabilities, and the relationship between near repeat probability and the number of neighbors who will call the police. Figure 2a shows, however, that things are much more complex surrounding the diffusion of benefits. The region of where *i* prefers to call the police is extremely limited even when neighbors have minor effects on exact repeats (i.e., low r_i). For the fixed parameters $C_i = -.15$, $L_i = -5.0$, $p_i = q_i = 0.1$ and $n = 10$, the *per neighbor* probability of deterrence must be below $r_i = 0.113$ for *i* to prefer calling the police; this obtains when all neighbors call the police (i.e., $k = 10$). In this case, the probability that all ten neighbors' calls to the police fail to deter an exact repeat at *i* is $(1 - 0.113)^{10} = 0.3$. If only three neighbors call the police, the deterrent benefit cannot exceed $r_i = 0.063$. In this case, even though just three neighbors jointly fail to deter an exact repeat – leaving what seems like a lot of room for an event to still occur $(1 - 0.063)^3 = 0.821$—any greater *per neighbor* benefit is enough for *i* to rely solely on her neighbors for deterrence. Indeed, except for the case when no neighbors call (i.e., $k = 0$), small increases in neighbor deterrence are usually enough to convince *i* not to call.

It is perhaps surprising that *i* is more willing to remain silent when there are three neighbors who call compared with ten who call. However, this again reflects the shift in balance between endogenous and exogenous sources of risk that occurs when more neighbors call the police. For the parameter regime used in Figure 2a, when the risk of an exact repeat exceeds the risk of a near repeat, this can override the benefits of being near more neighbors who are willing to call the police. In the extreme case where we assume that there are no near repeats (i.e., $q_i = 0$), but there is still diffusion of benefits (i.e., $r_i \geq 0$), then *i* prefers to not call the police whenever:

$$p_i(1 - r_i)^k < \frac{C_i}{L_i}. \tag{10}$$

Any amount of diffusion of benefits from neighbors who are willing to call the police (i.e., $r_i > 0$ and $k > 0$) provides inducement for *i* to remain silent. Under these circumstances, calling the police is reminiscent of a public goods game where *i* wants her neighbors to call so that she does not have to. As with other public goods games, we might expect *i's* neighbors to stop providing the public benefit once they recognize that *i* is "free-riding" (Fehr & Gächter, 2000).

5. Model predictions

The interdependent security game developed above suggests several theoretical predictions about the decision to call the police. The first set of observations concern the *diffusion of harm*:

- **Prediction 1**: If the cost of calling the police exceeds the cost of crime, then the police will never be called (from Eqs. (5) and (6)).
- **Prediction 2**: If the cost of crime suddenly increases (decreases), then people may suddenly start (stop) calling the police (from Eq. (5) and Figure 1a).
- **Prediction 3**: If the exogenous near repeat crime probability is high relative to the endogenous exact repeat probability, then people may prefer not to call the police (from Eq. (5) and Figure 1b).
- **Prediction 4**: Given the diffusion of harm, the more neighbors who call the police, the more likely people are to call the police themselves (from Eq. (5) and Figure 1c).

A final observation concerns the *diffusion of benefits*:

- **Prediction 5**: The greater the diffusion of benefits, the more people will prefer to remain silent (from Eqs. (9) and (10) and Figure 2a).

The above predictions are derived from a highly stylized, simple model. Simple models have the benefit of clarity and rigor at the cost of sacrificing some of the complexity of real-world situations. Here, we examine how the predictions derived from the model align with existing empirical evidence. We

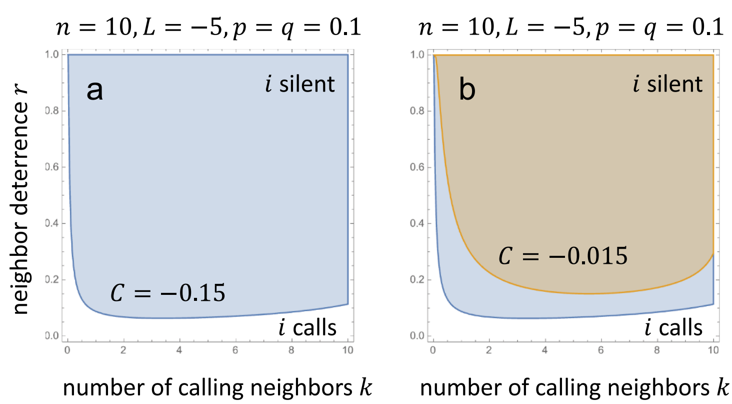

Figure 2. Parameter regions where *i* prefers to call the police (white) or to remain silent (shaded) as a function of the deterrence effect of neighbors (r_i) and the number of neighbors k willing to call the police. (a) Ten total neighbors with the cost of calling the police $C_i = -0.15$. (b) Changes in the region where *i* prefers to call the police given $C_i = -0.15$ (blue) and $C_i = -0.015$ (orange).

then turn to the limitations of the model and what the next steps in model development might look like.

Prediction 1 concerns the baseline relationship between the cost of calling the police and the cost of crime. Individual incidents such as the murder of George Floyd show that calling the police can sometimes produce egregious harms. Based on this event alone, one might expect people to rarely call the police because the potential cost is just too great (Brunson & Wade, 2019). However, calls to the police are both voluminous and often request response to low-harm crimes and an array of non-criminal matters (Antunes & Scott, 1981; Lum et al., 2022; Meyer, 1974; Midgette et al., in press; Jerry H; Ratcliffe, 2021). For example, according to publicly available data from Los Angeles (https://data.lacity.org) there were 502, 893 police calls-for-service made in the City of Los Angeles in the six months between January 1 to June 30, 2019. Only 17% of these calls were for Part I serious crimes including homicide, robbery, rape, burglary, aggravated assault and car theft. The remaining 83% of calls were for Part II crimes or non-criminal, order maintenance issues including minor disputes, street racing, runaways, and hundreds of other types of seemingly low-harm events (Jerry H. Ratcliffe, 2015). McCollister et al. (2010) estimated the tangible costs to victims of a residential burglary and theft at around $1, 947 and $686 in 2023 dollars, respectively. We might expect considerably lower tangible costs to victims for lesser crimes. Viewed through the lens of model Prediction 1, the tangible costs of crime set an upper boundary on the potential valuation of the costs of calling the police. If we use the model parameterization in Figure 1a, for illustrative purposes only, then the tangible cost of calling the police to avoid a future burglary should not exceed $195 and should not exceed $69 for a theft. The cost of calling the police for lesser crimes could be even lower. However, we caution that the parameterization used in Figure 1a is intended only to illustrate the functional relationship between the costs of crime and the costs of calling the police. More work would be needed to empirically calibrate the model, including careful consideration of the role that intangible costs such as pain and suffering might play in the decision to call the police.

Prediction 2 concerns how changes in the seriousness of crime impact preferences for calling the police. In cross-sectional victimization surveys, the rate of reporting for property crime is around five percentage points less than the rate for simple assaults, which is around ten percentage points less than the rate of reporting for serious violent crime (Langton et al., 2012; Xie & Baumer, 2019). In controlled experiments, Sola and Kubrin (2023) found that subjects appeared more willing to call the police when they were witness to a more serious than a less serious crime, holding situational features such as race of the observed participants constant. In a longitudinal setting, Brantingham and Uchida (2021) observed that calls to the police increased locally in the immediate aftermath of individual homicides. The increase was much higher for calls about violent crimes than for calls about quality-of-life disorder. Viewed through the lens of model Prediction 2, these results could reflect how a population of decision makers are split by a decision boundary defined by the cost of calling the police and the cost of crime. Specifically, assume that individuals vary in the costs they expect to incur from calling the police (i.e., $\mathrm{VAR}[C_i] > 0$), but expect to suffer the same cost of crime for a single crime type such as a burglary (i.e., $\mathrm{VAR}[L_i] = 0$). Over a community of rational self-interested decision makers, the model predicts some individuals to fall on one side of the decision boundary that favors calling the police and others to fall on the other side of the boundary that favors remaining silent (see Figure 1a). We conjecture that a *greater share* of the population may fall on the "silent" side of the boundary when they anticipate being the victim of a less serious crime compared with a more serious crime. Prediction 2 suggests that if the mix of crime changes toward a greater proportion of high-harm crime, then a greater share of the population may fall on the "call" side of the decision boundary. Thus, one interpretation of the data presented by Brantingham and Uchida (2021) is that knowledge of a homicide event pushes up a local population's perception of the costs of crime, thereby shifting their relationship to the decision boundary between calling and remaining silent. However, more work will be needed to tease apart cross-sectional and longitudinal population effects before any formal test of the Prediction 2 is possible.

Prediction 3 concerns the balance of risk between endogenous and exogenous sources of harm. Prediction 3 is most directly comparable to the analyses of interdependent security games by Kearns and Ortiz (2003) and Kunreuther and Heal (2003) where an individual's choice to invest in fire sprinklers or baggage screening only makes sense if her neighbors also make such investments. One's own investments make little difference if there is nothing to prevent a fire starting next door, or nothing to stop a bomb from being loaded onto a connecting airline. In the criminological context, Huebner et al. (2020) matched audio gunshot detections with calls to the police and found that the call rate decreased as the true rate of shootings increased. Thus, in higher crime neighborhoods, a *lower* proportion of shootings were called in to the police compared with lower crime neighborhoods. Viewed through the lens of Prediction 3 the lower call rate might reflect the feeling that calling the police does little to disrupt the exogenous risk of violence. To make progress on this empirical problem will require disentangling endogenous and exogenous sources of risk at a very fine spatio-temporal scale. This may be possible using self-exciting point process models combined with stochastic declustering procedures, developed originally to disaggregate earthquake mainshocks from aftershocks and used more recently in the statistical modeling of crime (G. O. Mohler et al., 2011; Park et al., 2021; Zhuang et al., 2002). Such an approach requires a ground truth independent of whether it has been called in to the police. Audio gunshot detections paired with police calls-for-service offer one of the best ground truth data sources of data presently available (e.g., Piza et al., 2024). Holding constant the number of neighbors who are willing to call the police, the greater the exogenous risk of crime, the less likely an individual is to call the police.

Predictions 4 and **5** pull in opposite directions. The model suggests that if there is diffusion of harm, then the rational self-interested individual will be *more willing* to call the police when more of her neighbors call. By contrast, if there is diffusion of benefits, then the model suggests that this same individual will be *less willing* to call the police when more of her neighbors call. Absent other corrective mechanisms (Szolnoki & Perc, 2017), game theoretic logic suggests that rational self-interested individuals will stop calling the police once they recognize they were paying the costs of deterrence for their "free-riding" neighbors. Studies of the community effects of private security have touched on related issues. Noaks (2000), for example, surveyed community members in suburban area of Southern Britain with private security provided to residents on a subscription basis. Nearly half ($n = 111$) of the 250 respondents interviewed subscribed to the private security service. Everyone had access to publicly-funded policing. Among the private security subscribers, 29% ($n = 32$) resented their neighbors who did not also subscribe, considering them "free-loaders" (Noaks, 2000). However, 42% of subscribers ($n = 47$) did not feel such resentment, considering it a matter of personal choice. In a similar setting in Ontario, Canada, Brown and Lippert (2007) found that subscribers were frustrated with free-riders who could not be excluded from the benefits of general deterrence provided by private security patrols. Both cases suggest that some community members were concerned with the problem of free-riding, but neither study provided evidence that people were willing to forgo their own use of private security because of free-riders (Prediction 5). Rather, because private security and affluence go hand-in-hand, it was observed that some people were still very willing to pay even if they resented free riders. How these observations would translate into to attitudes toward possible free riders in less affluent areas is not clear, nor is it clear that the very tangible costs of paying for private security are evaluated the same as the less tangible costs of calling the police. Miethe (1991) examined a related problem of the impact of civilian target hardening on burglary, theft and vandalism. Target hardening includes security investments such as installing extra locks, or getting a dog, burglar alarm, or weapon, as well as adoption of security-oriented behaviors such as locking doors, leaving the lights on or participating in a "neighborhood watch" program. Miethe (1991) found that individuals who invested in target hardening experienced significantly fewer burglaries themselves. However, when neighbors made an effort to lock their doors, it significantly increased the chance that an individual nearby was burglarized, suggesting near repeat crime displacement from harder to softer targets. By contrast, when a neighbor was part of an active "neighborhood watch" program, it significantly decreased the chance than an individual nearby was burglarized, suggesting individuals can benefit from the crime control activities of their neighbors. While Miethe (1991) described the latter effect as "free-riding" on neighbors' security investments, it is not clear that individuals chose to forego target hardening themselves because their neighbors chose to do so. The reductions in crime experienced by individuals who implement target hardening may represent gains through the suppression of endogenous risk (Prediction 4). The reductions in crime experienced when neighbors participate in a neighborhood watch program may also reflect the suppression of endogenous risk through the diffusion of benefits (Prediction 5). However, the present model does not account for the possibility that a neighbors' calls to the police could also displace crime, as observed by Miethe (1991), which might be interpreted as shifting some of the endogenous risk from neighbor j to i. While displacement of crime appears more often to be the exception rather than the rule (Telep et al., 2014; Weisburd et al., 2006), future theoretical work could include how crime displacement from calling neighbors might impact individual decisions to call the police.

6. Discussion

A primary limitation of the present study stems from the simplifying assumptions common to interdependent security games (see Heal & Kunreuther, 2005; Kunreuther & Heal, 2002). As in these earlier studies, we collapse the problem facing a decision maker (and her neighbors) into a one-shot game. We assume that all actors just experienced a crime and therefore all must make a simultaneous decision about whether or not to call the police. The model specifies that the decision is not based on the crime that just happened, but rather on the costs associated with calling the police balanced against the potential benefits in preventing a new crime in the next instant. The model does not consider the possible effects of victimization beyond the next immediate crime. In concrete terms, multiple future burglaries are perceived to be no worse than just one more burglary. These assumptions are clearly limiting. It is extremely unlikely for you and your neighbors to be victimized at exactly the same time – except perhaps in "crime spree" situations. However, spatial clusters of crime over relatively short-time intervals are common and perhaps even characteristic of crime (G. O. Mohler et al., 2017, 2011; David; Weisburd, 2015). Thus, in local neighborhood settings, you and your neighbors might indeed be faced with the decision to call the police in response to victimizations that occur within hours or days of one another. A simultaneous-move game is therefore not an unreasonable starting point to consider how baseline decision-making might operate given local clustering of crime. But it should only be considered a starting point. Whether real-world decision-making might follow the broad patterns suggested by the model depends substantially on the fine-grained spatial-temporal dynamics of crime and perceptions of crime risk. In particular, if calling the police produces a “diffusion of benefits” in real-world settings but this deterrence has a “half-life” (and spatial reach) that is shorter than time to the next exact or near repeat crime (Koper, 1995), then the benefits an individual receives from any one neighbor’s call may have dissipated long before it could ever be exploited as a public good. Under these circumstances, it seems unlikely that calling the police would succumb to the “tragedy of the commons” as expected from Prediction 5. Future work might simulate the present problem as an asynchronous repeated game, which would allow for modeling more complex deterrence effects as well as repeated victimization over longer time horizons than just the next event. Indeed, it is possible and, indeed, likely that the decision to call the police takes into consideration long-term risks of multiple future victimizations, though a “present-bias” in intertemporal choice suggests that the next victimization might still loom large (Berns et al., 2007). A next step would be to extend the current model to capture the discounting future events in a psychologically realistic way and compare mathematically how these different sets of results are related.

Another concern stems from the use of simple models of decision makers as rational self-interested actors (Steinmetz & Pratt, 2024; Whitford, 2002). The goal of the effort is to create one model-based framework to consider deviations in actual human decision-making. An assumption of rational self-interest is not the only one possible, but it is one that is well-suited to a game theoretic approach. Nevertheless, the present modeling framework almost certainly falls short on a number of fronts where decision making is neither rational nor entirely self-interested. For example, it seems possible that individuals may choose to call the police based on their own interests but also based on whether that choice may negatively or positively impact their neighbors. The central role of race in contemporary policing also deserves careful consideration for how it might influence the decision to call the police (Brunson & Wade, 2019; Carr et al., 2007; Sola & Kubrin, 2023). The tools available for studying both cooperative and noncooperative games are well developed and might reasonably be incorporated into the interdependent security game framework to address these complex issues. We leave these possibilities for future work.

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