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Exploring the links between personal networks, time use, and the spatial distribution of social contacts

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Abstract Although the study of the role of the social context in travel behavior and activity patterns has recently gained attention, the empirical evidence supporting the relationship between social networks and the temporal and spatial characteristics of social activities is still limited. With this motivation, this paper studies the link between "longer term" (social networks) and "shorter term" (social activities) social decisions, by exploring the intertwined relationship between the individuals' personal networks attributes, and the spatiotemporal characteristics of their daily social activities. The paper contributes to the literature by adding two key aspects to the study of the role of social networks on travel behavior: the social networks' structure, and the spatiality of all individuals participating on the social activities. Based on data which link people's personal networks and time use, and using a structural equation modeling approach, the paper studies the influence of individual and interactional attributes on the duration, distance, and number of people involved in social daily activities. The results show that aspects such as tie social closeness, gender and age similarity, and network density, help to understand social activity duration and distance, complementing traditional socio-demographic aspects such as income, occupation, and accessibility to services. In this way, socio-demographic attributes are not enough to explain the spatiotemporal dimension of daily activities which makes necessary to include variables related to the social context to explain with a higher level of accuracy both the duration and distance traveled to the activity.

Keywords Social networks · Social activities · Time use · Structural equation modeling

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Introduction

Incorporating the social dimension of transport behavior is a key research and modeling challenge in transportation planning, considering that social and recreational trips have been the most increasing segments in the last years (Axhausen 2005). Although understanding the role of social networks on travel behavior has gathered much interest recently, the specific links between the social context and spatiotemporal characteristics of daily activities remains as key research topic to understand and model. More specifically, the effects of the social context in the duration and spatiality of daily activities must be analyzed deeper to empirically determine their interrelations and effects on travel behavior.

In fact, even though there is a vast literature available on social networks in Sociology, with notably exceptions (Mok et al. 2010), their studies about social structure has little consideration about the relevance of the spatial distribution of social contacts (Urry 2003). On the other hand, the need of representing more accurately the complexities of the relationship between people, places, and daily life (Rainie and Wellman 2012), has substantiated the study and modeling of social networks as constraints and opportunities for behavior in time and space (Arentze and Timmermans 2008). In fact, the social dimension can be understood as a result of the development of spatial patterns of social interaction in time and space, being a key pre-condition to study the scheduling and spatiality of activities, especially those of social nature (Axhausen 2005). In this way, social activities can be potentially studied and modeled explicitly accounting for the interactions that occur in time and space rather than using broad and potentially inaccurate proxies such as population distribution measures (Kowald et al. 2012).

However, the development of these models needs to be supported on empirical evidence, which could guide the specific factors or variables that are more important when modeling the temporal and spatial characteristics of travel demand for social activities. With this motivation, data on personal networks have been collected in different countries around the world (Carrasco et al. 2008; Frei and Axhausen 2007; Van den Berg et al. 2009; Kowald and Axhausen 2012; Carrasco and Cid-Aguayo 2012). In particular, the most recent applications of these data collection methods have included the account of the respondents' activities in certain periods of times, as a way of understanding the relationship between the respondents' time use (social activities in this case), and their overall social contacts or personal networks (Van den Berg et al. 2009; Carrasco and Cid-Aguayo 2012)

Despite the progress that have been made in the past, the relationship between the characteristics of "medium/long term decisions" (i.e., the respondents' personal networks) and "short/medium term decisions" (i.e., their daily social activities), still constitutes a key challenge on any theoretical or empirical model linking social networks and activity-travel behavior. In this context, the objective of this paper is to study the link between these two aspects, by exploring the intertwined relationship between the individuals' social networks, and the temporal and spatial characteristics of their daily social activities. The paper also contributes to the literature by presenting empirical evidence to the study of the role of social networks on travel behavior, adding two key aspects: the social networks' structure, and the spatiality of all individuals participating on the social activity.

A database was generated using a study about time use and personal networks in four neighborhoods of the city of Concepción, Chile. The database contains daily activities with large detail regarding the attributes of the respondents, their personal networks, each social contact, and the social activities themselves. Differences in income and accessibility levels allow for the comparison between neighborhoods, analyzing the effects of the mentioned

characteristics on activity patterns. Structural Equation Models are used to link the social context and spatiotemporal characteristics of social activities, giving empirical evidence regarding the influence of personal, contextual, and social attributes on the duration, traveled distance, and number of people involved.

The article is structured in five sections. The next section corresponds to a brief literature and theoretical review regarding the study of the social context in daily activity-travel. The "Data and methods" section consists of a brief description of the data and methods used in the study. The "Model results" section describes the results obtained from the models, followed by final section of summary and conclusions.

Literature review and theoretical discussion

Despite the recognition about the potential role of the social context on activity-travel decisions, few studies have empirically explored the link between social activity scheduling and social networks.

One of the exceptions is Habib et al. (2008), who used data from the TAPS database in Toronto (Doherty et al. 2004) to study the relationship between duration, start time, and "with whom" the individuals performed social activities. Using discrete choice models, their results suggested that "with whom" was an important factor to determine some activity scheduling aspects of social activities. For example, this dimension has a positive correlation with duration when there are not household members involved in the activity, although there was significant influence on activity starting times. Using the same database, that study was revisited with a more sophisticated methodology that jointly incorporates the role of starting time, duration and with whom, with a trivariate joint econometric model (Habib and Carrasco 2011). A positive relation between travel times and activity duration and starting time of social activities as well as significant effects of the social network only on duration and presence of alters in activities were some of the evidence found in the study.

Using a different perspective, Sener et al. (2011) studied the social, spatial, and temporal context on recreational and physical activities using a Mixed Multiple Discrete Continuous Extreme Value approach to model the 2007 American Time Use Survey. The authors found that individuals have an inherent preference to make physical and recreational activities in the company of their personal social network, remarking the relevance of accounting the social dimension to properly modeling interactional based activities.

Although the two previous studies constitute interesting approaches to explore the relevance of social contact in people's time use, the characteristics of their databases limit their capability to understand the relevance of the social dimension in a broader perspective. In fact, the role of social context can be conceived not only as a mere attribute of the activity (i.e., with whom: family or friend), but also as part of the long term process that creates opportunities and constraints to social activities. In other words, the individual's social networks need to be studied more in depth to better account for the context where the scheduling decisions are made. On that regard, besides from with whom, two key aspects need to be understood in social activities: (1) the overall social networks of the respondents involved in the activities, and (2) the temporal and spatial characteristics of the social contacts involved in the activity.

Focusing on the overall social networks characteristics—although without explicit time use information—Carrasco and Habib (2009) used the personal networks collected in the Connected Lives Study in Canada (Carrasco et al. 2008) to study social activity frequency

and duration through an Ordinal Multilevel Probit model. Using variables at the ego-network and ego-alter level, their results showed that age and distance have negative effects on activity frequency, and that the presence of relatives and percentage of relatives in the social network lead to a higher frequency of social activities. In addition, they found that some variables capturing the personal network structure (i.e., shape of the contacts) had an incidence on aspects such as duration, and distance traveled in some ranges.

In a similar vein, data explicitly linking time use and personal networks were collected in Eindhoven in 2008, studying the relationship between social networks, ICT, and social activity patterns (Van den Berg et al. 2010). The authors used a Path Analysis approach, defining as exogenous variables attributes of the ego, spatial characteristics of the activity, and day of the week, and as endogenous variables trips with social purpose, ICT use and personal social network size. Their results highlight the positive effects of traveled distance by the respondents with respect to social network size, day of the week and traveled distance's negative effects caused by the presence of children in the household. Other recent work by these researchers studied the effects of activity characteristics, ego-network and ego-alter variables on activity duration (Van den Berg et al. 2012a), and the relationship between participation on associations, trip frequency, and social network characteristics (Van den Berg et al. 2012b). Aspects such as type of location, having joint activities, the presence of relatives, gender homophily (tendency to meet with same gender contacts), and personal network size, had a role on activity duration. These empirical results helped to build a simulation exercise to study the effect of physical and social spaces in trip generation and activity scheduling, assuming that the ego-alter tie characteristics are more relevant than the global structure of the social network (Ronald et al. 2012).

The previous examples, especially in the case of the Canadian and Dutch databases, suggest the need of incorporating explicitly with whom the social interaction is performed, as well as the overall social networks of those participating in these activities. However, more detail about the spatiality and the embedded personal networks are needed to better understand and model distance and duration of social activities. In particular, not only the relevance of the egos' spatial context (e.g., home-activity distance) needs to be explored, but also the same aspects for their alters. Furthermore, personal network properties traditionally only involve size, whereas in this study the role of other network structural aspects are explored, such as density and the degree of connectivity.

Next section presents the data used to perform the study as well as some key descriptive elements that guided the modeling effort.

Data and methods

Data description

The data employed in this paper come from the study "Communities in Concepción" (August 2008–April 2009), which focused on the characteristics of social activity-travel through the analysis of personal networks in four different neighborhoods of Concepción, Chile (Carrasco and Cid-Aguayo 2012). These four neighborhoods correspond to the combination of high/medium and low/medium income, on the one hand, and high and low distance to Concepción's CBD, on the other hand. In this way, a good representation of the overall city's population can be achieved. The instrument was applied face-to-face, and consisted of three main sections: (1) individual socio-demographics, (2) the respondents'

personal networks, (3) a retrospective two-day time use survey. In the section (2)—and following the approach by Carrasco et al. (2008)—name generator and interpreter techniques elicited the respondents' personal networks, including the frequency of interaction face-to-face, socializing, by telephone, and email, as well as the home locations of these social contacts. The time use section consisted of the retrospective collection of the activities performed by the respondents in one working day and one weekend day. Special care was taken on having a good representation and quality of information from all days of the week in the sample, making a balance between choosing days close to the interview, and uniformly eliciting all days of the week. Although retrospective data collection might have some biases (Stopher 2012), the face-to-face nature of the data collection helped to minimize missing responses and other related issues. For each activity, the instrument recorded start and end time; activity type (open ended and later classified); location (closest intersection, later geo-coded); and with whom it was performed (linking with the previously elicited personal networks).

Key characteristics of the activities collected in the instrument, differentiated by neighborhood are presented in Table 1, differentiating income and distance to the CBD. A total of 4,294 activities across 240 respondents (egos) regarding their daily activities during one working day and one weekend day were collected. If we analyze the whole sample, 8.96 activities per ego per day were performed with an average duration of 100 min per activity. In the case of working days, 9.86 activities per ego per day were performed, with an average duration of 94 min per activity (see Table 1). On the other hand, on weekends, 8.06 activities per ego per day were performed, with an average duration of 108 min per activity.

Activity types were classified into eleven categories: Basic needs, work, education, household obligations, drop-off/pick-up, shopping, services, recreation/entertainment, social, escorting children, travel, and other. From the whole sample of activities performed, the three most frequent activities are travel (28 %), basic needs (24 %), and social (12 %).

Table 1 Activities per neighborhood

Complete sample	Low income, near CBD	High income, near CBD	Low income, far from CBD	High income, far from CBD	Total
No. of daily activities	7.54	9.71	8.24	10.38	8.96
Duration (min)	114 (60)	88 (42)	107 (59)	94 (50)	100 (56)
No. of alters[a]	1.39	0.98	1.06	0.94	1.07
No. of Activities (total)	905	1.175	989	1.225	4.294
No. of Respondents	60	60	60	60	240
Labor days					
No. of daily activities	8.13	10.82	9.15	11.47	9.86
Duration (min)	108 (60)	84 (35)	101 (50)	87 (40)	94 (45)
No. of alters[a]	1.23	0.72	0.90	0.68	0.85
Weekends					
No. of daily activities	6.95	8.77	7.30	8.90	8.06
Duration (min)	122 (60)	93 (50)	115 (60)	104 (60)	108 (60)
No. of alters[a]	1.57	1.30	1.25	1.27	1.34

Mean values. In parenthesis, median values

[a] Considering only activities with alters involved

In terms of duration the median was between 1 and 2 h for all activities, except drop-off/pick-up and travel (which was lower than 1 h), and work and study (more than 2 h).

In terms of the characteristics of social contacts, the average number of alters from the respondents' personal networks that participated in social activities was 2.03, with an average episode duration of 168 min (median of 90 min), and a total average daily time spent in social activities of 312 min (median of 230 min). Recreation and entertainment activities have a similar mean duration, although a longer median (119 and 90 min, respectively); the mean alters' participation in this case was lower than 1 per activity (0.89). These values look reasonable considering the instrument employed, although they have to be taken with care considering the mix of weekdays and weekends.

Indicators regarding the spatial, temporal and social dimensions of social activities are presented in Table 2. People living in higher income neighborhoods have longer distances to their activities and alters, suggesting an important role of income in daily life spatial mobility. Also, people living closer to the CBD have shorter distances to their activities and alters than their same income counterparts, remarking the role of the spatial context where individuals live.

In the case of the temporal dimension, a time pressure measure—defined as the ratio of non-mandatory activities with respect to the total—presented mixed results across neighborhoods, showing that people with higher income and accessibility to the CBD have more free time, with a decreasing tendency for lower incomes and access to the CBD.

With respect to the social indicators, mixed results are found regarding number of alters in the activity, gender, and age homophily, showing different tendencies between income levels and access to the CBD. In addition, people is more likely to spend more joint activities with emotionally close alters, tendency that is more notorious in neighborhoods with better access to the CBD. If we analyze the ratio of household members and relatives,

Table 2 Social activity indicators by neighborhood

	Low income, near CBD	High income, near CBD	Low income, far from CBD	High income, far from CBD	All
Linear distance (km)					
Ego-alter	38.2 (3.0)	439.5 (8.6)	38.7 (1.2)	147.2 (8.7)	218.2 (5.8)
Ego-activity	0.76	1.13	0.81	1.69	1.14
Alter-activity	2.81 (0.99)	4.42 (2.59)	3.90 (0.79)	6.78 (4.69)	4.26 (1.91)
Temporal dimension					
Duration (min)	115 (60)	88 (45)	108 (60)	97 (52)	101 (59)
Starting time[a]	1.79	1.83	1.79	1.81	1.81
Time pressure	0.45	0.50	0.50	0.40	0.46
Social dimension					
No. of people	2.70	2.44	1.86	2.34	2.35
Ratio of gender homophily	0.60	0.55	0.38	0.47	0.55
Ratio of age homophily	0.42	0.44	0.49	0.38	0.44
Ratio of close and very close alters	0.94	0.84	0.61	0.59	0.55
Ratio of HH members and relatives	0.63	0.42	0.45	0.42	0.43

Mean values. In parenthesis, median values

[a] 1 if morning (5:00 am to noon), 2 if afternoon (noon to 8:59 pm) and 3 if night (9:00 pm to 4:59 am)

there are mixed results for every neighborhood, except for low income-low accessibility, which shows a tendency to have most of their joint activities with household members and relatives.

Finally, Table 3 presents an overall description of the variables studied in the models, and Table 4 presents descriptive statistics from these variables.

Method

Structural equation models (SEM) were used to study the links between the spatial, temporal and social dimension and attributes of the ego, alters and the activity itself. SEM have been used increasingly in transport research (e.g., Golob 2003), and further details can be found in reviews such as Washington et al. (2003). The method consists of a set of three equations that must be solved simultaneously:

$$Y = \Lambda_y \eta + \varepsilon \tag{1}$$

$$X = \Lambda_x \xi + \delta \tag{2}$$

$$\eta = \mathrm{B}\eta + \Gamma\xi + \varsigma \tag{3}$$

These equations correspond to measures of the dependent or endogenous variables (1) and independent or exogenous variables (2). Λ_i is the coefficient matrix of X and Y, η and ξ are vectors of the dependent and latent variables respectably, and ε and δ are vectors associated with the measuring bias. Equation (3) corresponds to the structural equation, where B and Γ are weights to be predicted between the different exogenous and endogenous variables considered. The residual vector representing unobserved dependent variables influencing latent variables, bias, and the stochastic component of the model is defined as ς.

The estimation of this model is made by the use of Covariance Analysis (method of the moments) so that the variances and covariance of the model are as similar as possible to the sample. However, because of the flexibility of this type of models, there are different estimation methods depending on the case or SEM structure, being the most common the maximum likelihood (ML) and the weighted least squares. In this paper, we used ML considering the existence of discrete variables, ordinal scales, and trunked variables, although simplifications were needed considering the limited sample size for the complex model structures studied. The software package used for the estimation was SPSS AMOS 20.0 (Arbuckle 2011). Next section contains the results associated with these models.

Model results

Two models were estimated to study the relationship between the spatial, temporal, and social dimension of daily activities, and the role of the attributes egos, alters, and activities. The first model considers as endogenous variables the distance travelled by the ego to the activity, as well as the episode duration, whereas the second model adds the number of people involved in the activity as a third endogenous variable. This two step approach was chosen as an useful way of studying the incremental effect of adding the social dimension in the overall model.

The rationale behind choosing episode duration and distance travelled to the activity is on exploring to which extend the activity scheduling process involves trade-off or relationships between space and time for the specific—and under-researched—case of social

Table 3 Description of variables considered in the model

Personal attributes	Type	Description
Age	Continuous	Ego age in year 2008
Household income	Continuous	0–1, from low to high income level
Time pressure	Continuous	Ratio of daily time available for leisure activities
Years living in neighborhood	Continuous	Years living in neighborhood
Vehicle ownership	Dummy	1 if car is available in household
Gender	Dummy	1 if woman
Occupation	Dummy	1 if employed
Access to CBD	Dummy	1 if household is close to the CBD
Car use frequency	Ordinal	1 if used daily, 5 if never used
Social network		
Size	Continuous	No. of alters in the social network
Density	Continuous	Ratio between the number of links in the social network and the maximum possible number of links, without considering the ego
Closeness	Continuous	Average number of links necessary to go from alter to alter in the social network
Degree	Continuous	Average number of links between each alter belonging to the social network
Time		
Duration	Continuous	Activity duration in minutes
Start time	Ordinal	1 if morning (5:00 am to noon), 2 if afternoon (noon to 8:59 pm) and 3 if night (9 pm to 4:59 am)
Day of the week	Ordinal	1 if weekday and 2 if weekend
Distance		
Ego-activity	Continuous	Linear distance between ego home and the place the activity takes place in km
Ego-alter	Continuous	Linear distance between ego home and alter home
Alter-activity	Continuous	Linear distance between alter home and the place the activity takes place in km
Social context		
No. of people involved	Continuous	No. of alters involved in activity
Age homophily	Continuous	Ratio of alters involved in activity with the same age group
Gender homophily	Continuous	Ratio of alters involved in activity with the same gender group
Alter closeness	Continuous	Ratio of alters involved in activity considered to be very or somewhat close
Alter role	Continuous	Ratio of alters involved in activity considered to be household members, direct or extended family

purposes. The logic behind adding the number of people involved in the activity as a variable consists in explicitly incorporating an indicator of the social context as another key variable of the temporal and spatial dimensions for performing social activities (Habib et al. 2008; Habib and Carrasco 2011). In other words, the variable explores embedded social component within the temporal and spatial decision-making process.

However, as the literature review suggests, there is a lack of theories that could guide the causality between the different variables. Then, all possible intuitive combinations of

Table 4 Descriptive statistics of the sample

Variables	Mean	SD	Median
Personal attributes			
Age	39.02	15.87	35.00
Household Income	0.59	0.30	0.63
Time Pressure	0.72	0.28	0.81
Years living in neighborhood	17.27	14.27	17.00
Vehicle ownership	0.49	0.46	0.00
Gender	0.62	0.49	1.00
Occupation	0.50	0.50	0.00
Access to CBD	0.60	0.49	1.00
Social network			
Size (alters)	21.70	8.80	20.00
Density	0.21	0.16	0.16
Closeness (links)	319.98	365.56	194.96
Degree (links)	3.77	2.70	3.00
Time			
Duration (min)	111	119	70
Distance (km)			
Ego-activity	2.17	4.22	0.25
Alter-activity	4.05	5.92	1.79
Ego-alter	187.02	1226.93	4.75
Social context			
No. of people involved	2.35	1.68	2.00
Homophily (age)	0.44	0.45	0.33
Homophily (gender)	0.55	0.40	0.50
Ratio of close and very close alters	0.80	0.35	1.00
Ratio of household and extended family alters	0.45	0.43	0.50

causality between exogenous and endogenous variables were tested, provided that the model would be statistically correct, and coefficients would be statistically identifiable.

It is important to remark about the ego's perspective of this multivariate analysis. In fact, the spatial endogenous variable corresponds to the distance travelled by egos from their homes to the social activity, which is studied with respect to other two distance variables: the mean distance between the alters' home and the activity, and the mean distance between the ego and the alters who participate in the activity. Although this egocentric perspective has some caveats—since the information about alters' characteristics and social context is rather limited—it is employed for two reasons. First, it is coherent with the data collection process, which is inherently based upon a personal network perspective. Second, this perspective is closer to the emergent social network modeling approaches in travel behavior (e.g., Kowald et al. 2012), being able to inform some of the hypothesized relationships assumed on those models.

The results of each model, including their goodness of fit, are presented in Table 5. Figures 1 and 2 present a schematic overview of the key statistical significant relationships found in each model.

In terms of the relationship between endogenous variables in the first model, and consistently with previous results from the literature (e.g., Habib et al. 2008), a higher ego-activity distance is associated with longer social activity durations. This result is intuitive, since longer distance (effort) shall be related to longer activity times at the destination.

Social context variables have statistically significant relationships with both activity distance and duration. In the case of distance, if the activity involves a higher number of people participating, the ego-activity distance will be longer, probably because the potentially underlying spatial negotiation process between the different alters involved. Similarly, there is a "symmetric" effect in terms of distances: a higher alter-activity distance mean also involves a higher ego-activity distance. A statistically weaker effect—although consistent with previous result by Van den Berg et al. (2010)—is that, if the activity is performed by people with similar (homophily) ages then distances tend to be shorter.

The social context is also relevant to understand the duration of social activities. In fact, the model shows a positive relationship with respect to the number of people involved, suggesting that people tend to spend longer times when there are more members of their personal networks involved in the activity. Similarly, the types of social ties involved in the activity have a relationship with duration; in particular, if the activity is performed with emotional close contacts, it tends to be longer than with weaker ties. A similar result is suggested by the model with respect to age homophily. Finally, the alter-activity distance presents a counter-intuitive negative sign with respect to activity duration. However, this result is statistically very weak to recognize it as an important effect, especially considering the strong positive effect of alter-activity distance in the ego-activity distance, and that the linear correlations between these variables are non-significant.

Finally, the first model presents few personal attributes explaining distance and duration. The results suggest a positive—although weak—relationship between distance and household income, and the same tendency with employed egos, although stronger. In terms of duration, only women egos have a weak positive tendency to longer activities.

As explained before, the second model adds the number of people involved as an endogenous variable that tries to capture the embedded social context as a key mediating variable in social activity distance and duration. The model presents a relative better goodness of fit than the previous one, although the effects are very similar, and practically every relationship has the same signs and order of magnitude. As a result, the model becomes behaviorally richer on explanatory variables that directly explain the social dimension, and that indirectly explain the social activity spatial and temporal context.

For example, the access to CBD, which was an expected relevant aspect according to the data descriptive analysis, has a positive relationship with the number of people involved. Similarly, family income shows a stronger positive relationship with distance, as expected from the descriptive analysis. Interestingly, the only network structure variable that becomes significant is network density. In that case, the positive relationship with the number of people involved follows the intuition that denser personal network involve higher chances of meeting more people at any social activity. In this sense, the role of density can be conceptualized as an indirect aspect influencing temporal and spatial characteristics of social activities.

Focusing on the values and signs of coefficients from Model 2, several comments arise. Regarding ego-activity distance (in kilometers), it is mainly influenced by income (normalized continuous variable, coefficient 0.248). If egos belong to the higher income neighborhood, then they might travel further to develop the social activity. Income weight is stronger when compared with the other attributes' weight: occupation (0.092), number of

Table 5 Results from Models 1 and 2

Dimension	Variable	Model 1			Model 2		
		Coefficient	Normalized coefficient	*T* statistic	Coefficient	Normalized coefficient	*T* statistic
Distance (ego-activity)	Household income	0.143	0.123	1.773	–	–	–
	Years in the neighborhood	−0.006	−0.248	−4.800	–	–	–
	Social network size	−0.002	−0.056	−1.084	−0.003	−0.067	−1.267
	Alters–activity distance	0.009	0.154	2.941	0.010	0.166	0.366
	Vehicle ownership	0.001	0.002	0.030	0.018	0.026	3.108
	Occupation	0.092	0.134	2.584	0.092	0.132	2.491
	Starting time	−0.038	−0.065	−1.251	–	–	–
	Gender	−0.074	−0.105	−2.032	−0.081	−0.114	−2.164
	Age homophily	−0.069	−0.089	−1.653	−0.056	−0.071	−1.300
	Family income	–	–	–	0.248	0.211	2.992
	Day of the week	–	–	–	0.034	0.048	0.920
	No. of people involved	0.031	0.152	2.936	0.028	0.133	2.481
Duration	Social network degree	2.193	0.050	0.931	–	–	–
	Social network size	–	–	–	0.887	0.061	1.045
	Social network density	–	–	–	51.959	0.075	1.265
	Day of the week	2.534	0.041	0.774	13.384	0.056	1.064
	Ego-alters distance	−0.003	−0.035	−0.656	–	–	–
	Close and somewhat close *alters*	39.957	0.119	2.194	41.891	0.125	2.309
	Gender homophily	−22.485	−0.076	−1.377	−23.098	−0.079	−1.373
	Distance (ego-activity)	41.842	0.121	2.181	48.580	0.143	2.487
	Gender	*21.809*	*0.089*	1.672	20.661	0.085	1.588
	Occupation	13.510	0.057	1.062	17.280	0.073	1.345
	Family income	–	–	–	−28.484	−0.071	1.302
	alters-activity distance	−1.786	−0.089	−1.623	−1.591	−0.0079	−1.449
	No. of people involved	16.549	0.234	4.350	16.196	0.230	4.014
	Age homophily	28.502	0.107	1.920	29.045	0.109	1.965

Table 5 continued

Dimension	Variable	Model 1			Model 2		
		Coefficient	Normalized coefficient	*T* statistic	Coefficient	Normalized coefficient	*T* statistic
No. of people involved	Access to the CBD	–	–	–	0.506	0.148	2.810
	Social network size	–	–	–	0.014	0.070	1.206
	Occupation	–	–	–	−0.514	−0.153	−2.915
	Social network density	–	–	–	1.494	0.152	2.618
	Starting time	–	–	–	0.181	0.064	1.214
	Gender homophily	–	–	–	−1.028	−0.247	−4.570
	Age homophily	–	–	–	−0.243	−0.065	−1.178
	Alters-activity distance	–	–	–	0.031	0.109	2.041
	Car ownership	–	–	–	0.103	0.031	0.582

Goodness of fit measures

Model 1: $\chi^2 = 336.18$; df = 110; $\chi^2/df = 3.06$; R^2 (IFI) = 0.62; RMSEA = 0.08

Model 2: $\chi^2 = 220.92$; df = 85. $\chi^2/df = 2.60$; R^2 (IFI) = 0.75; RMSEA = 0.07

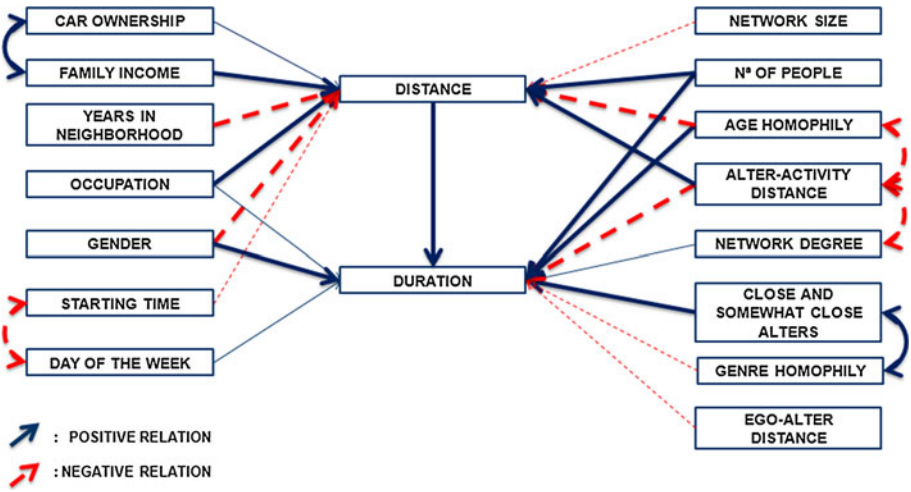

Fig. 1 Model 1 results. *Solid lines* represent a positive relationship, and *dashed lines* represent a negative relationship. *Darker lines* represent statistical significant relationships, whereas *lighter lines* represent near (but non) statistical significant relationships

people involved (0.028) and alters activity distance (0.010). The role of income is stronger even for larger values for the other continuous variables, such as 3 people involved in the activity or a 7 km distance. Being a female ego reduces slightly the activity distance (80 meters). Notice that deterrence to travel further for being a female ego cannot be

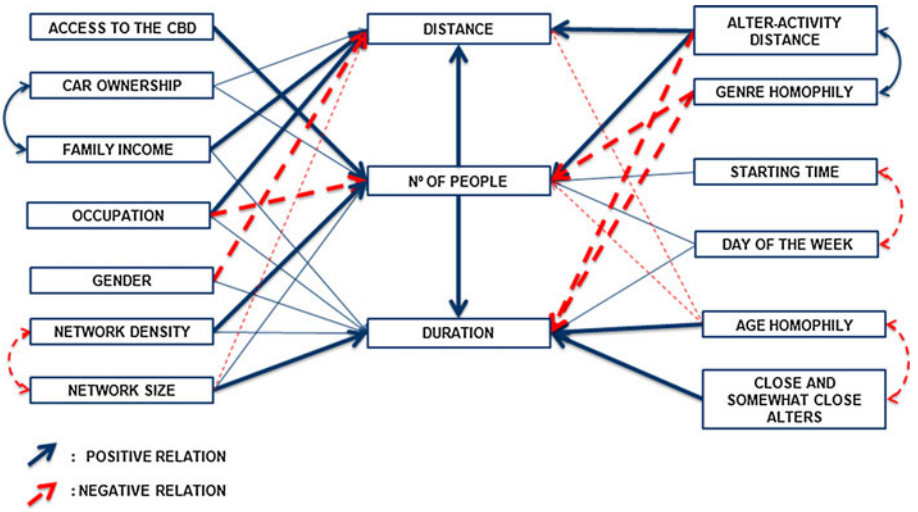

Fig. 2 Model 2 results. *Solid lines* represent a positive relationship, and *dashed lines* represent a negative relationship. *Darker lines* represent statistical significant relationships, whereas *lighter lines* represent near (but non) statistical significant relationships

counterweighed by the average number of involved people (−0.081 against 0.028 * 2.35), but occupation (being employed) might counteract the effect of being a woman on the travelled distance. Cultural and security issues might be responsible of these results.

Respect to the activity duration (in minutes), it is mainly affected by the social context: closeness, with whom and age homophile, and the ego-activity distance. Activity length might extend above an hour if alters are close and same age. An extra ego-distance kilometer might extend the activity duration in 48 min, whereas an extra alter would increase it in 15 min.

Finally, the number of people with whom there is social interaction is affected by spatial factors, social context aspects, social network characteristics, and personal attributes. Larger number of people to interact with can be achieved if access to CBD is good and the social network is denser, although density is the more important variable (coefficient 1.494). Being employed and having the same gender than the ego reduces the number of social interactions which might have to do with time constraints and cultural factors, respectively.

Overall, both models are consistent with the variables previously explored in the existing literature. For example, there are consistent relations between duration and closeness (Carrasco and Habib 2009), number of people involved (Habib et al. 2008), and day of the week (Van den Berg et al. 2012a). Also, the results suggest that properties in the nature of the social network ties are more important than the global network measures (Ronald et al. 2012), although—according to the previous results—aspects such as network density constitutes a relevant explanatory variable.

Summary and conclusions

Although the recent literature has shown progress on explaining the temporal and spatial characteristics of social activities through the incorporation of the embedded social

context, the empirical evidence supporting these relationships is still limited. In fact, the effects of the social context on activity duration and spatiality need to be disentangled in order to better understand and model this very important activity-trip purpose.

With this motivation, this paper adds empirical evidence supporting the fact that incorporating socio-demographic attributes are not enough to better explain the distance and duration of social activities. The analysis is based on data that explicitly collected both the respondents' medium/long term context (i.e., their personal networks) as well as their medium/short term decisions (i.e., their time use). This detailed information regarding the characteristics of egos, alters, and social activities, confirm results previously found in the literature, adding new evidence about the influence of the spatiality of all people participating in activities (and not only the respondent), and the personal network structure (social context) of the respondent.

Results presented in this paper remark that aspects such as tie social closeness, gender and age homophily, and network density, help to understand social activity duration and distance, complementing traditional socio-demographic aspects such as income, occupation, and accessibility to services. In addition, the incorporation of the number of people involved in the social activity as an endogenous variable serves as a good proxy for accounting the embedded social dimension, helping to understand the role of personal network structure and spatiality.

By adding empirical evidence on the importance of social ties, alter's characteristics, and personal network structure, the paper contributes to highlight the challenge of properly modeling the links between the social context and the spatio-temporal characteristics of daily activities. In fact, although an individual perspective is a possible starting point to model the duration and distance travelled to social activities, the results strongly suggest that aspects such as the alters' activity-home distance, emotional closeness, and homophily need to be explicitly incorporated.

In fact, even though recent models are explicitly taking into account social contextual variables to model activity-travel behavior (e.g., Kowald et al. 2012), a remaining challenge consists in gaining more evidence about the specific differential role of each of them. This issue directly relates to the increasingly need of linking decision making processes on different time scales, which in this case involves the formation, maintenance, and dynamics of social networks (Sharmeen et al. 2010).

Several future lines of enquiry arise from the results of this and other related studies, which strongly suggest the relevance of explicitly accounting the social dimension when studying the relationship of time and space in activity scheduling processes. First, more research is needed on the role of aspects such as income and transport availability on the individual's availability to accommodate time and move long distances to perform social activities. Second, further steps are needed to disentangle short terms decision making processes to accommodate social episodes, with respect to long term processes related to personal network formation and spatiality.

Finally, in terms of policy implications, the relevance of income and gender in the results suggest the need to concentrate on specific potentially disadvantaged groups in terms of their transport availability to interact with others. In fact, the relationship between the social context, and distance and duration, remarks not only the influence of social networks in daily time–space behavior, but also the potential role of transport to facilitate the access to people and resources.

Although much research is still needed regarding all these aspects, the empirical outcomes of this work support that not accounting for this social context may involve a poor

explanation about social daily activity-travel behavior and the role of transport on these processes.

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