The social dimension in action: A multilevel, personal networks model of social activity frequency between individuals

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Abstract

This paper presents a social activity-travel generation model, which explicitly incorporates the individual's social dimension through the concept of personal networks, modeling the multilevel structure of social relations defined by these networks. The objective of the analysis is to study the relevance of the social dimension as a source of explanation of social activity-travel generation behavior between an individual and each relevant person of their social life. The paper uses a disaggregated perspective of personal networks, explicitly incorporating the characteristics of each network member as well as the characteristics of the overall social structure. Using an ordinal multilevel specification that accounts for the social network in which individuals are embedded, four dimensions are studied: personal characteristics, "with whom" activities are performed, social network composition and structure, and ICT (information and communication technology) interaction. The results show that a proper and complete understanding of social activity generation requires going beyond the individualistic paradigm, explicitly incorporating the role of the social dimension in the study of this decision making process.

Keywords: social networks, activity-travel behavior, social activities, ICT, multilevel modeling

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1. Introduction

1.1. The context

Activity-based approaches recognize the need of more truly behavioral explanations considering travel as a *derived* demand, triggered by the desire to perform activities with others (Axhausen and Gärling, 1992). Although this recognition has been around for a long time, the need to complement the dominant individualistic approach is still an important research challenge. Travel demand models in general, and those that explain the *generation of trips* ("why" travel is performed) in particular still heavily rely on the individual socioeconomic characteristics of travelers, rarely considering the importance of the individual's *social dimension*. In the context of social activity-travel generation, this omission is even more crucial since precisely "with whom" individuals interact constitutes the main motivation to perform the social activity and related travel. In fact, as Bhat and Lawton argue, our understanding of social interactions in travel demand analysis is very scarce:

> (…) interactions among decision-making agents, and the effect of such interactions on activity patterns, are topics that have received limited attention thus far in the travel demand analysis literature. Interactions among decision-making agents might take the form of joint participation in certain activities, such as shopping together or engaging in recreational/social activities … (Bhat and Lawton, 1999: 3)

Complementarily, there is a growing interest in the study of social activities, recognizing their importance in the overall travel patterns, and their behavioral difference with more studied purposes, such as work and shopping (Bhat and Gossen, 2004). Despite this interest, theoretical and empirical analyses that explicitly link social travel behavior and social interactions have been very limited. Moreover, although there is considerable progress understanding and modeling activity-travel decision-making processes in time and space (e.g., Timmermans, 2005), little is known about the linkages between social interactions and travel behavior. A main reason about this gap in the literature is that only recently reliable data have been collected that could link social activity-travel and social networks. Still, the interest and study about the role of the social dimension in transportation is increasing over time, both using simulation studies (e.g., Dugundji and Walker, 2006; Páez and Scott, 2007), and empirical studies (e.g., Larsen *et al.*, 2006).

In this context, this paper presents a social activity-travel generation model, which explicitly incorporates the individual's social dimension through the concept of personal networks, modeling the multilevel structure of social relations defined by these networks. The objective of the analysis is to study the relevance of the social dimension as a *source of explanation* of social activity-travel generation behavior. Although the emphasis of the paper is on understanding the behavioral processes of social activity-travel generation, the final aim is to provide a "proof of principle" about the importance of explicitly incorporating the social dimension on future operational, forecasting models, especially microsimulation-based approaches, which may capture more complex activity-travel behavior at the disaggregated level (Miller, 2003).

The paper uses a disaggregated perspective of personal networks, explicitly incorporating the characteristics of each network member as well as the characteristics of the overall social structure, such as size, density, composition, and other related aspects. The method employed to model all these dimensions uses the advantages of this disaggregated approach, in terms of being able to study in detail the role of each of these previous aspects in the social activity frequency between individuals.

1.2. Social networks and activity-travel behavior

Axhausen (2002) illustrates the relevance of linking social networks and activity-travel behavior, arguing that the study of the social dimension in activity-travel behavior responds to

> (…) the need to underpin our travel models with a better understanding of the social structures of daily life and, as we implicitly forecast / speculate about them when we predict travel behavior over long time horizons, anyway… (Axhausen, 2002: 3)

This requirement is even more patent when a series of "possible transport questions" are considered, such as

> (…) physical spatial-temporal coherence / overlap (constraints), replacement of physical and telecommunication-based contact, interaction frequency and spatial reach, and interaction and information / knowledge transfer" (Axhausen, 2002: 10).

However, incorporating the social dimension in activity-travel analysis involves the challenge of constructing an appropriate underlying behavioral theory, designing and implementing a reliable and feasible data collection method, and performing an informative analysis of the main behavioral elements involved. In the case of the underlying theory, individualistic, economic based paradigms are clearly not enough to capture the complexity of social activities. The approach employed in this paper heavily draws from social network theory, which serves as a key underlying theory, as well as method. More precisely, the social dimension is studied using a *personal networks* approach, which serves as the key unit of analysis to capture the interaction between individuals.

The social networks approach incorporates network analytic theory, methods and four decades of substantive findings. It draws from a long tradition in sociology and, to a lesser extent, other disciplines such as anthropology, graph theory, and management science. Tindall and Wellman (2001) 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 (…). Their basic premise is that knowledge about the structure of social relationships enriches explanations based only on knowledge about the attributes of actors (p. 265-6).

Social networks are thus composed by two key components: *actors***,** who represent different entities (e.g., groups, organizations, as well as persons); and *relationships* between them (e.g., 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" (Tindall and Wellman, 2001: 256). From a theoretical perspective, Tindall and Wellman argue that the added value of social networks is that "… knowledge about the structure of social relationships enriches explanations based only on knowledge about the attributes of actors" (p. 265-6). In fact, theoretically, social network analysis conceives the overall behavior as more than the sum of individual behaviors, contrasting with explanations that treat individuals as independent units of analysis, as those traditionally used in travel behavior research. Behavior is explained by attributes, opportunities, and constraints, which are not only personal, but also *social***.** In other words, social structure characteristics – represented by the interaction among the different social network members – become a source of explanation that contrasts with travel behavior perspectives that only rely on psychological or economic aspects (e.g. Gärling, 1998; Ben-Akiva *et al.*, 2002). Tindall and Wellman are even more explicit in this departure from "methodological individualism" arguing that "network analysis does not treat social systems as the sum of individual attributes, but links attribute data with relational and structural data" (p. 267).

Thus, two key sources explain behavior: *personal attributes* and *relational attributes*, in which the latter explicitly incorporate the interaction among the different network members, adding the behavioral social dimension. Social networks' focus on the relations among individuals expands the unit of analysis of individuals adding the relations between them. It follows, then, that the analysis cannot be just confined to the individual level perspective, but also concentrates in higher-level behavioral processes. As a consequence, the social networks paradigm is conceived in this paper in a *multilevel* perspective, which conceives individual behavior as dependent of larger organizing principles, such as the networks where they are embedded (Wellman and Frank, 2001). A key link with travel behavior is that ties among people not only include their relationship but also the *potential activity and travel between them*. From this perspective, the social dimension defined by the individuals' structural characteristics – and the underlying individual attributes – constitute promising sources of explanation of activity and travel.

1.3. Social activities and travel

The study of social activities and their associated trips have received much less attention compared with purposes such as working or shopping. This trend is changing with the recognition of the increasing number, kilometrage and complex travel patterns of social trips (Miller and Shalaby, 2003; Bhat and Gossen, 2004; Schlich *et al.*, 2004; Larsen *et al.*, 2006). This tendency is also supported by an aging population (Banister and Bowling, 2004; Newbold *et al.*, 2005), steady increase in leisure time budgets, weaker separation of work and leisure time, and spreading of social networks (Wellman, 2001; 2002a; 2002b; Larsen *et al.*, 2006). However, the relevance of social activity-travel goes beyond the travel context, directly touching upon the overall individual's quality of life. In fact, as Larsen *et al.* (2006) argue, leisure activities in general (and social activities specifically) have become central in the people's lives and social cohesion, and the related travel is "essential" for work, friendship and family life.

In fact, social activities constitute a privileged way of interaction with the specialized social networks that provide social support, both emotional and material (Wellman and Wortley, 1990). This aspect links with the role of the resources that individuals get from their networks, namely their social capital (Lin, 2001), and the importance of providing better accessibility to people (and not only places), which is becoming a key aspect from a transportation policy viewpoint (Rajé, 2003; Miller, 2006).

From a behavioral perspective, social activity-travel is different with respect to other purposes, such as working and shopping. A main characteristic of social activities is its social dimension, reflected in the importance of "with whom" the activities are performed. This aspect was long ago recognized by authors such as Stutz (1973), who argued that social trips are "person to person connections", which makes them "more personalized (…) because the trip maker becomes socially involved at the trip destination", differing from pure leisure or shopping trips that are concerned with "person-to-activity" connections (Stutz, 1973: 7). In other words, since the main motivation of social activities is precisely the personal interaction, the associated travel generation has an intrinsic social dimension.

A complementary perspective to the importance of "with whom" as explanatory element is that the "attractiveness" of social activity destinations is defined by the *person* at the other end rather than by the location *per-se*. As a consequence, although accessibility is still related to the reachable locations for the individual (Pirie, 1979; Geurs and van Wee, 2004), conceptually it becomes a "people-based" rather than only a place-based measure (Miller, 2005). This argument also resonates with explanations from sociology, in particular with the hypothesis that societies are turning towards a *networked individualism* (Wellman, 2001). In his hypothesis, Wellman argues that, from a travel communication perspective, relationships have evolved from being *door-to-door*, rooted in local distance and densely knit networks, to *place-to-place*, where longer distances and households become the focal point of interaction, to *person-to-person*, where multiple specialized role-to-roles are the key characteristic relationships, favored by the increasing embeddedness of ICT in daily life.

These theories set the challenge for travel demand analysis to incorporate the intrinsic difference of social activities with respect to other purposes, which is currently ignored. In this context, the next section provides a pioneer attempt of studying the role of the social dimension in these activities, in the particular case of the activity-travel generation between individuals.

2. Data and Methods

2.1. Data: The Connected Lives Study

The data used to perform the analysis is part of *Connected Lives Study*, a broader study about people's communication patterns, conducted in the East York area in Toronto by the NetLab group at the Centre for Urban and Community Studies, University of Toronto, between May 2004 and April 2005 (Wellman *et al.*, 2006). The East York area is located east of downtown Toronto, and is fairly representative of overall inner city characteristics regarding socio-demographics and general transportation characteristics. The data were collected in a survey and a follow-up interview of 84 people, which elicited their personal network members (a total of 1019) and interactions with them.

Personal networks concentrate on specific people or *egos* and those who have relations with them, called *alters*. From the respondent's perspective, these networks constitute a "network of me" or a network of alters with whom the respondent has some relationship. The data are thus composed by two levels: i) *ego-network*, constituted by the ego's characteristics and overall social structure features; and ii) *ego-alter or ego-tie*, constituted by the characteristics of each alter and ego-alter ties. The personal networks collected in this study concentrated on the individual's *affective network* or people the respondent defines as *emotionally close*, an approach that seems useful to understand communication and social activity-travel patterns. Concretely, respondents named people who lived outside their household, with whom they felt *very close* and *somewhat close*. Very close consisted of "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, closeness 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 the existing strength they believed existed among alters; these connections are used to study the structure of the resultant personal networks. Finally, the data collection process also collected two sets of information regarding each alter. First, information about alters' characteristics was gathered, including age, relationship, job, and ethnic heritage as well as their home location and most frequent place of interaction with the respondent. Second, information about the communication and interaction patterns between each alter and the respondent was gathered, by face-to-face, socializing, telephone, email, and instant messaging. For further details about the collection procedure and main data characteristics, see Hogan *et al*. (2007) and Carrasco *et al.* (2008).

All these characteristics constitute a rather unique data set, where not only the respondents' characteristics are collected, but also specific details about with whom they interact, as well as the characteristics of the respondents' personal networks. The respondents' networks included detailed information not only about the alter composition by role or other attributes, but also about their structure (such as size, density, and subgrouping). In that sense, the analysis of this data set constitutes a unique opportunity of testing the social dimension in an approach that will truly go beyond the individual as the unit of analysis.

2.2. Method: Multilevel models

2.2.1. *Model specification*

The dependent variable studied in the empirical model of this paper corresponds to the frequency which the ego performs social activities with *each* alter, answering “how often do you socialize with [alter's name]?” Social activities include hosting, visiting, or gatherings at bars or restaurants. This very specific definition was chosen in order to simplify the study, although the method employed here does not prevent a definition that could include a broader set of activities. Analyses of the responses showed that ordinal variables were the most adequate to represent the distribution of frequencies, which was not continuous, had spikes associated with certain values, and had around 21% of “zero” responses (i.e., the ego never socializes with the alter). Considering this distribution, nine ordinal categories were defined: 1 = more than once a week, 2 = twice a month - once a week, 3 = once a month - twice a month, 4 = once a month - six times a year, 5 = four times a year - six times a year, 6 = twice a year - four times a year, 7 = once a year - twice a year, 8 = once a year or less, and 9 = never.

The bi-level structure of personal networks (ego-network and ego-alter) involves two sets of independent variables, one at each level. The *ego-network* level includes the egos' personal and household socioeconomic attributes, and their social network characteristics. Personal and household attributes include ego's gender, age, lifecycle stage (living with a stable partner and having children at home), household income, working at home, and years of residence in the city and in the same household. As reported in the literature (e.g., Srinivasan and Bhat, 2006), the ego's related attributes are relevant in social activity-travel generation.

Social network characteristics include network *composition* and *structure*. Social network *composition* variables are defined as the proportion of similar alters in the network who have i) the same role with respect to the ego (immediate and extended family members, neighbors, work/student mates, members from organizations, or friends) and/or; ii) the same closeness with respect to the ego (very close or somewhat close). In this way, the analysis can capture individuals who are, for example, more "family oriented" or who have more intimate networks than others, and how these social aspects are related to social activity-travel generation.

Social network *structure* includes:

- 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)
- Network subgrouping
- Difference in the potential "activity level" between alters

Although several network subgrouping measures were tested (an in-depth review of them can be found in Wasserman and Faust, 1994), the most successful in the models is the *number of components*, which represents the number of disconnected sub-networks existing in the personal network. In addition, the difference in the potential "activity level" between alters is measured using the *network degree of centrality*, which measures the differences in the alter's number of ties that link a specific alter with others in the overall network (called the *point centrality degree*). High degree centralization indicates that links are connected to disproportionately few central individuals suggesting that these individuals are particularly active in the network (McCarty, 2002). As discussed in the theoretical section, social network structure attributes capture relational aspects which truly go beyond personal characteristics, and that can be relevant for the phenomenon studied.

Finally, at the *ego-alter* level, the characteristics studied are: alter's gender and age; alter's role with respect to the ego (immediate family, extended family, neighbor, work/student mate, member from an organization, or friend); closeness with respect to the ego; ego-alter frequency of ICT interaction (information and communication technologies: telephone, email, and instant messaging); and alter's degree of centrality. Frequency of ICT interaction are categorical variables, using a similar logic as for the case of social activities, although in the reversal order (low categories involve lower frequencies). The focus on the alter's characteristics draws from the intuitive expectation that the frequency of interaction with certain alters can be different compared with others, for example in terms of kinship or participation in formal organizations (e.g., Van Duijn *et al.*¸ 1999).

Overall, the specification presented here contrasts with Carrasco and Miller (2006) in two fundamental aspects. First, the disaggregated approach employed in this paper enables the model to study explicitly the effect of each of alter in their social activity-frequency with the respondent, controlling for their specific attributes. This approach is especially suitable to employ in microsimulation approaches which in principle can model each interaction separately. The second key difference is that, using this more disaggregated version of the data enables the models to measure the effect of social network *structure*, which is not feasible to measure with the aggregated portion of the data employed in Carrasco and Miller (2006).

2.2.2. *Multilevel structure in the frequency of social activities*

The main objective of multilevel models is capturing phenomena where the data have a hierarchical clustered structure that "cannot be assumed to consist of independent observations" (Van Duijn *et al*., 1999: 187). Personal network data have a hierarchical structure, composed by the *ego-network* and *ego-alter* levels. These levels can also be conceived as two units of analysis, which are related, since several alters belong to the same ego, and must be treated in clusters (Snijders, 2003).

Multilevel models have been extensively applied both in social network research (Van Duijn *et al*., 1999; Wellman and Frank, 2001), and activity-travel behavior research (Bhat, 2000; Bhat and Zhao, 2002; Goulias, 2002; Weben and Kwan, 2003). For an in-depth review of the technique, the reader is referred to (Snijders and Bosker, 1999; Raudenbush *et al.*, 2002; Goldstein, 2003). The most basic model consists of two levels modeled by two sets of equations. The specification in this paper uses an ordinal response, which corresponds to ordinal categories of the frequency with which the ego performs social activities with each alter.

The functional form of this multilevel model can be derived as follows (adapted from Raudenbush *et al*., 2002). Let M be the number of ordered categories, $m = 1\ldots M$. Then, the dependent ordered variable can be defined as

$$Y_{mij} = \begin{cases} 1 & \text{if } R_{ij} \leq m \\ 0 & \text{otherwise} \end{cases} \qquad (1)$$

where Y_{mij} is the dependent variable for level ij and R_{ij} is the corresponding response variable for that level. Each dependent and response variable has a cumulative probability function:

$$\Pr(Y_{mij} = 1) = \Pr(R_{ij} \leq m) \equiv j_{mij} \qquad (2)$$

Note that $j_{1ij} = \Pr(Y_{1ij} = 1) = \Pr(R_{ij} = 1)$ and $j_{Mij} = \Pr(Y_{Mij} = 1) = \Pr(R_{ij} \leq M) = 1$

The cumulative probabilities in [2] can be defined as logit functions:

$$h_{mij} \equiv \log\left(\frac{j_{mij}}{1 - j_{mij}}\right) = \log\left(\frac{\Pr(R_{ij} \leq m)}{\Pr(R_{ij} > m)}\right) \qquad m = 1..M \qquad (3)$$

In this way, the *level 1* structural model (ij) can be defined as:

$$h_{mij} = b_{j0} + \sum_{k=1}^{K} b_{jk} x_{ijk} + \sum_{m=2}^{M-1} D_{mij} d_m \qquad (4)$$

where K are the attributes, where x_{ijk} is the k-*th* attribute (K in total), D_{mij} is a dummy variable indicating category m and d_m is the *threshold* value of category m. Note that each of these threshold values d_m "separate" categories $m - 1$ and m, defined from 2 → M. In personal networks, this level is the *ego-tie or ego-alter level* represented by alter i and ego j or simply the tie ij. In this regard, the variables x_{ijk} represent attributes either of the alter alone, or of the relationship between the ego and the alter.

The assumption about the probability function described in (2) and (3) implies that probabilities behave as "proportional odds", where the expected difference in log-odds between cases differing in values of x_{ijk} does not depend on the particular response category *m*. Using function (3) is practical since it simplifies calculations. Also there are no theoretical reasons to use a different expression in the context of the problem modeled here.

Level 2 is given by:

$$b_{jk} = g_{k0} + \sum_{l=1}^{L} g_{kl} z_{jkl} + n_{jk} \qquad n_{jk} \sim N(\mathbf{0}, \Omega) \qquad \forall k = 0 \to K \tag{5}$$

where L are the attributes, z_{jl} is the *l-th* attribute (L in total), and g_{kl} are the corresponding coefficients. In social networks, this is the *ego-network level*, represented by the ego and its corresponding network j. In that regard, the variables z_{jl} represent attributes either of the egos or their overall personal network structure or composition.

Combining (4) and (5), the multilevel model obtained is:

$$h_{mij} = \left[g_{00} + \sum_{l=1}^{L} g_{0l} z_{j0l} + \sum_{k=0}^{K} g_{k0} x_{ijk} \right] + \left[\sum_{k=1}^{K} \sum_{l=1}^{L} g_{kl} z_{jkl} x_{ijk} \right] + \left[n_{j0} + \sum_{k=1}^{K} n_{jk} x_{ijk} + \sum_{m=2}^{M-1} D_{mij} d_m \right] \tag{6}$$

Equation (6) shows the *three effects* in the response variable (each in 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 each level, and simultaneously, the interaction or dependence between them. From a statistical perspective, multilevel models account for the correlation induced by the nested structure of the two levels. From a social networks perspective, multilevel models account for the dependence effect given by ties belonging to the same personal network. More generally, multilevel models capture how content (macro -level) affects relations between individual-level variables (micro-level) (DiPrete and Forristal, 1994). This aspect contrasts with approaches that assume independence among the different response variables, without considering the macro effect over the micro level, ignoring the clustering characteristics in personal networks (Van Duijn *et al.*, 1999).

From the functional form shown in (3), coefficients have to be interpreted with care. A *negative* coefficient in a multilevel ordinal model such as (4) and (5) implies that *increasing* values of the related independent variable are associated with *increasing* probabilities with increasing values of *m*. In other words, negative coefficients imply a *positive* effect in the ordered response value, and vice versa.

The model is calibrated using the Penalised Quasi-Likelihood (PQL) method, which is one of the easiest and most reliable available methods to estimate these kinds of models (Raudenbush *et al.*, 2006). The basic idea of PQL is estimating using the joint posterior modes of both level coefficients, given variance-covariance estimates. These variance-covariance estimates are calculated using a normal approximation of the restricted likelihood. The coefficients calibrated using PQL correspond to approximate empirical Bayes estimates in the randomly varying level-1 coefficients, generalized linear squares estimators in the level-2 coefficients, and approximate maximum likelihood estimators of the variance and covariance parameters (Raudenbush *et al.*, 2006). Since PQL does not use full information likelihood, tests for overall model fit are not available. For more details about the algorithm and properties see (McCullagh and Nelder, 1989; McCulloch and Searle, 2001; Raudenbush *et al.*, 2002; 2006; Golsdtein, 2003).

3. Results

3.1. Model development

The results from the models are presented in Table 1. Models were estimated using the statistical package HLM (Raudenbush *et al*., 2006). As discussed before, the PQL estimation procedure does not compute reliable likelihood values to perform overall model statistical tests. For this reason, the main goodness of fit measure in the fixed coefficients are *t*-statistics; χ^2 tests are only used to highlight the statistical significance of the random errors. The models were specified using a sequential procedure inspired by Hox (1995) and Van Duijn *et al.* (1999), consisting of six progressive specifications:

1. Base model, includes intercepts from both levels and threshold coefficients
2. Add fixed ego-alter explanatory variables
3. Add fixed ego-network explanatory variables
4. Add random slopes to fixed ego-network explanatory variables
5. Using model 3 as base, add cross-level explanatory variables
6. Add random slopes to model 5.

Models 1 to 4 constitute a reference with respect to the more complex structures of models 5 and 6. These last two models are the more interesting from a theoretical viewpoint since they incorporate the cross-effect between both levels, that is, the *combined* effect that alters (and ties) and egos (and networks) have on the frequency to perform social activities. Model 6 also incorporates random effects in some coefficients. Note that some explanatory variables that were statistically significant in ego-network and/or ego-alter levels independently become significant only as cross-level variables in more complex models. Also, key variables that were non-significant in earlier models were again tested in posterior specifications in order to prevent the intrinsic bias of this type of forward specification.

A summary of the most important findings from these models is the following:

- Individuals earning high incomes, being male, not living with a partner, and/or working at home, have more frequent social activities with their social network members.
- Younger individuals tend to have higher frequency of social activities. At the same, when both ego and alter are old, their social activities are more likely to be more frequent, suggesting a homophily effect.
- People who have lived longer in the city, have an overall lower frequency of social activities.
- Longer distances between individuals involve a lower probability of frequent social interactions. This effect is stronger for distances not reachable by car in one day.
- "With whom" egos interact has a relevant role in the social activity generation.
- Individuals tend to have more frequent social activities with friends, males, and very close alters.
- Personal network composition mostly influences the frequency of social activities as a cross-level effect between the alter's attributes (role, closeness) and the proportion of those who share similar characteristics.
- Three network structure measures have a significant effect in social activity frequency: number of components, density, and degree of centrality.

- Telephone has a complementary role, and instant messaging has a substitution role with respect to social activities.
- Email seems to play both a strong substitution role for distant alters (who have low frequency of social activities) and a complementary role for closer alters (especially for those with medium intensity of social interaction).

The next sections present these results in more detail, grouping explanatory variables in four categories: ego and alter's personal and household attributes, personal network composition, personal network structure, and ICT interaction.

3.2. Personal and socioeconomic attributes

Egos with higher *income* are more likely to perform frequent social activities with each alter; a result complemented by their higher propensity to perform social activities, as seen using the same data in (Carrasco and Miller, 2006). *Female egos*, on the other hand, are less likely to socialize frequently with each alter. *Female alters* tend to have lower social frequency than males; however, there are no significant cross-level gender effects, that is, each gender effect is independent to the other. This lack of cross-level effects shows that there is no presence of homophily, that is, higher social activity frequencies are not related with egos and alters having the same gender. An opposite result occurs with *age*, where the only significant effect in the final models is the cross-level interaction, which shows that when *both* ego and alter are older, they are more likely to have frequent social activities. This positive cross-level effect is consistent with the positive effect of the alter's age found in models 2-4, which becomes statistically not significant in the final models. This result is also complemented by the lower propensity to perform social activities in older egos (Carrasco and Miller, 2006). Then, older egos overall tend to perform less social activities, but at the same time, if the alter's age increases, they are more likely to perform more frequent social activities. Note that these results are consistent with the literature review by McPherson *et al.* (2001), who show that in general homophily is much stronger with respect to age than gender.

When egos *have a stable partner*, their frequency of social activities with each alter is relatively lower than without a stable partner. Egos who *work at home* are more likely to socialize frequently with each alter, which is an aspect that can be explained by their potentially higher flexibility in managing their time budgets; this explanation is consistent with their higher propensity to perform social activities (Carrasco and Miller, 2006).

The more *years egos have lived in the city* the less frequently they socially interact with each alter, contrasting with the result that more years in the city involves a higher propensity to perform hosting/visiting social activities with strong ties, as shown in Carrasco and Miller (2006). That is, egos with older local social networks – as expected with those living more years in the city – specifically are more likely to host or visit strong-tie people, but overall they are less likely to perform frequent social activities. Note that *years in the same household* does not show any significant effect in any model, contrasting with the results in Carrasco and Miller (2006) of a high propensity to host/visit with strong ties. This explanatory variable does not show in these models presumably since neighborhood socializing propensities are more explicitly tested in network composition variables such as neighbor alters and the proportion of neighbor network members.

Finally, *distance* shows a strong negative effect in the probability of higher frequencies of social activities, both at the close spatial scale (alters reachable by car in one day of travel) and at the far spatial scale (alters not reachable by car in one day of travel). In addition, the absolute value of the coefficient of far spatial scales is higher than closer scales, that is, alters who are not reachable by car have proportionally a lower probability of higher social frequencies than those closer. These tendencies complement the result found in Carrasco and Miller (2006) regarding the positive propensity to perform social activities for egos that have a higher proportion of alters living in Canada at more than one hour of travel. In the case of the analysis of the propensity to perform social activities, distance is a network composition variable – involving how many people lived at more than one hour's travel – which measures the propensity to *maintain* those relationships. On the contrary, in this paper, distance measures how each ego-alter physical separation affects their social activity frequency. Then, the combined results show that, on the one hand, egos who have a high proportion of network members living relatively far away have a higher propensity to perform social activities, and that *at the same time*, longer distances between ego and alter involves a lower probability of frequent social activities between them.

3.3. Social network composition and "with whom"

Social network composition has an important effect in the frequency of social activities; although the effect varies according to alter type. If the alter is a *friend*, social activities are more likely to be more frequent, independently of the proportion of friends that the egos have in their network, that is, independently of the ego's network composition of friends. On the contrary, the effect of alters who are *extended family members*, *neighbors*, or *student/work mates* is only relevant in relation to the overall *proportion of people with the same role in the network*. In these three cases, higher proportions of alters in the network involve higher probability of frequent social activities. In other words, egos who are more oriented to a specific role (e.g., neighbor-oriented egos, with a high proportion of neighbors) tend to have higher social activity frequency with those kind of people than those who are not. This intuitive result illustrates the importance of knowing not only "with whom" activities are performed with, but the social networks within which they are embedded, that is, the egos' overall social *network composition.*

A much more complex set of explanations involve the effect of *immediate family* alters. First, and differently with respect to the previous roles, the *proportion of immediate family* has a *negative* incidence in the probability of higher social activity frequencies. That is, egos with a higher proportion of immediate family alters tend to have a relatively lower tendency of socializing than those who have a higher proportion of alters with other roles. Second, two specific ego characteristics affect the social activity frequency when the alter is *immediate family*: *living with stable partner* and *presence of children at home*. Egos with stable partner tend to have more frequent social activities, possibly since they may have more social obligations with family members. Note that the effect of this variable when the alter is an immediate family member goes in the opposite direction with respect to the overall effect of having a partner. On the other hand, *children at home* make less likely frequent social activities with immediate families; a possible explanation are time pressures due to more children-based obligations.

Finally, as intuitively expected, if the *alter is very close*, the ego is more likely to have more frequent social activities, that is, emotional closeness is positively related with more frequent social interaction. However, if egos have a higher *proportion of very close people* in their network, they are relatively less likely to have frequent social activities with very close alters. Then, there is a two-way effect: very close alters imply a higher probability of frequent social interactions, but when the ego has too many of them, this probability decreases. An explanation of this phenomenon comes from the definition of strong ties. Very close people are not necessarily those with whom egos regularly keep in touch and socialize, but also those with whom important matters are discussed or are available if help is needed. Then, egos with a *lower* proportion of very close people match the networked individualism hypothesis of egos, which argues about very intense interactions in networks with more weak ties (Wellman, 2001). Therefore, egos *not* matching those patterns may have less intense social interaction.

3.4. Social network structure

Three measures are statistically significant in the models: *number of components*, *density*, and *degree of centrality*. The *number of components*, which measures the number of disconnected subgroups in the network, has a positive influence in the frequency of social activities. This contrasts with the possible expectation that more components involve the egos' need to "divide" their social activity "time budget" among more alters, having as a consequence *lower* social activity frequency with each alter. However, the *number of components* better reflects the different subgroups that individuals are *willing to manage and maintain*. In other words, those egos with a higher number of components in the network are consistent with the *network manager* figure argued by the networked individualism hypothesis in sociology (Wellman, 2002a; 2002b): people maintain more specialized, role-to-role relationships, with memberships in several networks, and intense relationships with each of them. Each component probably represents these different specialized subgroups. Note that the intensity of contact is better captured by the *number of components* rather than by other alternative indicators, such as *network size* and *number of isolates* (alters only connected to the ego).

A second key structural explanatory variable is *network density*, which shows a positive effect, that is, egos with denser networks are more likely to have higher frequency of social activities with each alter. Since density is measured considering both strong and somewhat strong ties, higher values denote more *connectivity* among alters. Then, greater overall connectivity implies a higher probability of more frequent social interaction with each alter. In other words, in denser networks, if the ego has a social interaction with a specific alter, there is a higher likelihood that is also interacting with others.

The final structural measure found statistically significant in the models is the *degree of centrality*. Although this measure has been traditionally used in social network analysis as a measure of "power", it can be interpreted in this context as a general indicator of network activity level (McCarty, 2002). Although alters' *point degree of centrality* becomes non-significant in the final cross-level models, the positive sign in simpler models is consistent with the intuition that alters with higher degrees – that is, alters with more direct connections with other network members – have a higher probability of frequent social interaction with the ego. This explanation is similar to the previous argument used with *density*. The *network centrality degree* – which measures the variability in the point centralities in the network – has also a positive influence in social activity frequency, as a stand-alone measure in models 3 and 4, and as a crossed-level effect with *point centrality degree* in models 5 and 6. Although this cross-level effect is statistically not too strong, a possible explanation is the role that high degree alters play in networks with high centrality degree. These alters may play a role linking several other low degree alters with the egos in social activities (e.g., parents attracting siblings, friends attracting ego and other alter friends).

3.5. Ego-alter interaction using ICT

A final set of explanatory variables tested to what extend the frequency of ego-alter interaction by *telephone*, *email*, and *instant message* affects face-to-face social activity frequency. *Telephone* interaction shows a strong positive effect in the frequency of social activities, that is, telephone is *complementary* to face-to-face social activities. This result can be coupled with Carrasco and Miller (2006), where phone also showed a strong positive influence on the propensity to perform social activities. In fact, telephone has been argued as a social coordinating device (Wellman and Tindall, 1993; Larsen *et al.*, 2006; Mokhtarian *et al.*, 2006), and this result reinforces that idea. Furthermore, note that the telephone's effect in these models goes beyond exploring telephone use with alters. In fact, the focus of these multilevel models is on the frequency or *intensity* of telephone interaction between ego and alter with respect to their frequency of social activities. In that regard, the positive relationship implies not only that telephone interaction is complementary with social activities, but also that more intense telephone contact is related with more intense social activities.

Email frequency shows a different picture. In fact, the effect of this media is not statistically significant in any of the multilevel models, suggesting at first sight an overall neutral relationship. Furthermore, *email frequency* does not become statistically significant even if this variable is controlled by spatial scale (separating alters reachable by car and not, as the distance variable) or by the exclusion of non work/student mate alters (i.e., testing "social" email). This neutral relationship contrasts with the overall complementary effect found when studying the propensity to perform social activities (Carrasco and Miller, 2006). However, that complementary effect – consistent with other findings such as those of Boase *et al*. (2006) – corresponds to a network *composition* perspective: if egos have an overall very intensive email communication with their network members, they are more likely to perform more social activities. In the case of the models presented here, although controlling by the ego's characteristics, the effect of email is measured with respect to *each* ego-alter relationship. Then, although high email interaction with the overall network members is positively related with an overall high social face-to-face interaction (ego-network effect), a high email interaction with a specific alter is not necessarily related with a social activity with that alter (ego-alter effect).

A further look at the relationship between email and social activities can be seen in Figure 1, which shows overall low email use in all categories, and no particular higher email frequencies related with higher social activity frequencies. In fact, in terms of percentages, the majority of medium to low email frequencies (once a month or less) are associated both with medium to low social and null frequencies. A possible hypothesis is that email plays *both* a supplementary role for alters located too far away (possibly the majority of "never" in social activities), and a complementary role for other alters with medium intensity of interaction (e.g., those with whom the ego emails once a month or less and has social activities between once a month and every other month). In fact, if email and social activity frequency are divided by spatial scale (see Figure 2) the existence of a bimodal distribution is much clearer: very high email frequency for those with very low social activity frequencies in far spatial scales *and* a relatively high email frequency for frequent social activities (including a very higher number of alters with whom there is absolute no social interaction as well as no contact by email).

Finally, higher frequencies of *instant message* contact are related with less frequent social interaction, that is, there involves a *substitution*. This result is comparable with Carrasco and Miller (2006), where the frequency of instant message is negative related to the propensity to perform social activities.

4. Synthesis and Conclusions

In this paper, social activities have been explored from the perspective of the frequency of social interactions between egos and alters, explicitly considering their embedded social networks, and the effect of their interaction using ICT. In order to capture these complex effects, multilevel models provide a very useful approach since they take into account the nested structure of ego-alter relationships within specific ego-networks, modeling the systematic effects as well as the random variations of each level. The overall results show that if the frequency of social activities is only explained by the socioeconomic characteristics of egos, a whole set of important behavioral processes are completely overlooked.

Socioeconomics provide some explanations, mostly in terms of *income*, *gender*, and *age*, as well as lifecycle, *working at home*, and *years living in the city*; some of these aspects have been recognized long ago as important attributes influencing the frequency of interaction (Fischer *et al*., 1979; Fischer, 1982). However, the characteristics of "with whom" social activities are performed also play a crucial role, which is intertwined with the ego's characteristics. The case of age is a good example, where the ego's age is relevant mostly *with respect to* the age of the alter. A second key example is the effect of *distance*, which shows the alter's location as one of the strongest effects in the frequency of social activities; this result is consistent with previous similar studies (Fischer, 1982; Mok *et al.*, 2007). The importance of *"with whom"* as an explanatory variable is more explicit when the effect of the alter's role is considered. If the alter is a *friend* and/or is *very close*, the ego will tend to have more frequent social interactions with her/him. This association between frequency of interaction and strength of relationship is consistent with previous results in the literature (Wellman and Wortley, 1990). A second key aspect linked with the alter's characteristics is the ego's network composition, measured by the proportion of network members who share the same role or characteristic. In fact, as recognized by Wellman and Frank (2001), emergent properties in behavior arise from the network composition as well as its structure. The results show that higher proportion of extended family or neighbor or student/work mates involve egos more willing to have frequent social activities with that kind of people, all else being equal.

A further exploration of the importance of social networks in social activities would not be complete without studying the effect of structural measures. The significant explanatory variables highlight the relevance of *connectivity* and *specialization* within the network. In the case of *connectivity*, the fact that higher *network densities* involve more frequent social activities highlights the intuitive result that the more other network members an alter knows, the more social activities potentially she/he can participate. In a similar way, *degree of centrality* (both at the alter and network level) proves to be a good measure of the "network activity" (McCarty, 2002), where alters with higher degrees are more likely to perform frequent social activities (they "know" more people). The second relevant aspect corresponds to the egos' *specialization* in their social contacts, measured by the number of existing subgroups in their networks. In fact, more subgroups imply that the ego is willing – and capable – to "maintain" different specialized subnetworks, following part of Wellman's networked individualism hypothesis (2001; 2002a; 2002b). In particular this specialization was found in the significant positive effect of the *number of components* (number of disconnected subgroups in a network) in the frequency of social activities.

A fourth and final aspect investigated is the alternative ways egos and alters have to socially interact, using telephone, email or instant messages. The results showed dissimilar trends, suggesting that the effect of ICT over social face-to-face interaction is very media specific. *Telephone* shows a strong complementary effect with social activities; that is, more frequent telephone contact involves more frequent social activities, which is consistent with the intuition of considering phones as key coordinating devices between people (Wellman and Tindall, 1993; Mok *et al*., 2007). *Email*, on the other hand, is a completely different medium with respect to its effects on social activities. In fact, the model does not show a significant effect of email frequency on social activity frequency. However, as the follow up analysis argues, email is a key media for people located very far from egos (e.g., international contacts) with whom social activities are very rare. Conceptually, this result can be defined as "substitution"– as some authors such as Larsen *et al.* (2006) argue – since more email frequency involves less frequency of social activities. However, the behaviorally relevant aspect here is that, since distance involves a higher difficulty of social interaction with these far located alters, email plays a key role in maintaining the contact with these alters, potentially providing the opportunity – if conditions arise – for face-to-face social activities. In addition, for closer distances, email is found to be coupled with social activity frequency: if an ego never performs social activities with an alter, there is a high probability of no email contact between them; a relationship that is also very similar for medium to low frequency of social and email interaction.

A caveat of the previous analyses is that social networks are considered as a "static" rather than dynamic entity. This is acceptable from a short to medium term perspective, but is potentially incomplete from a point of view of long-term processes. Furthermore, since social networks provide useful insights about the social activity generation process, a step toward understanding this phenomenon necessarily involves the study of social network dynamics. Other aspects that potentially can expand our understanding of social activity generation within a social network framework include the explicit consideration of time use and activity scheduling processes; the study of the importance of agency in ego-alter interactions (i.e., how "proactive" seeking interactions egos and alters are); and the study of the role of personal networks in different urban and cultural contexts.

Overall, the explanation given by the four aspects studied in this paper (personal characteristics, "with whom" activities are performed, social structure, and ICT interaction) shows that a proper and complete understanding of social activity generation requires going beyond the individualistic paradigm, explicitly incorporating the role of the social dimension in this decision making process. In that sense, a main contribution of this study is providing empirical results about the role of the social context in the frequency of face-to-face (i.e., travel related) and virtual (i.e., ICT related) interactions, showing that both "with whom" and the embedded social networks do matter on understanding social activity-travel generation. In that sense, the great level of detail of the data and consequent analysis regarding the traveler´s social context gives the novel opportunity of understanding an aspect that rarely has been in the transportation researchers' radar in the past, precisely due to the lack of these kinds of data in the past.

In that sense, two further research opportunities from this research can be distinguished: modeling social networks in travel demand models, and new transport-related policy insights. Although still it is early days for an explicit implementation of social networks in a working travel demand model, this seems to be a feasible proposition, considering promising approaches in travel demand, such as microsimulation (Miller and Roorda, 2003; Salvini and Miller, 2005), which in principle can incorporate the role of personal networks in the decision to perform a social activity and the associated trip. A key research question in this regard is the need of explicit models of social network formation; and although some attempts have been recently made (Hackney and Axhausen, 2006), much more research is needed for a practical implementation.

Finally, from a transportation policy perspective, an explicit incorporation of the social dimension in the social activity-travel context provides the opportunity of linking the study of transport and accessibility provision policies with broader societal concerns, such as the access to people and their resources in the individual's network (social capital) as well as the relationship between low spatial accessibility and social exclusion. In fact, the data, methods, and results from this paper put upfront the relevance of the social dimension in social travel, showing that explicitly studying personal networks in this context can serve as a useful hinge between transport and broader urban policies aimed to encourage the connectivity among people.

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References

Axhausen, K. W. and Gärling, T. (1992) Activity-based approaches to travel analysis: conceptual frameworks, models, and research problems. *Transport Reviews*, 12, 323-41.

Banister, D. and Bowling, A. (2004) Quality of life for the elderly: the transport dimension. *Transport Policy*, 11, 105-15.

Bhat, C. R. (2000) A multi-level cross-classiffied model for discrete respons e variables. *Transportation Research B*, 34, 567-82.

Bhat, C. R. and Zhao, H. (2002) The spatial analysis of activity stop generation. *Transportation Research B*, 36, 557-75.

Bhat, C. R. and Gossen, R. (2004) A mixed multinomial logit model analysis of week end recreational episode type choice. *Transportation Research B*, 38, 767-87.

Boase, J., Horrigan, J. B. , Wellman, B. and Rainie, L. (2006) *The strength of Internet ties: The internet and email aid users in maintaining their social networks and provide pathways to help when people face big decisions*. Pew Internet & American Life Project, Washington D.C.

Carrasco, J.A. and Miller, E. J. (2006) Exploring the propensity to perform social activities: A social networks approach. *Transportation,* 33, 463-80.

Carrasco, J.A., Hogan, B., Wellman, B., and Miller, E. J. (2008) Collecting social network data to study social activity-travel behaviour: An egocentred approach. *Environment and Planning B,* forthcoming.

DiPrete, T. and Forristal, J. (1994) Multilevel models: Methods and substance. *Annual Review of Sociology*, 20, 331-57.

Fischer, C. (1982) *To Dwell Among Friends: Personal Networks in Town and City*. University of Chicago Press, Chicago.

Fischer, C., Jackson, R., Stueve, C., Gerson, K. and Baldassare, M. (1977) *Networks and Places: Social Relations in the Urban Setting*. Free Press, New York.

Freeman, L. (1979) Centrality in social networks: Conceptual clarification. *Social Networks*, 1, 215-39.

Goldstein, H. (2003), *Multilevel Statistical Models*. Arnold, London.

Goulias, K. (2002) Multilevel analysis of daily time use and time allocation to activity types accounting for complex covariance structures using correlated random effects. *Transportation*, 29, 31-48.

Hackney, J. and Axhausen, K. W. (2006) An agent model of social network and travel behavior interdependence. *11th International Conference on Travel Behaviour Research*. Kyoto, August 16-20, 2006.

Hogan, B., Carrasco, J.A. and B. Wellman, B. (2007) Visualizing personal networks: Working with participant-aided sociograms. *Field Methods*, 19(2), 116-44.

Hox, J. J. (1995) *Applied Multilevel Analysis*. T-T Publikaties, Amsterdam.

Larsen, J., J. Urry, and K. W. Axhausen (2006), Mobilities, Networks, Geographies. Aldershot: Ashgate Publishing Limited.

Lin, N. (2001) Building a network theory of social capital. *Social Capital: Theory and Research* eds N. Lin and K. Cook and R. S. Burt.

McCarty, C. (2002) Structure in personal networks. *Journal of Social Structure*, 3(1), http://www.cmu.edu/joss/content/articles/volume3/McCarty.html.

McCullagh, P. and Nelder, J.A. (1989), *Generalized Linear Models* (2nd ed.). Chapman & Hall, London.

McCulloch, C. and Searle, S. (2001) *Generalized Linear, and Mixed Models*. John Wiley & Sons, Toronto.

McPherson, M., Smith-Lovin, L. and Cook, J. (2001) Birds of a feather: Homophily in social networks. *Annual Review of Sociology*, 27, 415-44.

Miller, E. J. and Shalaby, A. (2003) Evolution of personal travel in Toronto area and policy Implications. *Journal of Urban Planning and Development*, ASCE, 129, 1-26.

Miller, E.J. and Roorda, M. (2003) A prototype model of household activity/travel scheduling. *Transportation Research Record*, 1831, 114-21.

Miller, H. J. (2006) Social exclusion in space and time. *Travel Behaviour Research: Proceedings of IATBR 2003* eds K. W. Axhausen. Elsevier, New York.

Mok, D. and Wellman, B. with Basu, R. (2007) Did distance matter before the Internet? Interpersonal contact and support in the 1970s. *Social Networks*, 29, 430-61.

Mokhtarian, P., Salomon, I. and Handy, S. (2006) The impacts of ICT on leisure activities and travel: A conceptual exploration. *Transportation*, 33, 263-89.

Newbold, K. B., Scott, D., Spinney, J., Kanaroglou, P. and Páez, A. (2005) Travel behavior within Canada's older population: a cohort analysis. *Journal of Transport Geography*, 13, 340-51.

Rajé, F. (2003) *Impacts of road user charging/workplace parking levy on social inclusion/exclusion: gender, ethnicity and lifecycle issues.* Transport Studies Unit, University of Oxford, Oxford.

Raudenbush, W. S. and Bryk, A. S. (2002) *Hierarchical Linear Models: Application sand Data Analysis Methods* (2nd ed.). Sage Publications, London.

Raudenbush, S. W., Bryk, A. S., and Congdon, R. (2006) HLM 6. Scientific Software International.

Salvini, P. and Miller, E. J (2005) ILUTE: An operational prototype of a comprehensive microsimulation model of urban systems. *Networks and Spatial Economics*, 5, 217-34.

Schlich, R., Schönfelder, S. Hanson, S., and Axhausen, K. W. (2004) Structures of leisure travel: Temporal and spatial variability. *Transport Reviews*, 24, 219-37.

Snijders, T. A. B. (2003) Multilevel analysis. *The SAGE Encyclopedia of Social Science Research Methods* eds M. Lewis-Beck and A. E. Bryman and T.F. Liao. Sage, Thousand Oaks, CA.

Snijders, T. A. B. and Bosker, R. (1999) *Multilevel Analysis: An Introduction to Basic and Advanced Multilevel Modeling*. SAGE Publications, London.

Srinivasan, S. and C. R. Bhat (2006), "Companionship for leisure activities: An empirical analysis using the American Time Use Survey," in *Innovations in Travel Demand Modeling Conference*. May 21-23, 2006, Austin, Texas.

Stutz, F. P. (1973) Intra-urban social visiting and leisure behavior. *Journal of Leisure Research*, 5, 6-15.

Tindall, D. and Wellman, B. (2001) Canada as social structure: Social network analysis and Canadian Sociology. *Canadian Journal of Sociology*, 26 (2), 265-308.

Van Duijn, M. A. J. , Van Busschbach, J. T. , and Snijders, T. A. B. (1999) Multilevel analysis of personal networks as dependent variables. *Social Networks*, 21, 187-209.

Wasserman, S. and K. Faust (1994) *Social Network Analysis.* Cambridge University Press, New York.

Weber, J. and Kwan, M-P. (2003) Evaluating the effects of geographic contexts on individual accessibility: A multilevel approach. *Urban Geography*, 24, 647-71.

Wellman, B. (2001) Physical space and cyberspace: the rise of personalized networking. *International Journal of Urban and Regional Research*, 25, 227-52.

Wellman, B. (2002a) Little Boxes, Glocalization, and Networked Individualism. *Digital Cities II: Computational and Sociological Approaches* eds M. Tanabe, P. van den Besselaar and T. Ishida. Springer-Verlag, Berlin.

Wellman, B. (2002b) N^3: The Intersection of Transportation Networks, Communication Networks and Community Networks. *Social Change and Sustainable Transport* eds W. Black and P. Nijkamp. University of Indiana Press.

Wellman, B. and Wortley, S. (1990) Different strokes from different folks. *American Journal of Sociology*, 96, 558-88.

Wellman, B. and Tindall, D. (1993) How social networks connect telephone networks. *Progress in Communication Sciences,* Vol. XII. eds G. Barnett and W. Richards Jr. Ablex, Norwood, NJ.

Wellman, B. and K. A. Frank (2001) Network capital in a multilevel world: Getting support in personal communities. *Social Capital: Theory and Research* eds N. Lin, K. Cook and R. S. Burt. Aldine de Gruyter, New York.

Wellman, B., B. Hogan, K. Berg, J. Boase, J.A. Carrasco, R. Coté, J. Kayahara, T. Kennedy, and P. Tran (2006) Connected Lives: The project. *The Networked Neighbourhood* ed P. Purcell. Springer, Berlin.

Table 1: Multilevel models of the frequency of social activities

	Model 1 ***Base Model***		**Model 2** ***Fixed ego-alter variables added***		**Model 3** ***Fixed ego-network variables added***		**Model 4** ***Random slopes added***		**Model 5** ***Cross-level variables added without random slopes***		**Model 6** ***Cross-level variables added with random slopes***	
Fixed Effects	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat
Intercept level 1												
Intercept level 2	-2.931	(-16.10)	-3.623	(-11.64)	-3.936	(-5.33)	-5.015	(-6.30)	-4.335	(-7.85)	-5.022	(-8.10)
Ego is female					-0.549	(-2.04)	-0.357	(-1.27)	-0.599	(-2.13)	-0.276	(-0.97)
Ego lives with a stable partner					-0.342	(-1.24)	-0.182	(-0.65)	-0.674	(-2.24)	-0.427	(-1.51)
Household income					0.209	(3.13)	0.181	(2.56)	0.234	(3.35)	0.161	(2.25)
Ego works at home					0.352	(1.28)	0.316	(1.11)	0.389	(1.36)	0.320	(1.12)
Years the ego lives in the city					-0.014	(-2.20)	-0.010	(-1.48)	-0.015	(-2.19)	-0.012	(-1.84)
Proportion of very close alters in the network					-1.811	(-2.06)	-2.391	(-2.49)	-	-	-	-
Number of components in the network					0.081	(1.75)	0.123	(2.66)	0.059	(1.34)	0.058	(1.26)
Density of the network					1.226	(1.20)	2.175	(1.88)	1.771	(1.91)	2.392	(2.41)
Network centrality degree					3.116	(2.12)	3.890	(2.57)	-	-	-	-
Alter is immediate family slope												
Intercept			-0.540	(-2.47)	-0.517	(-2.36)	-0.685	(-2.20)	-	-	-	-
Proportion of immediate family in the network									-1.163	(-1.47)	-1.487	(-1.31)
Ego lives with a stable partner									0.611	(1.90)	0.939	(2.12)
Presence of children in the household									-0.514	(-1.62)	-0.893	(-1.94)
Alter is extended family slope												
Proportion of extended family in the network									2.032	(2.10)	2.447	(2.01)
Alter is neighbor slope												
Proportion of neighbors in the network									1.400	(1.52)	1.783	(1.70)
Alter is a work/student mate slope												
Proportion of work/student mates in the network									0.971	(1.21)	0.707	(0.76)
Alter is a friend slope												
Intercept			0.299	(1.67)	0.282	(1.59)	0.419	(1.84)	0.517	(2.58)	0.712	(2.59)
Alter is female slope												
Intercept			-0.246	(-1.65)	-0.231	(-1.53)	-0.300	(-1.80)	-0.239	(-1.58)	-0.247	(-1.50)
Alter's age slope												
Intercept			0.356	(1.52)	0.380	(1.63)	0.336	(1.08)	-	-	-	-
Ego's age									0.669	(1.80)	0.456	(1.21)
Alter is very close slope												
Intercept			0.620	(3.82)	0.660	(4.04)	0.673	(3.36)	1.367	(2.94)	1.908	(3.44)
Proportion of very close alters in the network									-1.513	(-1.75)	-2.519	(-2.50)

Table 1 (cont'd): Multilevel models of the frequency of social activities

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Fixed Effects (cont'd)	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat
Log-distance (travel by car is feasible in one day) slope												
Intercept			-0.288	(-5.64)	-0.292	(-5.77)	-0.308	(-5.61)	-0.306	(-5.79)	-0.336	(-5.90)
Log-distance (only travel by plane is feasible in one day) slope												
Intercept			-0.432	(-12.47)	-0.435	(-12.60)	-0.477	(-12.21)	-0.440	(-12.34)	-0.481	(-12.01)
Alter's node degree slope												
Intercept			1.380	(2.80)	0.976	(1.63)	0.940	(1.34)	-	-	-	-
Network centrality degree									3.913	(1.96)	3.746	(1.50)
Frequency telephone contact slope												
Intercept			0.334	(6.98)	0.335	(7.02)	0.439	(6.23)	0.329	(6.86)	0.412	(6.43)
Frequency of instant message contact slope												
Intercept			-0.878	(-2.68)	-0.985	(-2.96)	-0.813	(-2.20)	-0.957	(-2.81)	-0.868	(-2.34)
Thresholds	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat
Threshold 2	1.149	(10.84)	1.197	(9.37)	1.192	(9.37)	1.300	(9.49)	0.669	(1.80)	9.47	(1.28)
Threshold 3	1.672	(14.29)	1.847	(12.86)	1.840	(12.86)	2.032	(13.13)	1.193	(9.34)	13.09	(1.99)
Threshold 4	2.662	(20.53)	3.177	(19.24)	3.173	(19.21)	3.530	(19.56)	1.845	(12.84)	19.53	(3.46)
Threshold 5	3.003	(22.55)	3.713	(21.46)	3.713	(21.42)	4.138	(21.79)	3.188	(19.23)	21.77	(4.06)
Threshold 6	3.515	(25.37)	4.466	(24.08)	4.471	(24.02)	5.010	(24.47)	3.733	(21.46)	24.42	(4.91)
Threshold 7	4.003	(27.75)	5.214	(26.03)	5.229	(25.97)	5.89	(26.49)	4.500	(24.06)	26.39	(5.78)
Threshold 8	4.518	(29.82)	6.041	(27.36)	6.071	(27.30)	6.898	(27.84)	5.272	(25.99)	27.68	(6.78)
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)	Std. dev.	χ^2 (p-value)
Intercept	1.172	469.89 (0.00)	1.060	323.94 (0.00)	0.862	250.38 (0.00)	1.723	65.62 (0.00)	0.909	268.50 (0.00)	1.816	116.11 (0.00)
Alter is immediate family							1.456	46.10 (0.00)			1.277	57.89 (0.01)
Alter is a friend							0.901	55.01 (0.00)			1.334	94.74 (0.00)
Alter is very close							0.725	36.96 (0.02)			0.777	63.92 (0.00)
Frequency telephone contact							0.395	41.37 (0.01)			0.318	63.06 (0.00)
Alter's age							1.356	41.83 (0.00)			-	-

Notes: Blank spaces corresponds to coefficients theoretically not included in the models, " -" corresponds to coefficients that become statistically non significant (with a t -stat < 1.20, except on Model 6). The chi-square statistics reported above are based on only the portion of all level-2 units that had sufficient data for computation (80 out of 84 in Models 1,2, 3, and 5; 21 out of 84 in Model 4; and 37 out of 84 in Model 6). Fixed effects and variance components are based on all the data. The ordinal response categories are: 1 = more than once a week, 2 = twice a month - once a week, 3 = once a month - twice a month, 4 = once a month - six times a year, 5 = four times a year - six times a year, 6 = twice a year - four times a year, 7 = once a year - twice a year, 8 = once a year or less, and 9 = never.

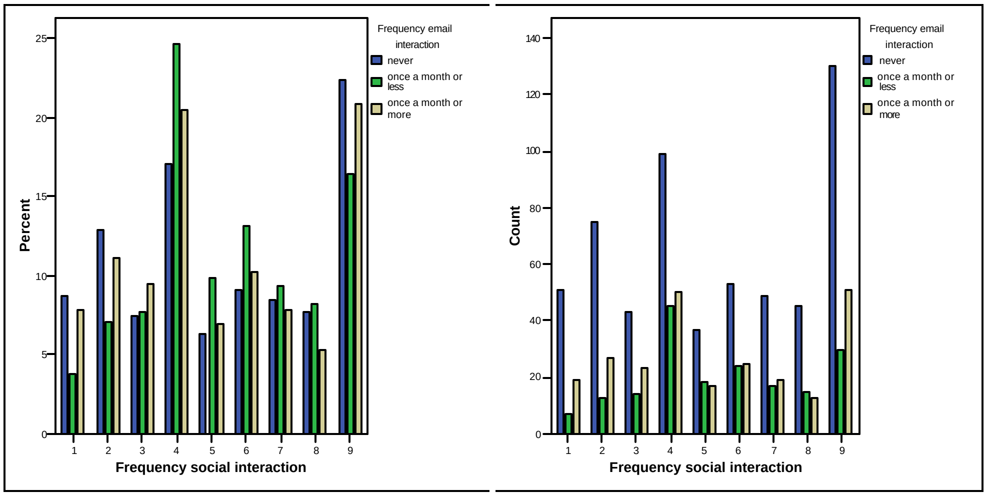

Figure 1: Frequency of email interaction and social activities per alter
Social activity frequencies: 1 = more than once a week, 2 = twice a month - once a week, 3 = once a month - twice a month, 4 = once a month – six times a year, 5 = four times a year - six times a year, 6 = twice a year - four times a year, 7 = once a year - twice a year, 8 = once a year or less, 9 = never

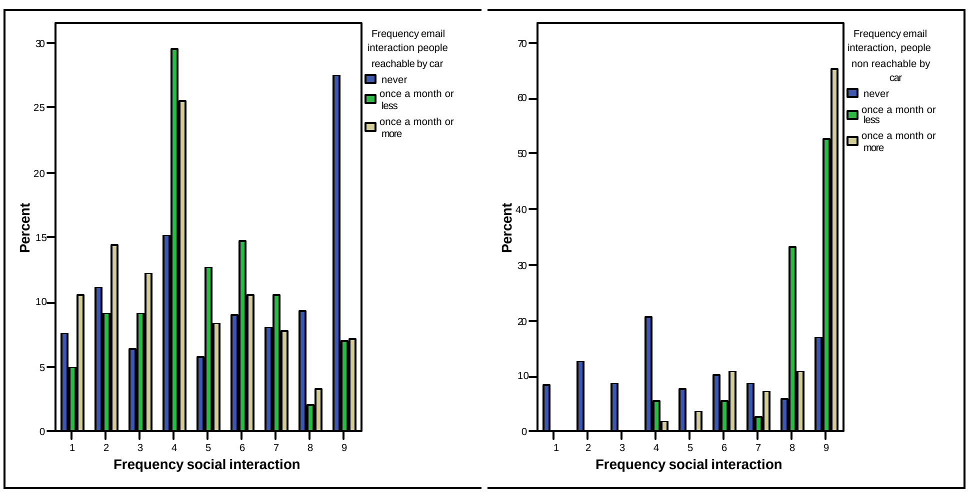

Figure 2: Frequency of email interaction and social activities (per alter), divided by spatial scale
Social activity frequencies: 1 = more than once a week, 2 = twice a month - once a week, 3 = once a month - twice a month, 4 = once a month – six times a year, 5 = four times a year - six times a year, 6 = twice a year - four times a year, 7 = once a year - twice a year, 8 = once a year or less, 9 = never