HOW FAR AND WITH WHOM DO PEOPLE SOCIALIZE? EMPIRICAL EVIDENCE ABOUT THE DISTANCE BETWEEN SOCIAL NETWORK MEMBERS

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ABSTRACT

Hägerstrand’s seminal argument that regional science is about people and not only locations is still a compelling and challenging idea when studying the spatial distribution of activities. In the context of social activity-travel behavior (hosting and visiting), this issue is particularly fundamental since the individual's main motivation to perform social trips is mostly *with whom* they interact rather than *where* they go. A useful approach to incorporate the travelers’ social context is by explicitly studying the spatial distribution of their *social networks*, focusing on social locations as *emerging* from their contacts, rather than analyzing social activity locations in isolation. In this context, this paper studies the spatial distribution of social activities, focusing on the home distances between specific individuals (egos) and their network members (alters) with whom they socialize -- serving as a proxy to study social activity-travel location.

Using data from a recent study of personal networks and social interaction, and multilevel models that account for the hierarchical structure of these networks, this paper provides empirical evidence on how the characteristics of the individuals and their social context relates with the distance separating them. The results strongly suggest that, although the spatial distribution of social interaction has idiosyncratic characteristics, there are several systematic effects associated with the characteristics of egos, alters, and their personal networks that affect the spatial distribution of relationships, and which can aid understanding of where people perform social activities with others.

1. INTRODUCTION AND THEORETICAL BACKGROUND

Hägerstrand's argument that regional science is about people and not only locations is still a compelling and challenging idea when studying the spatial distribution of activities. This issue is particularly important when analyzing social activity-travel, which is motivated precisely by people's need to interact. In this context, the main individual driver to perform a social trip is mostly ***with whom*** people interact rather than where they go. Yet spatial distance between people is a constraint to perform social activities, and thus the physical location of social activities remains a key aspect that shapes social activity-travel behavior. A very useful and theoretically sound approach to understand the overall social activity-travel process is the study of travelers' ***personal networks***, which are constituted by people (alters) with whom these travelers (egos) interact. With this motivation in mind, this paper presents an analysis of the ***duality of people and places*** in social activities, using the social network approach, which enables the mapping of social activities, linking the individuals' social and spatial networks. Just as places link people, people link places.

More explicitly, the objective of this paper is to present evidence about the distance patterns between individuals and their personal networks, analyzing which factors are related to the spatial distribution of home locations. From a travel behavior perspective, although home locations are related only to hosting and visiting, they can serve as a useful source of explanation to study the overall social-activity travel distances. An associated argument is that the spatial distribution of social activities *emerges* from the locations of the social network members who socialize, and thus the analysis shall start from their relationships and locations. In that sense, the consequent research question is whether these patterns have systematic effects that depend on the characteristics of the social network members interacting.

Overall, the empirical analyses offered in this paper constitute a first step towards the general goal of having a better understanding of the interplay between physical space and social space. The analysis presented in this paper complements studies of the frequency of social activities using a personal network approach that used the same data as here (*1*,*2*), as well as the study of the activity spaces defined by these social networks (*3*). In addition, it is expected that this analysis will enrich the behavioral components of operational agent-based activity–travel demand models, such as TASHA (*4*) and integrated land-use models, such as the ILUTE (*5*), which have, in principle, the ability of handling the duality of places and people more explicitly.

The paper is composed of four sections. First, we review the role of social activity-travel and personal networks, as well as the relationship between physical and social space. Second, personal network data are briefly described in conjunction with the statistical approach employed to study the distance patterns. Third, the main empirical results are presented, showing the relationship between individual characteristics, their personal networks, and the spatial structure of their contacts. Finally, key conclusions are summarized.

1.1. Social activity-travel and personal networks

Travel for social activities has received less analytic attention than travel for other purposes, such as working or shopping. However, there has been recent recognition of the importance of social activity-travel, both in terms of number and kilometrage, as well as its association with the quality of life (*6*). In fact, social activities constitute an important part of the manifestation of social support that individuals receive, since face-to-face social interaction is a privileged way of interacting with the specialized social networks that provide support and companionship (*7*). From a policy perspective, social networks also provide a link with the concept of social capital (*8*) -- the use of interpersonal resources -- which is becoming an increasingly key topic of discussion from a transportation policy point of view (*9*, *10*).

More generally, Tindall and Wellman (*11*) define the social network approach in the following way:

> Social network analysis is the study of social structure and its effects. It conceives social structure as a social network, that is, a set of actors (nodes) and a set of relationships connecting pairs of these actors (p. 265-6).

Hence, two components define this paradigm: **actors,** representing in this case the different persons composing the social network; and **relationships** or **ties,** representing flows of resources that can be related with aspects such as control, dependence, cooperation, information interchange, and competition. The core concern of the social network paradigm is to understand how social structures facilitate and constrain opportunities, behaviors, and cognitions (*11*). Social network analysis conceives the overall behavior as more than the sum of individual behaviors, and contrasts with explanations that treat individuals as independent units of analysis, as those traditionally used in travel behavior research. Thus, behavior is explained not only through personal attributes, but also by using social structural attributes that incorporate the interaction among the different social network members. From a travel behavior perspective, ties among people can be conceived as not only interactions between actors, but also as *links that represent potential activity and travel between them*. Consequently, the characteristics of these social networks – and the underlying individual relationships – become *sources of explanation* of activity and travel, as relevant as the traditional socio-demographic attributes.

Since a "whole" social network approach – which enumerates all the interactions in bounded social collectives (*12*) – is not feasible in large urban settings (lists of the population are not known in advance), this paper uses an **egocentric** or **personal networks approach.** Personal network studies focus on specific actors (**egos**), and those who have relations with them (**alters**). That is, from the respondent's perspective, egocentric networks constitute a "network of me" or a network of actors (alters) with whom the respondent has some relationship. Personal networks are thus composed of two *levels*: i) an ego-network level, constituted by the ego's characteristics and the overall features of an ego's personal network; ii) an ego-alter level, constituted by the characteristics of each alter and alter-ego tie.

1.2. Physical and social distance: Mapping social networks

Social activities involve person-to-person connections; for that reason, the role of space may not be the same was as in other purposes, such as shopping and working, which emphasize person-to-activity connections (*13*). In fact, the meaning of destinations is different because they are not interchangeable: a major part of social activity destinations are at homes of specific *persons* rather than at places that can be "chosen" depending on attractors such as costs, environment, and proximity. In this sense, physical space needs to include its **social context**, and the network approach provides a very useful way to incorporate explicitly this social dimension in space. In fact, the social aspect is very explicit in the activity-based paradigm; this is clear from Hägerstrand's call that "regional science is about people and not just locations" (*14*, p.7), and the seminal discussion by Horton and Reynolds (*15*), who explicitly mention the position in social networks as a key element in activity space formation.

In the study of social activities, the social dimension has been conceived in the past mainly as *social distances*, a definition that can be traced back to the Chicago School of Sociology (*16*, *17*) that treated socially closer individuals as those who share more similar characteristics, and will be more inclined to interact than those more distant. This "social" conception of space does not necessarily coincide with "physical" space, and is mainly related to similarities in socioeconomic characteristics.

Social distance is generally compared with physical separation in social interaction, and there is a long tradition in the scholarly literature of studying the effect of *distance decay* in the interaction between people and the relationship with social distance. Indeed, this work began even earlier than gravity and entropy models (*18, 19*). Some examples are the sociological study of the negative effect of distance in social interactions (*20, 21*) and the geographical concept of "contact fields" (*22*). In addition, the effect of the interdependence of social and spatial distance was studied by several authors in the 1970s (*13*, *23*, *24*, *25*). However, social distance in this literature is generally measured at an aggregated scale, comparing social trips between different income neighborhoods, and focusing on the preferences for homogeneous social contacts.

Although the social distance concept broadens the understanding of space beyond its physical component, the social dimension of activities and trips is even broader than the shared socioeconomic characteristics of individuals. In this sense, a more sensible approach to incorporate the social dimension is by explicitly studying social networks in space since they not only include social distance, but also capture the fundamental interaction nature of social activities. In fact, mapping social networks in space provides a useful way of studying the **social activity space** or set of potential locations to perform social activities (*15*). However, and surprisingly, our knowledge about the interplay between social and physical space is scarce, and few attempts to map and analyze social networks in space can be found in the literature (*6*, *26, 27, 28, 29, 30*). Although these studies have improved the knowledge about the relationships between distance and social interaction (especially *6* and *30*), the fundamental question about the spatial distribution of social networks remains open. In this sense, we still need much more empirical evidence about the spatial configuration of social networks to understand the interplay between social and physical space in travel behavior.

2. DATA AND METHODS

2.1. Data: The Connected Lives Study

The data used in the analysis is part of the *Connected Lives Study*, a broader study about people's communication patterns, conducted in the East York area of Toronto by the NetLab team at the Centre for Urban and Community Studies, at the University of Toronto, between May 2004 and April 2005 (*31*). The East York area is located east of downtown Toronto, and is fairly representative of the overall central city characteristics regarding socio-demographics and transportation level of service. Specifically, the data consist of two instruments:

i) A survey of a random sample of 350 people of overall interaction patterns, media use, and general social network characteristics;
ii) An in-depth interview of a subsample of 84 people that collected personal network data (including alter's characteristics, such as relationship, home locations, and frequency of face-to-face and telecommunication interaction); as well as a sample of social activities between the respondents and their alters.

For practical reasons, the methods to collect personal networks need to concentrate on a partial set of the overall individual's contacts, which depends on the object of study (*12*). The networks collected here correspond to the individual's *affective network* or people the respondent defines as *emotionally close*, an approach chosen to study communication and social activity-travel patterns. Concretely, respondents named the people who lived outside their household, with whom they felt *very close* and *somewhat close*. Very close were defined as "people with whom you discuss important matters with, *or* regularly keep in touch with, *or* they are there for you if you need help". Somewhat close consisted of "more than just casual acquaintances, but not very close people". This "closeness" approach defines two aspects. First, it measures tie strength: strong and somewhat strong. Second, closeness defines the personal network "boundary", excluding casual acquaintances and the social-activity generation that arise from those contacts. In addition, respondents were asked to record whether their alters knew each other and the strength of the alter-alter ties: these connections are used to study the structure of the personal networks, and are measured considering the entire personal network elicited.

The data collection process also gathered two sets of information for a subsample of alters, which privileged those alters closer to the ego (*32*). The first set of information from this subsample provides information about alters' characteristics, including age, relationship, job, and ethnic heritage, as well as their home location and most frequent place of interaction with the respondent. This spatial information was geocoded with a 95% of success, with a 7% of them geocoded only at the city level. Figure 1 provides detail with the overall ego-alter distance distribution. The second set provides information about communication and interaction patterns between each alter and the respondent: face-to-face, socializing, telephone, email, and instant messaging.

In terms of sample size, the complete personal networks ranged between 3 and 66 (the maximum allowed), with a mean of 23.76 alters, and a standard deviation of 14.48. The subsample geocoded ranged between 3 and 15, with a mean of 12.13 and a standard deviation of 3.17. For further details about the collection procedure and main data characteristics, see Hogan *et al.* (*33*) and Carrasco *et al.* (*32*).

As noted above, these personal network data are composed of two levels: i) *ego-network*, constituted by the ego's characteristics and overall social structure features; ii) *ego-alter*, constituted by the characteristics of each alter and ego-alter ties..

Ego-network explanatory variables include attributes both of egos and their overall personal network. Ego attributes are age, presence of children in the household, whether the they live with a stable partner, household income, years living in the study area, language spoken at home, and internet access. Personal network attributes are:

- Network size (number of alters)
- Number of isolates (alters only connected to the ego)
- Density (ratio between the number of ties present in the network and the maximum possible ties in a network of alters), including and not including isolates
- Level of sub-grouping
- Proportion of alters with the same characteristics
- Difference in the "level of activity" between alters

The level of sub-grouping in the personal network was studied using several different measures existing in the standard social networks literature (*34*): the most empirically successful measure was the *number of components*, which represents the number of subgroups that are related only to ego (but are not directly linked with each other). The attributes considered when measuring the proportion of alters with the same characteristics are: i) *role* with respect to ego (immediate and extended kin, neighbors, work/student mates, members of the same voluntary organizations, and other friends); ii) *closeness* between egos and alters (defined as very close and somewhat close alters, using the definitions explained before). Finally, the difference in the level of activity between alters is measured using the *network degree of centrality:* the differences in the alter's point centrality degrees (i.e., the number of ties that link a specific alter with others) in the overall network. A *high degree of centrality* of the network denotes a high variability in the point centralities in the network (*35, 36, 37*).

Finally, *ego-alter* level attributes are characteristics of the alter and of the alters' role with respect to the ego: their age, gender, tie strength, and degree of centrality.

2.2. Method: Multilevel models

The dependent variable in the empirical models corresponds to the log-distance between each ego and alter in the personal networks. Multilevel methods are used as they capture data that have a hierarchical clustered structure, which "cannot be assumed to consist of independent observations" (*37*, p. 187). Personal networks have this hierarchical structure, since each ego's alter and each ego-alter tie (ego-alter level) relates to specific egos and their personal networks (ego-network level). In other words, personal networks can be conceived as two associated units of analysis (ego-network and ego-alter) in a bilevel analytic structure, since several alters belong to the same ego (*38*). These kinds of models have been extensively applied in social sciences in the past. In particular, multilevel models has been previously used both in social networks (*37, 39*), and activity-travel behavior research (*40, 41, 42, 43*). For an in-depth review of this technique, the reader is referred to the existing broad literature in the theme (*44, 45*, *46*).

The analysis in this paper concentrates on the bilevel structure of personal networks. The model is derived by considering two sets of equations. *Level 1* (or lower or micro level) is given by:

$$Y_{ij} = \beta_{j0} + \sum_{k=1}^{K} \beta_{jk} x_{ijk} + \varepsilon_{ij} \qquad \varepsilon_{ij} \sim N\left(\mathbf{0}, \mathbf{\Sigma}\right), \mathbf{\Sigma} = \mathbf{I}\sigma^2 \qquad \forall ij \tag{1}$$

where Y_{ij} is the dependent variable (assumed continuous), x_{ijk} is the *k-th* attribute (K in total), and β_{jk} are the corresponding coefficients. In a personal network model, this level corresponds to the ***ego-alter level*** represented by alter i and ego j or simply the tie ij. In the particular case of this paper, the dependent variable Y_{ij} corresponds to the log-distance between egos and alters, and the dependent variables x_{ijk} correspond to alter and ego-alter tie characteristics.

Level 2 (or higher or macro level) is given by:

$$\beta_{jk} = \gamma_{k0} + \sum_{l=1}^{L} \gamma_{kl} z_{jkl} + \nu_{jk} \qquad \nu_{jk} \sim N\left(\mathbf{0}, \Omega\right) \qquad \forall k = 0 \to K \tag{2}$$

where l are the attributes, z_{jl} is the *l-th* attribute (L in total), and λ_{kl} are the corresponding coefficients. In a personal network model, this is the ***ego-network level***, represented by the ego and its corresponding network j. In the case of this paper, the variables z_{jl} correspond to egos' attributes and overall personal network characteristics.

Combining (1) and (2), the multilevel model obtained is:

$$Y_{ij} = \left[\gamma_{00} + \sum_{l=1}^{L} \gamma_{0l} z_{j0l} + \sum_{k=0}^{K} \gamma_{k0} x_{ijk} \right] + \left[\sum_{k=1}^{K} \sum_{l=1}^{L} \gamma_{kl} z_{jkl} x_{ijk} \right] + \left[\nu_{j0} + \sum_{k=1}^{K} \nu_{jk} x_{ijk} + \varepsilon_{ij} \right] \tag{3}$$

Equation (3) shows the *three effects* in the response variable Y_{ij} that multilevel models take into account (each effect in one parenthesis, respectively): the effect of each level, the cross-level interaction, and the variance effects of both levels. These three effects are the *raison d'être* of multilevel models: taking into account the importance of each level, and at the same time, the interaction or dependence between both levels. From a statistical perspective, multilevel models explicitly account for the correlation involved in the nested structure of the two levels. From a social network perspective, multilevel models account for the dependence effect given by ties belonging to the same social network. More generally, these models capture how macro-level content affects relations between individual-level variables (micro-level) (*47*). This contrasts with ordinary least square (OLS) methods that assume independence among the different Y_{ij} variables without considering the effect of macro over the micro level, and which ignore the clustering characteristics of specific contexts, such as ego-centric social networks (*37*).

Note that signs of the explanatory variables should be directly interpreted since the dependent variable is continuous: that is, a variable with a positive sign involves a higher propensity of alters to be located farther from egos.

The models were estimated with HLM software (*48*), using a full information maximum likelihood procedure, and performing an iterative generalized least square estimation procedure that assumes known values for regression coefficients and uses fixed coefficients to estimate the likelihood function. Iterations stop when minimum level of convergence is reached. The HLM software provides Empirical Bayesian estimates for level 1 coefficients, generalized least squares estimates for level 2 coefficients (achieved by ordinary least squares weighted by a precision matrix, which accounts for data clustering), and maximum likelihood estimates for variance and covariance components (*45, 46*).

3. EMPIRICAL ANALYSIS

Tables 1 and 2 show the two multilevel models studied in this paper. As explained before, the dependent variable corresponds to the log-distance between each ego-alter pair. The logarithmic form was chosen to smooth the effect of international distances in the results. ***Table 1*** includes all personal network members in the data, regardless of whether there was a face-to-face social interaction between egos and alters in the past year. ***Table 2*** includes only those personal network members with whom egos had a social interaction in the past year. The distinction between Tables 1 and 2 is important since overall personal networks may include people that egos consider as emotionally important, but with whom interaction is very infrequent because of factors such as distance, time, or financial constraints. In this sense, the contrast between Table 1 and Table 2 can highlight differences between the potential set of alters that egos consider as relevant social contacts, and those with whom egos travel to interact socially. It is important to note that these multilevel models do not try to establish a direct *causal* structure between independent variables and ego-alter log-distances, but only identify which characteristics are associated with the distance between egos and alters: i.e., egos and alters are more likely to be located far apart or close together . Note also that the focus in these models is mostly on *distance* rather than on the spatial scale of egos' networks (local, regional versus international).

There are no standard procedures to specify these kinds of multilevel models. The variable specification process shown in each of Table 1 and Table 2 follows an incremental process, inspired by (*37*) and (*49*) that consists on five progressively complex multilevel models:

- Model 1: base model, considers only random effects at both ego-network and ego-alter levels
- Model 2: adds fixed ego-alter explanatory variables
- Model 3: adds fixed ego-network explanatory variables
- Model 4: adds cross-level fixed explanatory variables
- Model 5: adds random slopes

In addition to this progressive method, several different forward selection combinations were performed in order to minimize the potential misspecification biases. The key statistical tests used to assess goodness of fit are the *t*-statistics for individual fixed coefficients and a χ^2 test for random slopes. In addition, a "deviance coefficient" (minus two times the model's log-likelihood) is used to perform likelihood ratio tests for each specification and between nested models. In this context, model 5 in both cases has the best goodness of fit, considering deviance and degrees of freedom, as well as individual statistical tests and explanatory power:

i.e., model 5 has explanatory variables in each level, as well as cross-level attributes and random slopes. Models 2 to 4 are useful in the analysis not only since they are part of the specification process, but also because they highlight how specific attributes change their statistical significance when cross level and random effects are added.

Finally, model 1, besides being the base case to assess the value added of explanatory variables, indicates the intra-class or intra-respondent correlation with respect to ego-alter log-distance, as well as the appropriateness of the use of the multilevel modeling structure (*35, 43*). This indicator consists of the ratio between the variance of the random slopes in each level. In the case of all alters, the intra-class correlation is $1.364^2 / (1.364^2 + 2.460^2) = 23.5\%$ for Table 1 and for the socializing alters (Table 2), the intra-class or intra-respondent correlation is $0.936^2 / (0.936^2 + 2.175^2) = 15.6\%$. In other words, although most of the log-distance variance is explained by the ego-alter level, 23.5% and 15.6% of the total variance corresponds to the ego-network level in the two models, respectively. Note that if ego-alter ties would not have been considered as embedded in specific networks (e.g., using OLS methods), this variance would have been neglected. The smaller drop in the intra-class variance when only socializing alters are considered shows that ego-alter attributes play a smaller role when only socializing alters are considered.

A summary of the most important findings of this multilevel analysis is the following:

- Lower income egos tend to have more distant personal contacts, but spatially closer socializing alters than their counterparts. The same effect occurs for older egos, who are likely to have more distant overall alters but closer alters with whom they actually engage in social activities.
- Immigrants tend to have more distant alters in their overall personal networks, but no farther alters in their socializing personal networks
- More years in the city and working at home are associated with more local personal networks.
- Ego-alter role relationships are associated with ego-alter distances. In particular, kin alters are more likely to be located farther than alters with other roles, both in the overall as well as in the socializing networks. Egos perform longer social trips when alters are kin.
- There is a relationship between network composition and ego-alter distance patterns. The effect of higher proportions of alters in the network with the same attribute “counterbalances” the effect of that attribute at the ego-alter level. For example, although extended kin have an *individual* tendency to live far away, higher proportions of extended kin in the networks make them more likely to be spatially closer to the ego.
- Social network structure measures are less relevant than ego and alter characteristics, and the network composition.

The results are discussed next in more detail, grouped into three categories: egos’ characteristics, alters’ characteristics; and social network composition and structure.

3.1. Ego’s characteristics

Egos that have *children at home* are more likely to have alters physically close, a result that also occurs when only socializing alters are considered. A possible explanation about this effect can be drawn from time constraints, which are probably higher for egos with children, making both tie maintenance and social activities more difficult with people located far away. In addition, the presence of children in the household is also relevant as a cross-level effect with immediate family members considering all network members, although with a different sign: if egos have children, they are more likely to be further from their immediate family members. This result contrasts with the hypothesis that families with children would tend to live closer to their immediate family members so that they could receive support, such as daycare. On the contrary, this result suggests that other location dynamics associated with the lifecycle stage of having children (e.g., job location, household size, immigration) may be more powerful than the potential support from immediate family members.

Although the *ego's age* is significant at the ego-network level only in earlier multilevel models, it becomes a much stronger explanatory variable crossed with *alter's age* in the final model 5 of both Table 1 and Table 2. In the model of all network members (Table 1), the *alter's age* slope indicates that, in general, older alters tend to be located closer to their egos. However, the crossed effect alter's age - ego's age suggests an opposite trend, indicating that, when ***both*** egos and alters are older, the previous tendency of alters locating closer is counterbalanced, with egos and alters tending to locate further than if any of them would have been young. In other words, although older alters have a higher probability of being located close to egos, this tendency becomes the opposite when the ego is also older. A possible explanation comes from mobility biography: older egos tend to have personal network members they know for a long time; and these alters have a higher propensity to locate further away (e.g., in other cities and countries) due to the ego and alter's spatial mobility in time. In contrast, the model with only socializing alters shows a negative effect of the ego's age, crossed level with alter's age, instead of the positive sign in the all alters model. That is, when egos and alters are older, they tend to perform social activities when they are spatially closer, possibly due to greater needs for accessibility and social support. In sum, when egos *and* alters are older, their distances are more likely to be longer, but if they socialize, alters are more likely to live closer to egos, as compared to their younger counterparts.

Besides *age*, the other explanatory variable that changes signs between the two sets of models is *income*. In fact, ego-alter distances in egos with higher income tend to be shorter overall, but at the same time, when only socializing alters are considered, ego-alter distances in egos with higher income tend to be longer. This result suggests that equity issues may play a role in the spatial scope of individual networks, with higher income egos having higher mobility to perform social activities both from a spatial point of view – as seen here – and from the frequency of interaction perspective, as the results from Carrasco and Miller (*2*) suggest. In other words, although low-income egos may have a more dispersed personal network, their mobility constraints lead them to socialize less frequently and in a smaller spatial scope than their higher income counterparts.

The negative sign of *English spoken at home* in the all-alters model shows that recent immigrant egos tend to have more distant networks, confirming that the geographical scope of relevant contacts is heavily influenced by personal biography and mobility (*6*). At the same time, recent immigration does not play a significant relationship with ego-alter distance when only socializing alters are considered. This latter result suggests that, although recent immigrant egos tend to consider alters living farther as relevant (possibly maintaining the relationship using communication technologies), their socializing patterns do not differ too much from non-immigrant egos, from a distance viewpoint, controlling for factors such as income. This latter result is also consistent with the inexistence of ethnic enclaves in the study area (*31*).

Finally, three other personal and socioeconomic attributes show a significant effect on ego-alter log-distances. The *years the ego has lived in the city* shows a statistically significant effect in both final models (Tables 1 and 2): egos that have lived longer in the city are more likely to have closer contacts both overall and for social activities. Then, people who probably have longer-time local social networks tend to value these contacts both when they define their close alters, as well as when they perform social activities. This result is also consistent with Fischer's finding (*54*) that newcomers in the city tend to name twice as many middle distance alters and an even higher proportion of long distance kin alters. Note that this variable does not show high levels of correlation with that of recent immigration, since captures egos that have moved both internationally and nationally.

Egos who work at home are more local in their overall social networks, as the negative relationship with log-distance shows, an effect that is significant only in the all-alters case, but not in the only socializing network. Complementing Harvey and Taylor (*51*), who found that people who work at home spend more time with family at home or alone, they presumably also have a higher chance of interacting with more neighbors and, in general with more local alters. However, at the same time, these more locally relationships in egos who work at home do not translate into less long-distance socializing contacts compared with to those egos working outside home. This latter result is also consistent with Harvey and Taylor's evidence that, despite the potential low social interaction with work/student mates, working at home does not translate into less travel (*51*).

When egos have *Internet access at home*, they are more likely to include longer distance alters in their networks. In fact, this variable serves as an indicator of whether the ego uses communication technologies to maintain relationships. In this sense, the sign of Internet access precisely shows part of the egos' capability of maintaining their longer distance alters. Note that this effect is only significant for the overall alter model, but has no relevant effect when only socializing alters are considered. Then, Internet access involve the ability to contact alters living at a long distance and maintain these relationships, but not necessarily to socialize with them. Distance is still an important barrier to face-to-face social interaction (*30*).

3.2. Alter's characteristics

In the case of the influence of the alter's role, network members who are *immediate* or *extended kin* are more likely to live further from the ego. Mobility biography can be a potential source of explanation about this phenomenon: egos are more willing (or have more obligations) to maintain their ties with kin. The positive relationship between ego-alter distance and kinship relationship remains when only socializing alters are considered, that is, kin are those who locate farther in the socializing personal network. This result is interesting to complement with the evidence by Carrasco and Miller (*2*), who – using the same data – showed that, controlling for the negative effect of ego-alter distance, individuals tended to socialize less frequently with kin, compared with other roles. In this sense, the frequency of kin social interaction is lower than with other alters, not only due to spatial separation but also because other factors (such as socializing being felt to be a kinship obligation). However, at the same time – since kin are located farther than other roles in the socializing personal network – egos are more willing to travel longer distances to socialize and maintain their ties with kin, compared to other roles. These results can be explained both because of kinship norms of connectivity and because kinship systems foster connectivity.

By contrast, n*eighbors* (as obviously expected), *work/student mates* and *friends* are more likely to locate closer to the ego (the latter having a very weak association). Note that out of those three roles, only *neighbors* have a significant positive effect when only socializing alters are considered. Interestingly, Carrasco and Miller (*2*) showed that, controlling for the negative effect of ego-alter distance, egos tended to have more frequent social activities with *neighbors*, *work/student mates* and *friends*, compared with *kin*. In this sense, the results in this paper show that, although egos socialize more frequently with these three roles, they are less willing to travel longer distances to socialize with them, as compared with *kin*.

Finally, the degree of centrality – which accounts for the alter's number of links with others in the personal networks – shows a positive relationship with ego-alter distance, in the overall contact network. Although the effect is weak, a possible explanation is that egos tend to maintain ties at longer distances with more connected alters, since they are more structurally important in their personal networks: for example, kin or friends who know most of the other persona network members. Note that a similar result was found regarding ego-alter frequency of social interaction (*2*).

3.3. Social network composition and structure

The composition of the social network, measured by the proportion of each role in the network, has some statistically significant effects, which tend to be in the opposite direction as the effect of their corresponding role in distance. For example, although *extended kin alters* tend to be located at far distances, if the ego has a higher *proportion of extended kin in the network*, they tend to be located closer, all else equal. By contrast, higher *proportions of neighbors, work/student mates or strong ties* are related with alters of each role locating at further distances. Note that, with the exception of the *proportion of strong ties*, these role composition effects are present only in the socializing alters model (Table 2). Thus, alters with roles that tend to locate further (closer) overall will locate relatively closer (further) if their proportion in the network is high. Possibly, there is a compensation mechanism between having long distance and short distance alters. For example, if a high proportion of alters in an ego-network are kin (i.e., who have some tendency to be located farther from ego), it will be more likely that at least some of these alters will be located closer than the average corresponding to their specific role.

Finally, network structure explanatory variables are almost absent as significant explanatory variables in the log-distance between egos and alters. The *number of components in the network* (excluding isolates) shows a weak negative relation with distance, suggesting that egos with more subgroups will tend to have spatially closer network members. The cross-level effect of *network degree of centrality* with the *alter's degree of centrality* also shows a negative effect, suggesting that the longer distance trend between well-connected alters and their egos is counter-balanced when the personal network has high differences in the degrees of connections with others.

Overall, these results suggest that, although network composition and structure are associated with the physical distribution of alters, they are somewhat weaker as explanatory variables than when they are used as explanatory variables for the frequency of social activities (*1, 2*).

4. CONCLUSIONS

Although the spatial distribution of social interaction is a key characteristic of social activity-travel behavior, our current knowledge about this issue is very scarce. This paper has studied the spatial distribution of social networks, recognizing that home locations of alters and egos constitute a key element to understand where social interaction occur. Using a data collection procedure that captures a relevant portion of the overall individual's social contacts, and through the multilevel analysis technique, the analysis focuses on the distances between egos and alters, explicitly considering the embedded social networks. The multilevel models employed in the study are capable of accounting for the statistically relevant intra-class variance produced by the nesting structure of ego-alter attributes embedded in specific ego-networks. The results show that a relevant portion of the variance of ego-alter distances cannot be explained without considering the personal networks where these egos and alters belong.

The empirical models presented in this paper explicitly make the distinction between ego-alter distances in networks considering all alters and only those alters who actually socialize with egos. The distinction is important both conceptually and empirically because people tend to maintain certain contacts, but without interacting socially face-to-face (or at a very low frequency).

In general, the dichotomy all-alters / socializing-alters proved to be relevant in the analysis, especially for attributes such as income and age. For example, the results on this paper suggest that low income egos tend to have more spatially distant alters overall, but at the same time, they tend to have spatially closer socializing alters than their higher income counterparts. Similarly, older egos tend to have more spread networks overall, but more local socializing networks accessible for support and interaction. These relationships suggest an interesting venue for linking social network spatial distribution, and equity and social exclusion issues, where the focus on accessibility to people is put upfront.

Several other ego characteristics have a statistical relevant relationship with respect to the personal networks spatial patterns. For example, the relevance of egos' age and the presence of children at their homes, give empirical ground to the importance of lifecycle in the personal network distance patterns, as was theoretically recognized long ago by Horton and Reynolds (*15*). Another significant result respect to the egos' attributes, suggests that more years living in the city involves shorter distances with alters, showing that newcomers in the city have more contacts at farther spatial scales, consistently with previous findings (*50*). In addition, the empirical evidence in the paper shows that egos that work at home tend to have spatially closer networks overall, but not necessarily closer socializing distances, showing that telework does not decrease all travel distances necessarily.

The nature of ego-alter ties are associated with the spatial distribution of social networks. Kin tend to live farther than friends, and social activities between kin tend to be at longer distances than between friends. Thus, individuals maintain kinship ties at longer distances than with friends and are more willing to travel longer distances to socialize with them. From a transportation policy perspective, this finding suggests that patterns of travel distance certainly vary according to whom is involved in the social activity.

Aside from ego and alter attributes, the analysis presented in this paper explicitly tested whether social network characteristics have some influence in the spatial distribution of alters. Network composition shows a compensation effect, where a higher proportion of a certain role in the network balances the spatial scope of that role. For example, although kin alters tend to live farther than other roles, networks with a higher proportion of kinship ties involve some of them living closer.

Finally, except for weak negative associations with the number of components and network degree of centrality, there is no evidence of strong systematic effects of network structure in spatial distance. This result contrasts with the important influence of structural measures such as size and the number of components in the frequency of social activities between individuals (*2*). In that sense, understanding the spatial structure of relationships and consequent trips does not need a strong knowledge of the embedded social structure of these interactions.

More generally, the analyses performed in this paper reveal that, although the spatial distribution of personal networks can have some idiosyncratic characteristics, there are several systematic effects that affect the spatial distribution of ties and which can aid understanding of where people perform social interactions with others. Furthermore, from a transport policy viewpoint, the dependency of the spatial distribution of personal networks on aspects such as income, and lifecycle point to the relevance of studying the spatial distribution of individual's home locations as potential source of social activity travel. The analyses presented in this paper also highlight the importance of explicitly studying with whom egos interact, and the composition and structure of the personal networks in which these ties are embedded, as such network characteristics influence and constitute sources of explanations of ego-alter distances and the spatial distribution of social activities.

Overall, the empirical evidence presented in this paper give illustrate the need for understanding social activity-travel from a person-to-person perspective rather than focusing only on physical place (and destinations), analytically isolated from the traveler's social context. In that sense, the explicit incorporation of personal networks provides a useful and sensible approach to go beyond the traditional individualistic paradigm in the study of the spatial distribution of social activity-travel, and situate travel behavior in social and physical space.

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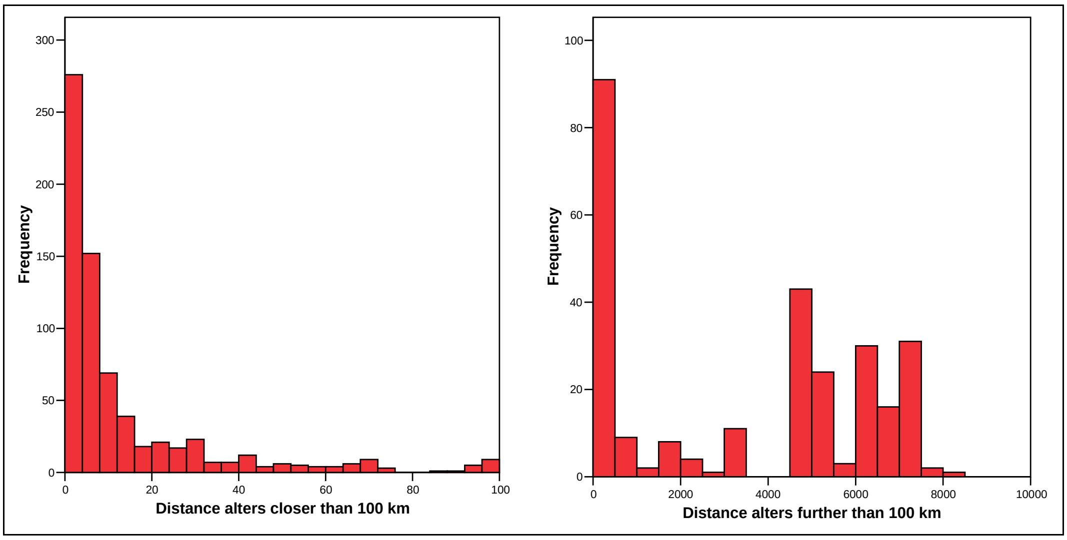
Figure 1: Distance distribution of alters



Note: Mean distance: 1,017 km. Standard deviation: 1,303 km. Median: 741 km

Table 1: Multilevel models of the log-distance between egos and alters (all alters)

	Model 1 *Base Model*		**Model 2** *Fixed ego-alter variables added*		**Model 3** *Fixed ego-network variables added*		**Model 4** *Cross-level variables*		**Model 5** *Random slopes added*	
Fixed Effects	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat
Intercept level 1										
Intercept level 2	3.507	(20.62)	3.786	(11.24)	2.579	(2.60)	5.591	(9.59)	4.857	(9.16)
Ego's age					0.745	(3.89)	-	-	-	-
Presence of children in the household					-0.460	(-1.65)	-0.707	(-2.44)	-0.613	(-2.46)
Household income					-0.350	(-1.03)	-0.104	(-1.57)	-0.154	(-2.68)
Ego works at home					-0.744	(-2.42)	-0.703	(-2.27)	-0.788	(-2.92)
Years the ego lives in the city					-0.040	(-5.01)	-0.026	(-3.49)	-0.024	(-3.68)
Proportion of strong ties in the network					-1.150	(-1.31)	-	-	-	-
Proportion of immediate kin in the network					2.290	(2.37)	-	-	-	-
Proportion of neighbors in the network					1.415	(1.35)	-	-	-	-
Proportion of work/student mates in the network					3.139	(3.26)	-	-	-	-
Proportion of friends in the network					1.804	(2.76)	-	-	-	-
Number of components in the network					-0.037	(-0.93)	-0.046	(-1.15)	-0.008	(-1.23)
English is spoken at home					-0.642	(-1.62)	-0.568	(-1.38)	-0.303	(-1.86)
Ego has internet access at home					0.569	(1.83)	0.701	(2.14)	0.658	(2.34)
Alter is immediate kin slope										
Intercept			1.194	(3.59)	1.074	(3.25)	0.819	(2.25)	1.124	(2.64)
Presence of children in the household							0.968	(2.73)	0.860	(1.76)
Alter is extended kin slope										
Intercept			1.136	(3.24)	1.087	(3.17)	2.784	(4.96)	3.178	(4.43)
Proportion of extended kin in the network							-6.984	(-3.59)	-7.267	(-2.72)
Alter is neighbor slope										
Intercept			-2.515	(-7.65)	-2.573	(-7.68)	-3.273	(-7.88)	-3.156	(-7.93)
Proportion of neighbors in the network							0.053	(3.23)	0.051	(3.23)
Alter is a work/student mate slope										
Intercept			-0.337	(-1.06)	-0.538	(-1.68)	-1.217	(-2.6)	-1.050	(-2.36)
Proportion of work/student mates in the network							3.685	(2.74)	3.805	(2.97)
Alter is a member from an organization slope										
Intercept			-0.875	(-2.16)	-0.906	(-2.28)	-	-	-	-
Proportion members from organizations in network							-2.300	(-1.76)	-1.405	(-1.12)
Alter is a friend slope										
Intercept			-0.478	(-1.71)	-0.615	(-2.19)	-0.383	(-1.46)	-0.007	(-1.02)

Table 1 (cont'd): Multilevel models of the log-distance between egos and alters (all alters)

	Model 1 *Base Model*		**Model 2** *Fixed ego-alter variables added*		**Model 3** *Fixed ego-network variables added*		**Model 4** *Cross-level variables*		**Model 5** *Random slopes added*	
Fixed Effects (cont'd)	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat
Alter is strong tie slope										
Intercept			0.352	(2.14)	0.357	(2.16)	-	-	-	-
Proportion of strong ties in the network							0.555	(1.85)	0.609	(2.10)
Alter degree of centrality slope										
Intercept			-	-	-	-	1.420	(1.71)	1.189	(1.45)
Network degree of centrality							-10.721	(-3.35)	-9.194	(-2.73)
Alter is older than 40 years old slope										
Intercept			-0.388	(-2.25)	-0.481	(-2.76)	-1.295	(-2.66)	-1.375	(-3.11)
Ego's age							0.303	(1.81)	0.326	(2.17)
Random effects	Std. dev.	χ^2 (p-value)	Std. dev.	χ^2 (p-value)	Std. dev.	χ^2 (p-value)	Std. dev.	χ^2 (p-value)	Std. dev.	χ^2 (p-value)
Intercept	1.364	380.12 (0.00)	1.288	390.87 (0.00)	0.779	190.77 (0.0)	0.815	213.22 (0.0)	0.824	24.31 (0.15)
Alter is immediate kin									1.537	20.66 (0.20)
Alter is extended kin									2.066	35.05 (0.09)
Alter is a friend									1.322	35.24 (0.11)
Level 1 random effect	2.460		2.221		2.224		2.177		1.982	
Deviance	4642.88		4213.30		4160.76		4127.61		4058.08	
Number of parameters	3		11		25		25		35	

Notes: Blank spaces correspond to coefficients theoretically not included in the models, "-" correspond to coefficients with a t-stat < 0.90. The chi-square statistics reported above are based on only the portion of all level-2 units that had sufficient data for computation (84 out of 84 in Model 1, 82 out of 84 in Models 2, 3, and 4; and 27 out of 84 in Model 5). Fixed effects and variance components are based on all the data. Deviance corresponds to -2 times the log likelihood function Standard deviations of fixed effects correspond to robust standard errorsand variance-covariance parameters and fixed level-2 coefficients are estimated by maximizing their joint likelihood..

Table 2: Multilevel models of the log-distance between egos and alters (only alters with whom ego socializes)

	Model 1 *Base Model*		**Model 2** *Fixed ego-alter variables added*		**Model 3** *Fixed ego-network variables added*		**Model 4** *Cross-level variables added*		**Model 5** *Random slopes added*	
Fixed Effects	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat
Intercept level 1										
Intercept level 2	2.926	(21.98)	2.919	(16.28)	2.554	(3.37)	3.498	(7.20)	3.546	(7.72)
Ego's age					0.171	(1.02)	-	-	-	-
Presence of children in the household					-0.617	(-2.74)	-0.581	(-2.78)	-0.580	(-2.84)
Household income					0.124	(2.3)	0.106	(1.99)	0.072	(1.47)
Years the ego lives in the city					-0.024	(-3.8)	-0.016	(-3.27)	-0.015	(-3.43)
Proportion of strong ties n the network					-1.344	(-1.6)	-1.061	(-1.34)	-	-
Proportion of immediate kin in the network					1.581	(1.88)	-	-	-	-
Proportion of neighbors in the network					1.025	(1.03)	-	-	-	-
Proportion of work/student mates in the network					1.866	(2.26)	-	-	-	-
Proportion of friends in the network					0.991	(1.81)	-	-	-	-
Alter is immediate kin slope										
Intercept			1.538	(7.37)	1.547	(7.44)	1.592	(7.38)	1.608	(5.49)
Alter is extended kin slope										
Intercept			1.445	(5.79)	1.472	(5.87)	2.769	(5.52)	2.800	(3.67)
Proportion of extended kin in the network							-5.176	(-2.93)	-6.011	(-2.49)
Alter is neighbor slope										
Intercept			-1.986	(-6.96)	-1.854	(-6.02)	-1.845	(-6.61)	-1.843	(-8.2)
Alter is a work/student mate slope										
Proportion of work/student mates in the network							1.027	(1.35)	0.745	(1.55)
Alter is strong tie slope										
Proportion of strong ties in the network							0.194	(1.22)	0.147	(0.95)
Alter degree of centrality slope										
Intercept			-0.754	(-1.52)	-0.821	(-1.71)	0.922	(1.23)	1.025	(1.37)
Network degree of centrality							-7.681	(-2.81)	-7.621	(-3.28)
Alter is older than 40 years old slope										
Intercept			-0.292	(-1.76)	-0.383	(-2.23)	-	-	-	-
Ego's age							-0.098	(-1.68)	-0.089	(-1.36)

Table 2 (cont'd): Multilevel models of the log-distance between egos and alters (only alters with whom ego socializes)

	Model 1 *Base Model*		**Model 2** *Fixed ego-alter variables added*		**Model 3** *Fixed ego-network variables added*		**Model 4** *Cross-level variables added*		**Model 5** *Random slopes added*	
Random effects	Std. dev.	χ^2 (p-value)	Std. dev.	χ^2 (p-value)	Std. dev.	χ^2 (p-value)	Std. dev.	χ^2 (p-value)	Std. dev.	χ^2 (p-value)
Intercept	0.936	225.5 (0.0)	0.788	197.1 (0.0)	0.561	137.3 (0.0)	0.589	144.5 (0.0)	0.588	41.34 (0.0)
Alter is immediate kin									1.658	64.08 (0.0)
Alter is extended kin									1.688	47.63 (0.0)
Alter degree of centrality									1.259	59.86 (0.0)
Level 1 random effect	2.175		1.991		1.990		1.969		1.801	
Deviance	3461.49		3173.87		3146.44		3135.24		3087.12	
Number of parameters	3		8		17		16		25	

Notes: Blank spaces correspond to coefficients theoretically not included in the models, "-" correspond to coefficients with a t-stat < 0.90. The chi-square statistics reported above are based on only the portion of all level-2 units that had sufficient data for computation (83 out of 84 in Model 1, 81 out of 84 in Models 2, 3, and 4; and 29 out of 84 in Model 5). Fixed effects and variance components are based on all the data. Deviance corresponds to -2 times the log likelihood function. Standard deviations of fixed effects correspond to robust standard errorsand variance-covariance parameters and fixed level-2 coefficients are estimated by maximizing their joint likelihood.