



# The network dynamics of co-offending careers

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## ABSTRACT

Despite the long-standing acknowledgement that crime is a group phenomenon, little research treats co-offending as a dynamic network process. This study analyses the individual and network processes responsible for long-lasting criminal relationships using co-offending dyads from eight years of arrest records in Chicago. Results from proportional hazard models suggest that homophily with respect to age, race, gender, geographic proximity, and gang identity lead to sustained partnerships. Victimization increases the probability of continued co-offending, while the victimization of one's associates dissuade continued collaboration. Supra-dyadic processes (centrality, transitivity) influence the likelihood of continued co-offending. Results are discussed regarding opportunities and turning points.

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## 1. Introduction

Most criminal offenders do not act alone. The fact that the majority of criminal events involve more than one offender has been observed in many eras and geographic regions (Breckinridge and Abbott, 1912; Carrington, 2002; Sarnecki, 2001; Shaw and McKay, 1942; Warr, 2002) and is one of the few conclusions often considered as “criminological fact” (McGloin et al., 2008). Furthermore, this group nature of crime underlies many influential criminological theories either explicitly or implicitly (Akers, 1998; Cloward and Ohlin, 1960; Cohen, 1955; Sutherland, 1947). Despite the awareness of the importance of co-offending on crime and individual criminal trajectories, only recently have studies situated the understanding of co-offending within a formal network context to investigate its patterns, processes, precursors and consequences. (McGloin and Nguyen, 2014; Papachristos, 2011). While this line of network research has begun to explore the static effect of centrality, homophily, density, and transitivity (e.g. Grund and Densley, 2014; McGloin and Piquero, 2010; Morselli, 2009; Warr, 1996), few studies have modeled co-offending as a simultaneous product of individual characteristics, the characteristics of the ties between two offenders, the surrounding structure of these relationships, and their evolution in time.

The present study takes a dynamic approach to understand the individual and network processes influencing the co-offending partnership lifespan. Using more than eight years of data on co-offending in Chicago, Illinois, we extract samples of co-offenders from a co-offending network of more than 170,000 individuals. From this sample, we analyze the continuity of accomplices' partnership and the factors that influence the continuation of these particular relationships. Our statistical approach simultaneously considers individual, dyadic, and supra-dyadic co-variables to better understand why some co-offending partnerships are sustained while others are not. Consistent with prior research, our results suggest that co-offending partnerships are generally short-lived (Reiss and Farrington, 1991; Sarnecki, 2001; Warr, 1996). However, the continuation of co-offending partnerships appears to be driven by past experiences, homophily along age, race, gender, and neighbourhood proximity, as well as membership in the same street gang. Furthermore, supra-dyadic processes—especially node activity and transitivity—also play a key role in the sustainment of co-offending relationships. These findings shed new light on the importance of the trust required to sustain co-offending collaborations, on the criminal opportunities provided by a covert network and on traumatic events as “non-conventional turning points” in one's criminal career.

### 1.1. Stability of co-offending relationships

Offenders' criminal careers typically are comprised of a combination of solo and co-offending (Reiss and Farrington, 1991). While some scholars have found that preferences can emerge for solo

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versus group offending (Conway and McCord, 2002; Hindelang, 1971, 1976; Reiss, 1988), the study of criminal careers or life course trajectories only rarely differentiates between offending alone and offending with others. Instead, life course research tends to consider the number of offenses and the timing of an individual's criminal career, focusing on particular “turning points” in one's life that either enhance or mitigate subsequent involvement in crime (Laub and Sampson, 2003; Sampson and Laub, 1993). Turning points are considered as a change in the trajectory line of an individual that induces a modification in their social environment (Laub and Sampson, 1993). Typically, however, research tends to focus on “positive” turning points in offenders' life trajectories like marriage, military service, or employment; rarely does this research consider potential influences or turning points coming from within the criminal milieu, like prestige, violence, opportunities, and social influences (Charette, 2015).

Such a focus on conventional turning points treats the group nature of crime and delinquency as constant or stable, an especially problematic assumption given that much of involvement in crime (especially among young people) is influenced by group processes and peer influence (Hindelang, 1971, 1976) and that these processes are dynamic (Weerman, 2003). As noted by Warr (2002), “criminal events often depend not on the activities of any one individuals, but on the intersections between the criminal careers of numerous offenders” (p. 86). Moreover, many of criminology's core theories—including social learning (Akers, 1998), differential association (Sutherland, 1947), and opportunity theory (Cloward and Ohlin, 1960)—center on the role groups or group structure play on criminogenic processes (see also Papachristos, 2011). Even the conventional turning points within life course criminology are inherently defined by group processes. Marriage, for example, involves creating new network ties that might pull an individual from a criminal life-style (e.g. Laub et al., 1998). Likewise, involvement in education or employment removes an individual from the networks that got her involved in crime and places her in less criminal prone networks (e.g. Uggem, 2000).

Despite the importance of groups for criminal careers, we still know very little about how co-offending patterns evolve over time. Setting aside more formally organized criminal groups (street gangs, crime syndicates, drug dealing crews, and so on), most co-offending groups tend to be small in size, lack any formal organizational structure or leadership, and contain members who are similar along social and demographic dimensions (see, Warr, 1996 for a review). In particular, co-offending between any two individuals tends to be short-lived with only a small percentage of co-offending dyads enduring over time (Reiss and Farrington, 1991; Warr, 1996). For example, in a sample of young delinquents in Stockholm, Sarnecki (2001) found that only 2.5% of the co-offending relationships persisted for more than 6 months.

Rather than focus on the dissolution of co-offending, our study examines why co-offenders continue to offend together. Building on research from both life-course criminology and social network analysis, we posit that the decision to remain in co-offending relationships with past partners is determined by a mix of individual (e.g., race, age, and gender), dyadic (e.g., homophily or residing in nearby neighborhoods, being in the same gang), and supra-dyadic factors (e.g., centrality, or triadic closure among friends). Prior research offers some insights into some of the potential factors that lead to the sustainment of co-offending relationships.

Age, race, and criminal history may play an important role in the sustainment of criminal partnerships. In general, co-offending appears to more closely follow the “age-crime” curve in that rates of co-offending decreases with age and with offenders changing from co- to solo-offending as they grow older (Carrington, 2002; Conway and McCord, 2002; Piquero et al., 2007; Reiss, 1988; Reiss and Farrington, 1991). Similarly, McGloin and Piquero (2010) observed

that offenders engaged in co-offending tend to desist from crime earlier than solo offenders. Race and ethnicity may also play a role in co-offending. In a study of juvenile offenders from Philadelphia, McGloin et al. (2008) found that co-offending stability was greater for white offenders as compared to non-whites. Finally, criminal history may also play a role in co-offending stability. When analyzing which offenders are more likely to re-offend with the same partners, McGloin et al. (2008) observed that more frequent offenders also had a greater stability in their co-offending patterns. In other words, high-volume offenders were the most likely to maintain co-offending relationships.

Outside of such individual level characteristics, our study also considers the extent to which the sustainment of co-offending relationships relates to non-conventional turning points within criminal careers: opportunities/social capital, specialization/versatility, and victimization.

## 1.2. Social capital and trust

The decision to co-offend in general is a partial function of the total pool of potential co-offenders one knows. A larger pool of potential co-offenders means that one might have a greater range of possible co-offenders from which to choose. In contrast, those with smaller pools of potential co-offenders would be more likely to re-offend with the same partners. Accordingly, McGloin et al. (2008) observed that individuals with a larger social network were more likely to change collaborators when committing crimes.

But the availability of potential co-offenders alone does not determine with whom you may offend (Tremblay, 1993). Given the inherently risky nature of criminal offending—both the risks inherent in the crime itself (such as victimization) as well as the risk of detection by the police—offenders do not pick partners like random draws from a pool (McCarthy et al., 1998). Rather, as noted by Weerman (2003), the selection of co-offenders should reduce the risk related to offending, not increase it. Fundamentally, “the decision to cooperate is a decision of trust” (Burt and Knez, 1995, p. 257). But how to know if someone is trustworthy?

One way to ensure trust is through experience. If you already had experiences with an individual, then you can assess her trustworthiness. However, learning by experience is itself a risky bet as it might entail a lot of failures. Another way to evaluate trust would be to rely on people that are similar to you, a process often referred to as homophily. Homophily can be observed in conventional social networks according to race, age, religion, education, occupation and gender (McPherson et al., 2001). Homophily has been shown as an explanation of why cooperative behaviors are localized in social space (Mark, 2003). Co-offending networks have also been shown to be homophilous in terms of age (Kleemans, 1996; Reiss and Farrington, 1991; Warr, 1996), gender (Warr, 1996), and race (Grund and Densley, 2014; Reiss, 1986).

Another way to ensure trust would be to rely on one's interpersonal connections, i.e., social capital. Dense and strong networks can facilitate the development of trust, simplifying the attainment of communal goals (Coleman, 1988). However, these dense relationships rapidly become redundant as they are not able to supply new opportunities (Burt, 1992; Granovetter, 1973). An ideal situation would be when one can be considered as a trustworthy bridge bringing new opportunities between isolated parts of a network (Burt, 1992). A good balance between these two structures would forge a personal network that combines trust and the possibility to reach new opportunities. In the same way, the search of a suitable co-offender becomes a balance of weak and strong ties (Tremblay, 1993). While strong ties generate trust, they also increase visibility, which lead to higher risks of denunciation by one's peers (Morselli, 2009). Studies in criminology have shown that an efficient network structure helps to bring new opportunities (McGloin and Piquero,

2010) and allow a higher return on crimes (Morselli and Tremblay, 2004).

### 1.3. Type of offenses and specialization

Different levels of co-offending have been observed for different types of crime (Erickson, 1971; Hindelang, 1971, 1976; Warr, 1996). Specifically, co-offending rates tend to be *higher* for drug offenses, vandalism, burglary, and robbery and *lower* for violent offenses, minor thefts, and shoplifting (Weerman, 2003). The standard logic for higher rates of group involvement in the former types of crimes posits that some offenses require partners to be committed, especially crimes consisting of an event chain, like a script with different scenes (Cornish, 1994; Morselli and Roy, 2008). These sorts of crimes require multiple persons, places, and events to come to completion. Violent crimes, on the other hand, are usually less planned, and do not require that structure. However, these crimes present higher risks, their penal costs being more severe. Moreover, there's a group hazard related to co-offending, leading to higher risks to come to the attention of the police and more likely to result in arrest (Hindelang 1976). Thus, when perpetrated in groups, these crimes require a high level of trust to avoid partner denunciation risks (Tremblay, 1999). We could then hypothesize that a particular bond will be created between two offenders that commit violent offenses together, and that these ties will last longer.

Criminological research has also examined the propensity of individuals for committing the same offenses throughout their criminal career, classified on a continuum between specialized and versatile offenders. Generally, we observe little specialization in the offending patterns during a whole criminal career (Blumstein et al., 1988; Blumstein et al., 1986), although specialization can be found over shorter periods of time (Sullivan et al., 2006). Warr (1996) observed that individuals are more versatile than groups, which suggests that the versatility observed at the individual level might be due the diversification in the choice of co-offending groups. Taken together, these findings suggest a dynamism in terms of specialization over the life-course both at the individual and group level.

Offenders usually do not stick to the same co-offenders but seek out companions depending on the particular situation (Maguire and Bennett, 1982; Shover, 1973; Walsh, 1986). As they switch from one co-offender to another during their criminal career, offenders also usually switch from one type of crime to the other, according to the opportunities that they face. Interestingly, social ties are a good vector for new opportunities in the licit world (Aldrich and Zimmer, 1986), as well as in an illicit milieu (Kleemans and de Poot, 2008; Morselli, 2005; Warr, 2002). In the present analysis, we will discuss how co-offending as social ties influence the availability of criminal opportunities.

### 1.4. Violent victimization

Studies have shown that active offenders experience high levels of victimization (Levitt and Venkatesh, 2000; Taylor et al., 2007; Tremblay and Paré, 2003). These risks can be even higher when an individual is part of a gang or co-offending network (Papachristos et al., 2014; Taylor et al., 2007). In Chicago for example, the risk of being a shooting victim for the general population is 62 per 100,000 inhabitants: a risk that is six times higher for individuals who have been arrested, and twelve times higher for individuals part of a co-offending network (Papachristos et al., 2014; Taylor et al., 2007).

Such high risk of victimization might play a major role on the decision to continue or not a criminal career. For example, when interviewing 24 ex-gang members in St-Louis, and asking them why they left their gang, Decker and Van Winkle (1996) received a consistent answer; all of them said that “they left their gang as a

consequence of experiencing violence, either *directly* or *indirectly*.” (p. 269) Results from the analysis of Montreal street gangs show that being victim of violence or knowing someone that has been victimized reduces your probability of pursuing your criminal career (Tremblay et al., 2016). Violent victimization among offenders follows a diffusion pattern through social ties, while the risk of being victimized in a criminal network increases if your alters have been victimized, even after three degrees of distance (Papachristos et al., 2014). Deterrent effect of violence might also follow this diffusion pattern, and we can hypothesize that not only your own victimization influences your behaviour, but also the victimizations of your surroundings. If violence decreases the likelihood of pursuing an individual criminal career, we can hypothesize that it will also deter the continuation of dyadic careers. Such traumatic events are good example of possible non-conventional turning points: having a friend that got shot might be as an important turning point as getting married.

### 1.5. Objective

This study's objective is to treat co-offending as a dynamic process that unfolds over time and is influenced by a range of individual, contextual, dyadic, and supra-dyadic forces. Specifically, we examine the continuation of co-offending relationships over time by asking the following question: *What influences the likelihood of the continuation of a co-offending relationship?* To answer this question, we consider the individual and partner attributes, criminal careers patterns, and the supra-dyadic effects of their surroundings. We argue that unconventional turning points (victimization, new accomplices), trust (past experience, homophily, transitivity) and alternative opportunities (specialization) will influence the duration of criminal partnerships.

## 2. Data & methods

Data for this study is drawn from arrests record and non-fatal gunshot victims gathered by the Chicago Police Department. More precisely, we analyze the evolution of co-offending careers and dyads' characteristics of samples of 8,621 offenders nested in 14,640 co-offending dyads located in the co-arrest network for the city of Chicago during an eight-year period (2006–2013). These samples are drawn from the entire co-arrest network that consists of the population of individuals arrested for any type of crime with at least one other person: in total, 181,615 offenders nested in 365,800 dyads. The network consists of 25,339 distinct connected components with 63% of all nodes contained in the largest connected component. Considering the size of this population and the dynamic nature of our proposed statistical model, attempts to analyze the entire network led to a computational failure; even on high-power computing clusters, our analysis requiring too much computer memory. We therefore confined our analysis to randomly selected subsamples of dyads.

### 2.1. Co-offending patterns and sampling

Fig. 1 shows survival curves of the time between the commission of two offenses of any type by one individual, the time between two co-offenses with anyone by one individual, and the time before a dyad of offenders co-offend again together. Fig. 1a shows that, at the end of the observation period (8 years), 57.6% of the offenders re-offend and 45.9% re-offend again with *any* co-offenders; only a small percentage, approximately 5.3% co-offend again with a same co-offender from a past event. As can be observed in Fig. 1b, when such dyadic recidivism occurred, it happened relatively rapidly after a first co-offending event, relative to the other forms of recidivism: 80% of dyadic recidivism occurred 754 days after a first event,

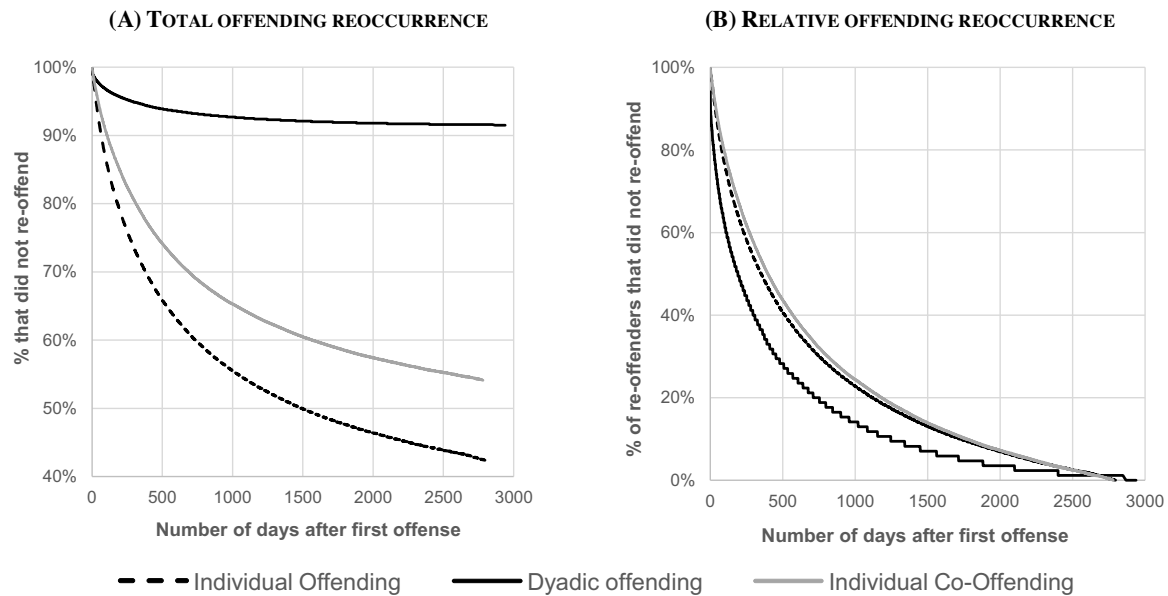


Fig. 1. Total (a) and relative (b) survival curves before the reoccurrence of individual offending, individual co-offending, and dyadic offending.

while this threshold happened after 1124 days for offending in general, and 1194 days for co-offending. Thus, when two individuals co-offend again, they do so more quickly than either co-offending more generally or individual re-offending; Co-offenders with more than one co-arrest experiences together re-offended in an interval of 373.8 days on average ( $SD = 444.9$ ), just over one year.

Since our dependent variable is the reoccurrence of dyadic co-offenses, and these events are uncommon ( $N = 19,518$ , 5.3%), we used an endogenous stratification sampling strategy, as we over sampled these dyads and selected random samples of 25% of the recurring dyads ( $N = 4880$ ). As a comparison sample, we selected dyads that were non-recurring, doubling the size of this recurring sample ( $N = 9760$ ). Each sample represents 2.8% of the total number of non-recurring dyads in the population ( $N = 346,282$ ). To ensure the representativeness of the selected dyads, models are run iteratively on a pool of 100 random samples. To ensure the representativeness of recurring dyads, cases were weighted according to their proportion in the population (Cameron and Trivedi, 2005).

We calculated all of the structural characteristics of individuals and dyads based on the complete network before selecting dyads in order to capture extra-dyadic structural features (e.g. centrality, transitivity). The statistical modeling was computed only on the subsamples, but including the full network measures. The computational challenge of this analysis is due to the dynamicity of each covariate: the whole network population comprised 10,809,140 time entries, and each sample of data represents on average 645,845 time entries ( $SD = 5,683.2$ ). Table 1 presents the descriptive analyses of the population and the average sample for the nodal and dyadic characteristics. For the dynamic characteristics, we present the value at the end of the observation period.

## 2.2. Individual static characteristics

### 2.2.1. Race and gender

Arrest data contain information about gender and race (i.e. black, white, Hispanic, other). However, there was some discrepancies in the different observations of a same individual (most of

the discrepancies were observed between whites and Hispanics<sup>1</sup>). Considering that a change in these characteristics is not likely, we assume that these discrepancies are due to a noise related to data entry. The selected category is based on the highest occurrence. Considering race, 8% of the sample was identified as white, 70% as black, 21% as Hispanic, and 1% as from other ethnicities. 81% of the sample were males.

### 2.2.2. Age

In the case of any discrepancies, the average date of birth noted in the arrest was considered. Age is, of course, dynamic, but considering that it is evolving at the same rate for everyone, we can consider it as static and therefore use age at the first dyadic event. Individuals from our samples were on average 26 years old ( $SD = 10.8$ ).

### 2.2.3. Gang membership

We rely on police identification of gang membership. There are limitations associated with the use of police identified gang membership (Katz et al., 2000). However, this was the only source available that could provide any assessment for the population of this size and past research has considered police source of gang membership as internally valid (Katz et al., 2000). Furthermore, while gang membership is itself a dynamic process, our data lack the degree of precision to identify a precise date at which gang membership started or ended. Approximately 29% of individuals in our sample were ever considered as gang members by the police.

## 2.3. Individual dynamic characteristics

### 2.3.1. Number of previous solo and co-arrests

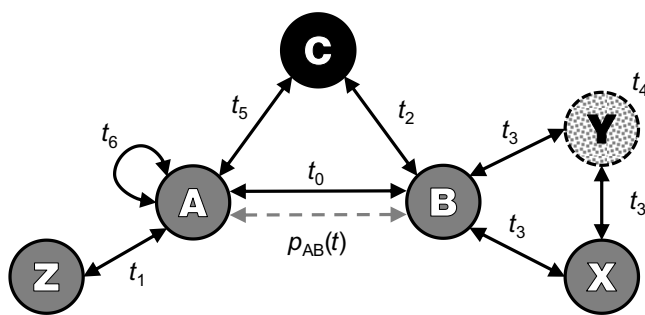
Individual propensity for committing crimes varies tremendously and is heavily dependent on a range of individual and

<sup>1</sup> Individuals were only defined as black in 97.9% of the cases, but also as Hispanic in 1.3%, as other and white in 0.5% of the cases. Individuals were defined only as Hispanic in 91.2% of the cases, but also as white in 5.7%, as black in 3.2%, and as others in 0.6% of the cases. Individuals were defined only as whites in 88.3% of the cases, but also as Hispanic in 8.9%, as others in 2.1%, and as black in 1.8% of the cases. Individuals were only defined as others in 63.0% of the cases, but also as white or black in 17.5% and as Hispanic in 7.6% of the cases.



**Table 1**  
Description of the population and the pooled samples.

	Population		Samples	
	n/M	%/SD	n/M	%/SD
Nodal characteristics	(n = 181,615)		(n = 8621)	
Male	141,841	78.1%	6981	81.1%
Race				
White	16,908	9.3%	689	8.0%
Black	126,059	69.4%	6000	69.7%
Hispanic	36,741	20.2%	1846	21.4%
Others	1635	0.9%	71	0.8%
Age	28.32	11.77	26.28	10.82
Gang membership	37,376	20.6%	2525	29.3%
Victimization	0.05	0.25	0.08	0.32
2nd order victimization	3.33	14.45	8.17	26.55
Solo offending	3.01	4.63	3.72	4.95
Same type of offense	1.40	2.99	1.72	3.17
Different type of offense	1.59	2.79	1.97	3.05
Co-offending	2.02	2.04	3.01	2.96
Same type of offense	1.48	1.25	1.99	1.86
Different type of offense	0.52	1.26	1.00	1.80
Centrality	4.03	5.01	6.42	7.10
Same type of offense	3.63	4.82	5.15	6.51
Different type of offense	1.28	3.56	2.54	5.05
Dyadic characteristics	(n = 365,800)		(n = 14,640)	
Proportion re-offense	19,518	5.3%	4880	33.3%
Time before re-offense	373.80	444.90	373.80	444.90
Type of offense				
Violent	49,149	13.4%	2142	14.6%
Market	55,514	15.2%	2145	14.7%
Predatory	132,218	36.1%	4341	29.7%
Justice	213,696	58.4%	9049	61.8%
Homophily				
Gender	312,583	85.5%	12,743	87.0%
Race	330,098	90.2%	13,280	90.7%
Gang membership	80,896	22.1%	3774	25.8%
Same gang	60,470	16.5%	3013	20.6%
Age distance	5.75	6.77	4.62	5.86
Geographic distance (km)	8.21	3.75	8.00	3.88
Transitivity	5.82	13.80	12.14	25.97
Same type of offense	5.38	12.07	10.12	21.23
Different type of offense	0.44	4.47	2.02	10.23



**Fig. 2.** Schema of the co-offending dynamics.

ecological factors. Further, individuals have different propensity of committing offense alone or with others. As such, our analyses consider the total number of previous offenses perpetrated alone and with other offenders as an important control variable. This measure is dynamic, evolving across the study period. Fig. 2 presents a schematic example of a dyad between Node A and Node B and what happened to these two nodes and to their surrounding associates (nodes C, X, Y, and Z) through time ( $t_x$ ) that might influence their probability of committing an offense together again [ $p_{AB}(t)$ ]. In this example, Node A had committed a sum of 2 co-offenses by Time 1 (with Node B at  $t_0$ , and with Node Z at  $t_1$ ) and a total of 3 co-offenses by Time 5 (Node B at  $t_0$ , Node Z at  $t_1$ , Node C at  $t_5$ ). At the end of the observation period, the offenders of the samples had on average a total of 3 co-offenses ( $SD = 3.0$ ) with any other offenders. Node A had

also committed one solo offense after Time 6 ( $t_6$ ). By the end of the observation period, individuals from our samples had on average a history of 3.7 offenses perpetrated alone ( $SD = 5.0$ ).

We also considered the type of crime of the offending act. Following a similar classification to other studies (Charette, 2015; Morselli and Tremblay, 2004), offenses were classified in four categories: violent offenses (e.g. assault, murder), market offenses (e.g. drugs, prostitution), predatory offenses (e.g. burglary, robbery), and offenses against the administration of the justice (e.g. breach of probation, disturb the peace). These categories represent four relatively different orthogonal pathways: offenses involving victims (violent, predatory) and those that do not (justice, market), and offenses involving monetary gains (market, predatory) and those that do not (justice, violent). These categories allow to observe a relatively drastic change in offending career patterns (Tremblay, 1999). This classification by type of offense also control partially for an incapacitation effect, in that some offense types of crime have greater rates of imprisonment which, ipso facto, would remove the node from subsequent chances of offending (Blumstein et al., 1986). A more fine-grained classification could have been possible, and would have control more efficiently for neutralization, but would have shown less drastic change in the type of crime perpetrated (i.e. specialization/versatility) and less different opportunities. For example someone evolving from drugs possession to drugs trafficking is less of a change than from drugs trafficking to burglary. Our strategy was then considered as a compromise between precision and conceptualisation. As observed by Sullivan et al. (2006) specialization can be found on the short term. In this paper we then

consider specialization influence between each offenses (i.e. Are offenders more likely to choose the next offense type in function of the past types they were involved in?) and not at the aggregate level, which would lose all the precision of trajectories' dynamicity.

### 2.3.2. Number of previous co-offenders

Our analyses also consider each node's degree centrality, which in this case is the number of co-offending associates one has in his network. The number of people that one associates with is also time variant. For example, in Fig. 2, Node A had a degree of 2 (*B, Z*) at Time 1 ( $t_1$ ), while at Time 5 its degree was of 3. We thus use a time-varying measure of degree that sums the number of different co-offenders you had since the start of the observation period. At the end of the observation period, the members of our network had been arrested on average with 6.4 different co-offenders ( $SD = 7.1$ ). We also consider the type of offense perpetrated with that co-offender to assess the available social opportunities: having past co-offenders who are perpetrating robberies in one's social network might not be useful for someone who wants to do drugs trafficking.

### 2.3.3. Victimization

We hypothesize that being victim of a violent event will decrease one's and one's friends' likelihood of pursuing a criminal career by increasing their perception of endogenous risks (Jacobs et al., 2000; Jacobs and Wright, 2006; Tremblay and Paré, 2003). Since victimization occurs at a discrete point in time, we can assume that its influence occurs after the event. For example, in Fig. 2, let's say that Node Y was shot at Time 4. If there is a vicarious deterrent effect of violence, this shooting should then influence the probability that Node A offending after that point and, consequently, also the odds that Nodes A and B offend again together again. We use gunshot victimizations as recorded by the police as a source of victimization. While shooting victimizations are rare statistical events, their effects can be traumatic and enduring both emotionally and physically (Lee, 2012; Ralph, 2014). In our sample, offenders were victim of shooting on average 0.08 times ( $SD = 0.32$ ). Similarly, one's acquaintance victimization might also present a deterrent effect: offenders had on average 8.2 victims ( $SD = 26.6$ ) among their relations.

## 2.4. Dyadic static characteristics

### 2.4.1. Homophily

Beyond the characteristics of the individuals in the dyads, the similarities between these two might also play a role in the likelihood of a future offense. Following the well-known principles of homophily (McPherson et al., 2001), we hypothesize that individuals similar along various personal and offending characteristics would be more likely to re-offend together. In Fig. 2, Nodes A and B are gray, while Node C is black. A and B are thus homophilous on this characteristic whereas A and C are not. For categorical variables (race, gender, gang membership), homophily was coded for each dyads as 1 if both co-offenders were similar, and 0 if they were not. In our sample, 91% of dyads were homophilous in terms of race and ethnicity, 87% with regard to gender, and 26% with regard to gang membership. For gang members, we also considered if the members of the dyad were in the same gang: 21% of the co-offenders in the sample were in the same gang according to police information. For continuous variables (i.e. age), we took the absolute value of the differential to observe similarity. On average, co-offenders were separated from 4.6 years ( $SD = 5.9$ ).

### 2.4.2. Type of offense

As for the individual criminal history, the type of offense in which the co-offenders were involved together at the dyadic level will be considered, first because they represent a different risk of

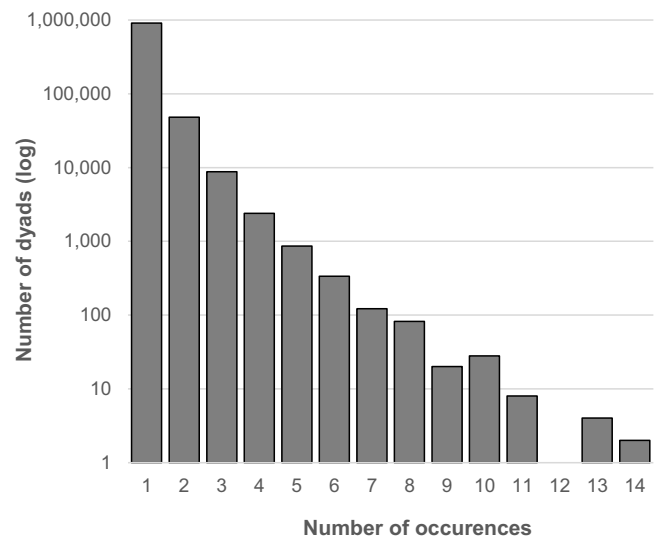


Fig. 3. Number of co-offenses per dyads.

arrest and, second, because the type of offense can represent a choice in the career of the offender. The same categorization as mentioned above will be used. In our samples, dyads were formed by committing mostly offenses against the justice system (61.8%), but also predatory crimes (29.7%) and to a less extend market crimes (14.7%) and violent crimes (14.6%).

## 2.5. Dyadic dynamic characteristics

### 2.5.1. Number of past joint co-offending

The first factor to consider at the dyadic dynamic level is the number of time the members of the dyad co-offended together in the past. Fig. 3 plots the total number of co-offenses per dyad. On average, co-offending dyads had 1.4 co-arrests ( $SD = 0.7$ ). Of the total number of observed co-arrests, 67% of co-offending dyads ended after the first offense.

### 2.5.2. Geographic distance

Another factor that could influence the fact that two people are co-offending together is the simple fact that they live close to each other (Felson, 2003). However, we need to consider that people are not sedentary, that they are moving from one part of the city to the other. Since offenders usually commit their offenses close from their home (Wiles and Costello, 2000) we might hypothesize that relationships between co-offenders are less likely if they become too far from each other or the cost of traveling from one part of the city to the other becomes higher than the benefits of pursuing a given partnership. Accordingly, Reiss (1986) hypothesizes that the short life of delinquent groups might be due to residential mobility.

Every time an offender has a contact with the police, information about his/her address is archived. For each of the time points in the data, the offenders can therefore be geo-localized. We hypothesize that as co-offenders are moving away from their partners, they might become less likely to co-offend again in the future. In the current study, we situate each offender's address in a local "neighbourhood" (for our purposes, defined as a "police beat"). The distance between two offenders is measured by their Euclidian distance from the centroids of their respective neighborhoods.

### 2.5.3. Transitivity

According to network theories, the structure of one's local relational network must be considered to understand relationships that extend beyond the dyadic level. Transitivity, the general

tendency towards triadic closure in networks, is one such supra dyadic effect that has significance in a broad array of human social networks (Easley and Kleinberg, 2010). In our study, transitivity would occur if two individuals that co-offend at one point in time share a third co-offender between them. Moreover, transitivity must be considered as dynamic. In Fig. 2 for example, Nodes A and B are co-offenders at Time 0. Node C did co-offend with B at Time 2, but it is only at Time 5 that the triad between these 3 nodes closed. We hypothesize that at this point, the probability that A and B co-offend together again in the future [ $p_{AB}(t > 5)$ ] will change due to that new structure.

We consider two transitivity measures. First, a basic measure of how many nodes both members of the dyad share with each other. In the sample, dyads shared on average 12.1 contacts ( $SD = 26.0$ ). Second, we also consider the type of crime that was committed with the third party as a measure of the variety of opportunities offered by social ties. A third party was involved in the same offense types as the dyad in 83% of the cases.

### 3. Analyses

A key element of our study design is right-hand censoring: individuals enter the network at different time points and not all dyads are observed for the same duration. Such a design feature suggests that survival models are best suited to fit the data to account for differential exposure time. To assess the effect of multiple covariates on a risk of an event, we employ the Cox's proportional hazard semi-parametric models (Cox, 1972). A survival approach also allows for time-dependent covariates. These time-dependent covariates will be used to operationalize the dynamicity of the individual characteristics (co-offenses, offenses, victimization), but also the dyadic and networks attributes (geographic distance, degree, transitivity, alters' victimization).

To account for the dependence of the observations related to dyadic settings, we used a two-way cluster robust estimator of standard errors at the node level (Cameron and Miller, 2015). More adapted models exist for this type of design, but the size of our dataset and the complexity of the design lead to convergence failure for these more computationally demanding models (e.g. crossed-classified random effects models; Snijders and Bosker, 1999). Thus, our results tend to underestimate standard error, increasing Type 1 error (i.e. false positive results) and should be interpreted accordingly (Cameron and Miller, 2014).

The logarithm function of continuous variables was extracted to limit the effect of extreme values and distributions' skewness (Howell, 2003; Tabachnick and Fidell, 2007). Standardized coefficients ( $\beta$ ) were calculated using standardized covariates (i.e. Z-scores; Wooldridge, 2013). These coefficients must then be interpreted as an increase in one standard deviation, and can be compared between each other.

## 4. Results

### 4.1. Predictors of dyadic recidivism

Proportional hazard models explain which dyads are more likely to reoccur in the future, considering the different characteristics of the nodes involved and their surroundings evolving across time. Table 2 presents the results from these models predicting the reoccurrence of a co-offending dyad. The first model includes offenders' characteristics, homophily measures, and basic centrality and transitivity measures as predictors. The second model adds the distinction between the type of crimes for criminal history, of solo offending and co-offending, for centrality and for dyads transitivity.

### 4.2. Offenders' characteristics

The first model represents our base model. While race of the offenders does not seem to have any effect on the reoccurrence of future partnerships, male offenders are more likely to have longer criminal partnerships. Age also influences the likelihood of future collaborations: following the age crime curve, the older the individuals of the dyad, the less likely they are to be part of a repeated dyad in the future. Individuals identified as gang members are more likely to repeat another dyadic offense with the same partner. In terms of past co-offending behaviour, the total number of co-arrests that happened with any other individuals increases the likelihood of carrying on a partnership. The number of solo offenses a person commits also increases this probability, but on a far lower level ( $\beta = 0.06$  vs.  $\beta = 0.44$ ). The number of gunshot victimizations an individual experiences has no deterrent effect, and, on the contrary, increases the likelihood of two offenders pursuing their collaboration.

On the other hand, the number of offenders in your social surrounding who were victim of violence, decreases your likelihood of co-offending again with the same individual. Perhaps individuals can assess the fact that increased network exposure brings with it additional risks of one's own victimization (Papachristos et al., 2014). It thus seems that while direct victimization does not appear to curtail co-offending behaviour, indirect victimization does: seeing your associates shot appears to deter co-offending.

Model II differentiates co-offending versus solo-offending thereby adding the type of offense to the equation. The history of co- and solo-offending is then divided as to whether they were from the same type of offense as the actual partnership, or from a different type. This model shows that the type of offense has little differential effect for past co-offending: other experiences of co-offending, notwithstanding their type, have an effect on the likelihood of future offenses with your partner. However, the total number of past co-offenses of the same type as the present are more influential than of a different type ( $\beta = 0.57$  vs.  $\beta = 0.11$ ). On the other hand, only solo offenses of the same type increase the likelihood of partnership. Offenders that commit offenses of other types, but alone, will not increase their likelihood of pursuing a collaboration. These two results show a tendency towards specialization in the type of offenses but also in terms of solo vs. co-offending.

### 4.3. Dyadic characteristics

When we consider the characteristics of the dyad, the first thing we should consider is the history of the dyad. Results from Model I show that the more instances of co-offending one has with an individual, the more one is likely to commit further crimes with this same person. However, this relationship is not linear and Fig. 4 shows the quadratic effect of this relationship. There is an increase in the probability of future cooperation for a dyad after each collaboration, but there is a plateau effect after 4 offenses. After that point, the dyad is still 7 times more likely to be observed again in the future.

Looking at the reason of the arrest, we can observe that offenders co-arrested for violence, offenses against the justice system, and market crimes are less likely to co-offend again together than those who committed predatory crimes. First, violence offenses are less planned, using the same co-offender is then less likely. It is also possible that the moral and human conditions needed to perpetuate violent crimes require greater levels of trust and investment. Coupled with their less planned nature, this might mean that offenders must rely on ties and associates that are both trustworthy and quickly accessible. On the other hand, even if market crimes are mostly planned, the risk of being arrested for these crimes

**Table 2**  
Survival models predicting reoccurrence of a dyad (n = 8,621 offenders; n = 14,640 dyads).

	Model I			Model II		
	$\beta$	Exp(b)	(95% CI)	$\beta$	Exp(b)	(95% CI)
Nodal characteristics						
Male	0.04 *	1.14	(1.02–1.29)	0.16 **	1.18	(1.05–1.32)
Race (reference = White)						
Black	0.04	1.09	(0.92–1.29)	0.10	1.12	(0.95–1.33)
Hispanic	0.04	1.12	(0.96–1.31)	0.12	1.14	(0.97–1.33)
Others	0.00	1.05	(0.70–1.57)	0.01	1.04	(0.69–1.56)
Age (log)	–0.05 ***	0.82	(0.73–0.92)	–0.17 **	0.71	(0.69–0.73)
Gang member	0.22 ***	1.56	(1.44–1.69)	0.47 ***	1.60	(1.48–1.73)
Victimization (log)	0.04 *	1.15	(1.03–1.29)	0.17 ***	1.19	(1.06–1.33)
2nd order victimization (log)	–0.14 ***	0.92	(0.89–0.94)	–0.09 ***	0.91	(0.89–0.94)
Number co-arrests	0.44 ***	1.98	(1.81–2.16)	–	–	–
Same type	–	–	–	0.57 ***	1.78	(1.63–1.94)
Different type	–	–	–	0.11 **	1.12	(1.04–1.21)
Number of solo arrests	0.06 ***	1.06	(1.03–1.10)	–	–	–
Same type	–	–	–	0.06 **	1.06	(1.02–1.11)
Different type	–	–	–	0.01	1.01	(0.97–1.05)
Dyadic characteristics						
Past of dyadic co-arrests (log)	0.95 ***	10.40	(8.73–12.38)	2.17 ***	8.54	(7.14–10.21)
Past of dyadic co-arrests (log; sq)	–0.29 ***	0.52	(0.46–0.60)	–0.58 ***	0.57	(0.49–0.66)
Type of offense (reference = Predatory)						
Violent	–0.05 ***	0.85	(0.79–0.91)	–0.12	0.93	(0.87–1.00)
Market	–0.10 ***	0.80	(0.76–0.85)	–0.07 *	0.92	(0.86–0.98)
Justice	–0.05 ***	0.91	(0.87–0.96)	–0.04	1.04	(0.97–1.11)
Homophily						
Gender	0.12 ***	1.55	(1.39–1.73)	0.43 ***	1.52	(1.36–1.70)
Race	0.05 ***	1.23	(1.12–1.35)	0.20 ***	1.21	(1.10–1.33)
Age differential (log)	–0.27 ***	0.71	(0.69–0.73)	–0.35 ***	0.71	(0.69–0.73)
Same gang	0.16 ***	1.41	(1.27–1.55)	0.31 ***	1.37	(1.24–1.52)
Different gang	–0.11 ***	0.67	(0.59–0.76)	–0.41 ***	0.67	(0.59–0.76)
Geographic distance (log)	–0.16 ***	0.96	(0.96–0.97)	–0.04 ***	0.96	(0.96–0.97)
Network structure						
Centrality (log)	–0.28 ***	0.69	(0.64–0.74)	–	–	–
Same Type (log)	–	–	–	–0.34 ***	0.71	(0.66–0.76)
Different Type (log)	–	–	–	0.04	1.03	(0.98–1.09)
Transitivity (log)	0.07 **	1.06	(1.02–1.10)	–	–	–
Same Type (log)	–	–	–	0.08 ***	1.08	(1.04–1.13)
Different Type (log)	–	–	–	0.01	1.02	(0.98–1.06)
Likelihood ratio test	3262.2; df = 34; p < 0.001			3218.9; df = 41; p < 0.001		
AIC	41370.4			41350.8		

\* p < 0.05.

\*\* p < 0.01.

\*\*\* p < 0.001.

are relatively low (Bouchard, 2007). Accordingly, the probability of observing a dyad arrested again is also less likely.

The similarity between the two nodes in a dyad (i.e. homophily) influences their probability of working together again in the future. Individuals from the same gender, the same race, of similar age, or living in areas not too far apart are more likely to commit a crime together again. Likewise, membership in the same gang also greatly increases continued co-offending. Homophily, on several dimensions, then, places a key role in tie formation.

#### 4.4. Supra-dyadic effects

While we observed in Model I that the individual propensity to co-offend (i.e. individuals more likely to co-offend in general are also more likely to co-offend with the same person), we can also observe that, considering the network structure, the total number of offenders that you already partnered with (i.e. the centrality) will decrease your likelihood of pursuing a collaboration with someone. Basically, someone is less likely to continue with the same partners the more alternative partnerships are available. Model II shows that centrality has a specific effect according to the type of crime. If your pool of potential offenders of the same type as the present dyad is larger, then it will decrease the likelihood of pursuing a partnership. However, this is not the case for your partners of other types of crimes: the number of partners in other types of crime will

not influence the likelihood of co-offending again with the same co-offender.

A triadic effect in the form of transitivity is also observed in Model I. The more the two nodes of a dyad have friends in common, the more they are likely to pursue their own relationship. Model II presents transitivity varied by the type of tie closing the triad to estimate the effect of the type of crime committed by the co-offender that Nodes A and B have in common (e.g. C). This model shows that transitivity with another node participating in a same type of offense than A and B increases their likelihood of continuing their collaboration; in this case, the third party becomes then an asset to the partnership. The same effect does not appear to extent to third parties tied by different types of offense.

## 5. Conclusion

This study examined the factors leading two offenders to commit other crimes together over time, considering their individual characteristics, the characteristics that they share at a dyadic level, as well as the events that happened within their surroundings. Consistent with previous research (Reiss and Farrington, 1991; Sarnecki, 2001), we observed that partnerships between co-offenders are short-term, most of them ending after their first experience. When the co-offending relationships continued, they were most likely to occur within a two-year period with more than



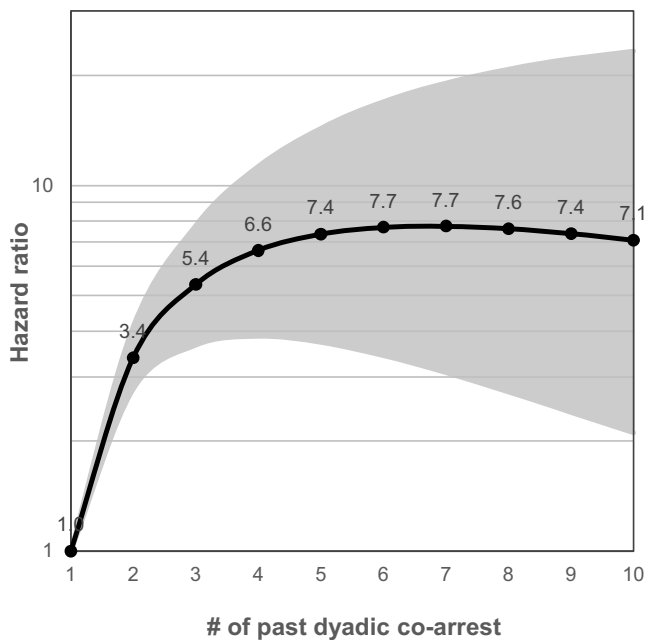


Fig. 4. Hazard ratio in function of the number of past experiences of cooperation (95% confidence interval).

80% occurring within a year. This result gives a good insight on the duration of criminal relationship and could be used as a value to assess the duration of observation period when using arrest data to create static co-offending networks or dynamic networks with discrete aggregated time periods.

This low prevalence of long-lasting relationships suggests that searching for suitable co-offenders is a constant concern during offenders' trajectory (Tremblay, 1993). We observed that once you found a good partner, you stick with him. Offenders that had past experiences together built trust in each other, and are more likely to co-offend again in the future. After four collaborations, dyads are seven times more likely to be observed again in the future. Factors other than experience, homophily may very well serve as such a source of trust. Indeed, we found that offenders were more likely to keep their co-offenders when they were similar to them in terms of neighbourhood, age, gender, and race, and when they were in the same gang.

These dyadic relationships are nested in broader criminal trajectories. We observed that individuals having the highest propensity to co-offend in general were more faithful to their partners, notwithstanding the type of offenses committed in these collaborations. For example, an individual who committed a lot of co-offenses of any type is more likely to return to the same co-offender than an individual who committed few co-offenses in the past. Similar to McGloin et al. (2008), we observed that individuals who committed more solo-offenses in general were more likely to co-offend again with the same partner. However, this propensity to offend has been shown to be specific on the type of crime: perpetrating solo-offenses of the same type in parallel of a given partnership increased its duration. For example, an individual who commits more thefts on his own is more likely to return to his co-offender with whom he was committing thefts. However, if the same individual is perpetrating drugs trafficking on his own, it will not influence his partnership with his thief associate.

The analysis of turning points in criminology has often been considered as a commitment to "conventional" life course events that pull one out of delinquent trajectories, such as marriage, military service, employment, education, or having children (Sampson and Laub, 1993). However, this study suggests that we should also

consider that offenders will face potential turning points within their criminal networks: violent victimization, new criminal opportunities, and new potential accomplices. These "non-conventional" turning points are also likely to influence offending trajectories, and the dynamics of criminal social networks investigated here provide a unique opportunity to analyze these events.

For example, victimization can act as a major non-conventional turning point faced by offenders on a day to day basis and can influence the duration of a criminal partnership. One's own victimization *increases* their likelihood to co-offend in the future with the same individual. In contrast to a desistance perspective, this finding suggests that continued co-offending might be the result of a need to establish trustworthy or protective ties: victims need trustworthy co-offenders who might help reduce subsequent victimization or, in the case of gang membership, even offer needed protection (Decker and Van Winkle, 1996; Melde et al., 2009). It could also be that victimized brings a certain level of prestige in the group that increases one's popularity and status (Harding, 2014; Sauvadet, 2006). Unfortunately, our data do not allow us to further explore this issue, but future research might consider how victimization relates to continued co-offending.

While individual victimization increases co-offending, similarly to Tremblay et al. (2016), our results found that peers' violent victimizations *decreased* the likelihood that two individuals continue to co-offend. This could be seen as a vicarious deterrent process, where the risk of one's peers will influence his own decisions (Stafford and Warr, 1993). Given the high level of violence within co-offending networks such as these (Papachristos et al., 2014), it is far from unlikely that one's friends be victim of violence. As noted by Decker and Van Winkle (1996), "it is a cruel irony that many gang members became part of their gang for protection against violence of rival groups in nearby neighborhoods, only to find out that the gang amplified the violence they already were exposed to." (p. 269) Thus, while individuals may desire to seek out past co-offenders as trusted protectors or collaborators when victimized, victimized alters might be less than desirable as they might attract violence towards their peers.

Non-conventional turning points can also be nested in the structure of one's entourage. The size of one's network matters. Similar to McGloin et al. (2008), we found that more central individuals—those having more co-offenders in their network—were less likely to co-offend with same individuals. Having a larger pool of potential offenders, these individuals rich in criminal social capital have a wider choice of accomplices, social opportunities, and are not limited to co-offend with the same individuals.

Having common friends (i.e. transitivity) also increased the likelihood of pursuing a continued criminal partnership. Such an interpretation of transitivity might be seen as a form of strong ties as the more closed triads one's network presents, the less structural holes will be left to create weak ties structures (Burt, 1992). This creates denser networks of individuals that know each other, fostering trust (Burt and Knez, 1995). However, this structure in covert network might have the downside of limiting the number of criminal opportunities, everyone sharing the same information (Morselli, 2001, 2005, 2009). When considering the type of offenses perpetrated with the third party, we saw that only shared third parties perpetrating the same type of offense increase the strength of a given partnership, while it was not the case when the third party was perpetrating different type of offenses. We might think that third parties involved in similar crimes brings new opportunities to a given criminal relationship. However, third parties involved in other crimes do not decrease the strength of the relationship. As noted by Warr (1996), individuals are more versatile than groups, which suggests that the versatility observed at the individual level might be due the diversification in the choice of

co-offending groups. One dyad won't be undermined by the fact that individuals are using the group (here the third party) for other purposes or offenses.

These findings should be circumscribed by several limitations. First, arrest data have the benefit of having really precise information on time and location of events and can be gathered relatively easily on large scales. However, considering the "dark figure of crime" (i.e. unreported offenses; Biderman and Reiss, 1967; Coleman and Moynihan, 1996), arrests represent only a small portion of the events that really occurred. Accordingly, we need to assume that these events are representative, even if we know that they are not (e.g. Charette and Van Koppen, 2016; Maltz, 1984; Marvell, 2002). The present study largely interprets the absence of re-arrest as an absence of crime. However, as mentioned by Ouellet et al. (2013), using official data to analyze criminal trajectories makes it hard to disentangle between desistance and justice avoidance. The observation of an arrest might also be interpreted, not as the continuation of the criminal career, but as a failure to avoid the justice system. In return, the absence of arrest might not represent the desistance of the criminal career, but rather the avoidance of the justice system. Accordingly, co-arrests are likely to underestimate the scope of co-offending relationships and some of these relationships might be much more enduring than those observed in the current study. This effect is however slightly reduced by group hazard, i.e. the fact that group crimes are more likely to lead to arrest (Hindelang, 1976).

These limitations notwithstanding, this study represents an important advancement in considering the network dynamics of co-offending. Further studies should investigate the risk of punishment with a dyadic point of view for a better understanding of this critical issue, and help with the interpretation of the official data on co-offending. By its design, the present study focuses on the continuation of co-offending careers. The patterns observed here should however be interlocked into a more general offending career. Moreover, in the present study, no information was available about conventional turning points. Future research should investigate conventional and non-conventional turning points simultaneously within a network perspective, to disentangle between the differential effects of these processes within one's criminal career.

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