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ORIGINAL ARTICLE

A multilevel path analysis of contact frequency between social network members

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Abstract Recently, there has been an increasing interest in the role of social networks in spatial-choice and travel behavior. It has been acknowledged that social activities and the travel for these activities can emerge from individuals' social networks and that social activities are responsible for an important portion of travel demand. The influence of information and communication technologies (ICT's) is also important in this respect. The purpose of the paper is to examine the effects of characteristics of egos and ego-alter relationships on the frequency of social interaction by different communication modes, using multilevel path analysis. The analyses are based on social network data collected in 2008 in the Eindhoven region in the Netherlands among 116 respondents. The results indicate a complementary relationship between contact frequencies by different modes. The contact frequencies of the different modes, especially face-to-face and telephone, can also be largely explained by the ego's personal characteristics and the type of relationship and the distance between ego and alter.

Keywords Social networks · Communication technology · Contact frequency · Multilevel path analysis

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1 Introduction

The study of social activities is important as these activities often involve meeting with other persons at a certain location. Social activities account for a large part of trips, and they constitute the fastest growing segment of travel (Axhausen 2005). The study of social activities has been neglected in urban planning and travel behavior research. However, recently, some studies on this area have been undertaken (Carrasco and Miller 2006; Farber and Páez 2009; Mokhtarian et al. 2006; Schlich et al. 2004; Van den Berg et al. 2010).

As social networks are the main motivators for social spatial-choice behavior, including social activity travel, they need to be studied. The need to incorporate the effects of social networks in travel behavior was first emphasized by Axhausen (2005), Dugundji and Walker (2005) and Páez and Scott (2007). The fact that social networks are important in the new context of information and communication technology (ICT) has also been acknowledged (e.g. Carrasco and Miller 2006; Larsen et al. 2006; Tillema et al. 2010).

Communication between people by ICT does not take place independently of face-to-face contacts (Dijst 2009). As face-to-face contacts require travel, the communication patterns between social network members (frequency and type of communication media used) are relevant to an understanding of social travel demand. ICTs provide opportunities to maintain contacts over longer distances. They are therefore important in understanding the maintenance of social networks that are becoming more geographically spread (Axhausen 2002; Urry 2003; McPherson et al. 2006). This maintenance depends on the frequency and the kind of contact.

The available literature shows that the knowledge about the relationship between ICT's, social networks and activity–travel behavior is rather limited. Although the importance of social networks and ICT use for (social) travel behavior has been acknowledged, only a few data collection efforts have been made thus far in order to fully incorporate social networks in models of travel demand (e.g. Carrasco et al. 2008; Axhausen 2008; Van den Berg et al. 2009).

The purpose of the paper is to explore the relationship between ICT use and social activities within social networks in the Dutch context. As the maintenance of social networks is realized through ICT-mediated communication and face-to-face contact, this maintenance is an important contributor to travel. The communication frequencies between social network members are studied to better understand the travel demand for social activities. This paper analyzes how often social network members interact by different communication modes, based on characteristics of the ego (gender, age, education level) and characteristics of the ego-alter relationship (the distance between their homes, strength, duration and type of relationship). It will offer theoretical and practical insights into social travel behavior.

For the purpose of this study, data on social networks were gathered in 2008 in the Eindhoven region in the Netherlands. Multilevel path analysis is used to test a

set of hypotheses on the causal relationships between characteristics of the ego-alter relationship and the contact frequency by different communication modes.

The remainder of the paper is organized as follows. The next section discusses the existing literature. Based on this literature, some hypotheses are formed and discussed in Sect. 3. Section 4 describes the data collection. Next, the structure of the multilevel path model is outlined. In Sect. 6, the analysis results are presented. Finally, Sect. 7 contains the conclusions and discusses the implications of the findings for transport planning and modeling.

2 Literature review

This section describes the main concepts of this study: social networks, ICT use for social interaction, social networks and communication frequency.

2.1 ICT's and social interaction

New information and communication technologies (ICT's), such as mobile phones and the Internet, have provided new ways of communicating with social network members. Contact is not coupled with particular places and times anymore (Carrasco and Miller 2009). Individuals no longer have to be at a certain place at the same time to be contacted. This has resulted in considerable speculation about the consequences for social interactions as well as individuals' social activity–travel behavior. Recently, research on travel demand analysis has started to focus on the effects of ICT on activity–travel patterns (Salomon 1986; Mokhtarian 1990). However, with regard to the effect of ICT on travel for social activities, relatively little is known.

Face-to-face communication often requires travel, whereas ICT-mediated communication does not. Therefore, using ICT's may reduce the need to meet face-to-face and the associated travel (substitution). This substitution effect has received considerable attention, especially for activities such as working and shopping. However, the ICT-based alternatives that are available for social activities are not as good as the alternatives for other activities such as working or shopping. Therefore, social contacts via ICT are not likely to decrease the need for face-to-face social contact. Instead, increased contacts via ICT are more likely to increase the making of plans and appointments for face-to-face social activities and the number of social trips (complementarity). Thus, complementarity is more likely than substitution for social activities (Mokhtarian et al. 2006; Senbil and Kitamura 2003; Mokhtarian and Meenakshisundaram 1999).

Although the link between social activity travel and ICT has been discussed, social networks characteristics are rarely included. Some exceptions are Carrasco and Miller (2006), Larsen et al. (2006), Tillema et al. (2010) and Frei and Axhausen (2009).

2.2 Social networks

Although an important share of trips is made for social activities and thus induced by social networks, the study of social networks is relatively new to transportation

research. However, in social sciences, there is a rich amount of literature on social networks. In social network studies, different approaches have been employed (e.g. community studies and the social capital approach; the small-world approach; and social network analysis). Community studies and the social capital approach study social networks as traditional local structures based on kinship, friendship and support. Small world analysis attempts to explain the notion that all people are separated by only a short chain of intermediaries. In our study, the social network approach is applied. Social network analysis considers social networks as sets of actors (nodes) and relationships connecting these actors (Wasserman and Faust 1994).

Within social network analysis, social networks can be studied as whole or as egocentric networks. In the case of whole networks, all actors are known beforehand and are regarded as social collectives (organized communities or groups with shared interests), for example school classes, club members, the employees of a company or the inhabitants of a neighborhood (Marsden 2005).

If one is concerned with behavior on the level of individuals instead of a fixed group, such as in the case of travel behavior research, the egocentric approach is more appropriate. Egocentric network studies concentrate on the network of a person (ego) that consists of all the people (or groups) he or she has a relationship with (alters).

The social network can be elicited using a name generator: a certain set of questions that defines who should be regarded as network members (Degenne and Forsé 1999; Marsden 2005). The use of multiple name-generating questions instead of a single one generally results in fewer forgotten social network members (Molin et al. 2008; Brewer et al.

2000). The choice of name generators depends on the purpose of the study.

Generally, four name-generating approaches can be distinguished (Van der Poel 1993; Molin et al. 2008). First, the interaction approach asks for a record of all the alters with whom the respondent (ego) interacts in a certain period (including casual and unknown contacts). In this approach, a (long-term) diary can be used to reveal the social network (Fu 2007). A disadvantage of this approach is that it does not take into account the strength of importance of the relationship. Another approach is the role relation approach: a record of people with whom the individual has a certain role relationship, such as family, relatives, neighbors or friends. Third, the affective approach asks respondents to record the people with whom they have a close personal relationship, or who are especially important to them. Finally, the exchange approach concentrates on people with whom the individual has social exchange, such as help, social activities or talk about worries.

In the field of transportation, different name-generating approaches have been used. Frei and Axhausen (2009) estimated a multilevel structural equation model of contact frequencies with social network members by different modes. They asked the respondents to record alters with whom they discuss important problems, with whom they stay in regular contact or whom they can ask for help. The second name generator asked for persons with whom the respondents spend leisure time every now and then.

Carrasco et al. (2008) and Carrasco and Miller (2006, 2009), drawing on the work of Wellman (1979), asked the respondents to name the persons who live outside their household, with whom they felt very close and somewhat close. Very close people consist of those persons with whom the respondent discusses important matters *or* regularly keeps in touch with, or are there for them if they need help. Somewhat close people were described as those persons who are more than just casual acquaintances, but not considered to be very close. Carrasco and Miller (2009) used a multilevel ordinal model to study how often social network members socialize (face-to-face). Personal and household characteristics, characteristics of "with whom", social network composition and structure and the frequency of telephone, e-mail and instant message contact are used as explanatory variables.

Other studies in the field of transportation that capture the link between social activity travel, ICT and social networks used a limited approach with respect to social networks. Larsen et al. (2006) explored the geographical spread of young people's social networks in the north-west of England and the consequences of this spread for social interaction and travel patterns. They asked their respondents to list up to 10 people they consider most important for their social network.

Tillema et al. (2010) analyzed data from the Netherlands to study face-to-face and electronic communication frequencies between social network members. They conducted an ordered probit analysis to test the effects of geographical and relational distance, social network characteristics, use of ICT and respondent characteristics. Respondents were asked to record five relatives (excluding household members) and five friends with whom they communicate most frequently.

For this paper, we are interested in contact frequencies with all alters that are emotionally close, as these are the most important motivators for social interactions. We will therefore use a set of name-generating questions, similar to those used by Carrasco et al. (2008) in which the affective approach is combined with the exchange and role approach. The name-generating questions used for our study are described in Sect. 4, as well as the additional questions (name interpreters) used to obtain more information about each alter or the ego-alter relationship.

2.3 Factors influencing communication frequency

The maintenance of social networks is realized through communication, either ICT-mediated or face-to-face. This maintenance is therefore an important contributor to travel. To better understand the travel demand for social activities, the communication between social network members needs to be studied.

The needs to communicate or perform social activities differ between individuals. Personal characteristics, such as gender, age and income have been found to affect contact frequency between social network members (e.g. Carrasco and Miller 2009; Tillema et al. 2010; Frei and Axhausen 2009). Moreover, the motivation to perform social activities is also by the alters with whom individuals interact. Contact frequency is thus influenced by the characteristics of the link between ego and alter.

Both geographical distance and relational distance between network members has been found to affect their communication frequency with different modes. For

example, Carrasco and Miller (2009) found higher social activity frequencies for social network members who live closer together.

In the context of the Pew Internet & American Life Project, Boase et al. (2006) found that face-to-face contacts diminish with geographical distance. Telephone calls (mainline and mobile phone) showed no relationship with geographical distance, while the frequency of e-mail use increased with geographical distance. Larsen et al. (2006) found the frequency of face-to-face and telephone contact to decrease with geographical distance, and the frequency of e-mail communication to increase, because of the relatively low costs. Frei and Axhausen (2009) found that face-to-face contact frequency decreases fastest with distance. They found distance to have a negative effect on telephone and SMS contact frequency as well. For e-mail, no effect was found.

Tillema et al. (2010) also found that face-to-face and electronic communication frequencies decline not only with increasing physical distance, but also with increasing relational distance to the social network members. Other studies have also shown that relational role and distance affect the contact frequency via different communication modes. Carrasco and Miller (2009) found that people tend to have more frequent social activities with friends and alters that are very close (emotionally).

Boase et al. (2006) concluded that in the USA, all communication means are used more for core ties (family and close friends) than for significant ties (colleagues and less close friends) in social networks. Frei and Axhausens (2009) showed that work mates are contacted less often face-to-face and by telephone, whereas relatives are contacted more often by telephone. A study by Rivière and Licoppe (2005), comparing text messaging in Japan and France, indicated that in Japan, text messages are sent to all contacts, independent of relational distance. Telephone calls, which are relatively expensive, are mainly used to contact people that are emotionally very close, like parents or partners. In France, SMS messages are mainly sent to the most intimate members of close circles and not to acquaintances or professional contacts (Rivière and Licoppe 2005).

The available literature shows that some research attempts have been made to study the link between social activity travel, ICT and social networks characteristics. However, the knowledge about the factors that influence communication frequency between social network members is rather limited and needs further investigation. Moreover, there might be substantial differences between countries and cultures in these relationships. The purpose of this paper is therefore to explore the factors influencing communication frequency between social network members in the Dutch context.

3 Hypotheses

Although relatively little is known about the influences of ego and ego-alter link characteristics on the frequency of social interaction with different communication modes, some hypotheses can be formed based on the existing literature.

Personal characteristics are assumed to reflect underlying attitudes, needs, opportunities and constraints. It is hypothesized that gender, age and education level of the ego will affect the contact frequency with social network members with different communication modes. Young people may have more needs for face-to-face social contacts. However, the oldest age group is likely to have more time for social contacts. This may result in higher than average face-to-face contact frequencies. Beside age, gender and education level of the ego are likely to have an effect on the contact frequency with social network members. With regard to the use of ICT's, young, highly educated men were the forerunners, probably because these technologies were introduced at their workplace relatively early. Although e-mail and mobile phones have now also been highly adopted by other groups, it is likely that the use is still higher for the forerunners.

In addition, contact frequency is influenced by characteristics of the link between ego and alter. At the level of the ego-alter relationship, the nature and the frequency of social interaction will depend on the geographical and relational distance between ego and alter. Tie strength is a measure for relational distance. We hypothesize that contact frequencies with all modes are higher if social network members have a very close relationship. The duration of the relationship (how long ego and alter have known each other) and the social category (relative or friend) are also to some extent indicators of relational distance.

Furthermore, the frequency of interactions will decrease with increasing costs. The costs of different communication forms depend on the distance between the homes of the ego and the alter. This relationship is strongest for face-to-face contact, less for telephone and SMS and almost negligible for e-mail. We therefore expect to find a large negative effect of geographical distance on face-to-face contact frequency and smaller negative effects on telephone and SMS contact frequencies.

Finally, the endogenous variables are affected not only by the exogenous variables, but also by the other endogenous variables. We hypothesize that the contact frequencies with different modes are complementary at the within level: network members with high ICT-mediated contact frequencies are likely to have a high face-to-face contact frequency as well.

4 Data

In this study, we use a data set that was collected as a follow-up of a larger study involving a two-day social interaction diary. The data were collected between January and June 2008 in a number of neighborhoods in the Eindhoven region in the Netherlands. The social interaction study involved 747 respondents. A subset of 227 indicated to have no objections to be contacted for the follow-up survey. The paper and pencil social network questionnaire was mailed to them, and 116 respondents actually completed the social network questionnaire.

The purpose of the social network questionnaire was to elicit the ego's social network members: the people he or she feels very close and somewhat close to. We used similar name generators to the ones used in the connected lives study (Hogan

et al. 2007). These questions were not only used to define the social network boundaries, but also to measure tie strength (Carrasco et al. 2008):

1. Think about the people you feel very close to. They are people with whom you discuss important matters, or regularly keep in touch with, or that are there for you if you need help. They can be relatives, colleagues or fellow students, neighbors, club members and (other) friends.
2. Think about the people you feel somewhat close to. They are people that are more than just casual acquaintances, but not very close. They can be relatives, colleagues or fellow students, neighbors, club members and (other) friends.

The maximum numbers of social network members that could be recorded were determined in the larger study, in which the same name generators were used to ask the respondents about the number of very strong and somewhat strong ties. The answers indicated that 97% of the respondents know up to 25 people they feel very close to and 96% know up to 40 people they feel somewhat close to. Therefore, in the social network questionnaire, 25 very strong network ties and 40 somewhat strong network ties could be recorded.

In total, among the 116 respondents, 2,854 social network members were recorded. This means an average of 24.6 social network members. However, only 2,696 links will be included in our analyses. The 158 household members that were recorded are not included in the model presented in this paper, since this category is not particularly interesting in relation to travel for social purposes, stemming from contact frequency and geographical distance.

To obtain more information about each alter, name interpreters are used. For this study, we are interested in the contact frequencies between social network members with different communication modes. We hypothesized these frequencies to depend on costs (geographical distances) and relational distance. The name-interpreting questions used in this paper therefore reveal the following characteristics of the ego-alter relationships:

- The frequency of interaction (never; less than once a month; once a month; 2 or 3 times a month; once a week; 2–5 times a week; (almost) every day) for face-to-face, telephone, e-mail and SMS. The ordinal frequencies were converted into the number of interactions per year (the mean of the middle).
- Tie strength (very strong; somewhat strong).
- Social category (recoded into: relative; other (friend)).
- How long ego and alter have known each other (categorical variable recoded into: less than 15 years; 15 years or more).
- The distance between the homes of the ego and the alter (0 km; 0–1 km; 1–2 km; 2–5 km; 5–15 km; 15–30 km; 30–60 km; 60–100 km; 100–200 km, more than 200 km, namely *X* km). The distance categories were recoded to the middle value of the category. For the highest class, we used the number of kilometers that was filled in. For a better model fit, the natural logarithm of the distance (+1) was used.

Although there is some correlation between the explanatory variables (e.g. the duration of the relationship between relatives is usually long), this is not too high to

Table 1 Descriptive statistics of the sample

	Mean	SD
Endogenous variables		
Frequency of face-to-face contact per year	48.74	70.42
Frequency of telephone contact per year	31.51	53.17
Frequency of e-mail contact per year	13.65	33.60
Frequency of SMS contact per year	7.17	26.22
Exogenous variables		
Between level (ego characteristics)		
Male (1 if true, 0 otherwise)	0.30	
Younger than 30 (1 if true, 0 otherwise)	0.08	
Older than 60 (1 if true, 0 otherwise)	0.35	
High education (1 if BSc or higher, 0 otherwise)	0.46	
Within level (tie characteristics)		
Tie strength (1 if very strong, 0 otherwise)	0.44	
Relatives (1 if true, 0 otherwise)	0.44	
Known 15 years or more (1 if true, 0 otherwise)	0.60	
Ln(distance) between homes	2.78	1.70

cause a problem. Therefore, all these variables can be included in our model. However, as our sample size is relatively small (116 respondents), the number of exogenous variables is restricted. For that reason, we recoded some categorical variables into continuous or binary variables even though this means a loss of information. Moreover, only the most important socio-demographic characteristics of the egos (gender, age and education level) can be entered into the model. These variables were collected in the larger study. Table 1 shows the descriptive statistics of the sample.

5 Model structure

To analyze the influences of ego and ego-alter link characteristics on the frequencies of social interaction with different communication modes, and the relationships between these contact frequencies, a multilevel path analysis will be conducted. Path analysis is a special case of structural equation modeling (SEM). SEM is a method that is increasingly used in travel demand modeling (e.g. Lu and Pas 1999; Golob 2001). With this method, a set of equations can be computed simultaneously. The model can have several endogenous variables, which can be functions of the exogenous variables and of other endogenous variables. Whereas SEM can include latent variables (also known as factors, constructs or unobserved variables), path analysis only includes measured variables. As all the variables in our model are observed characteristics or behavior, we use path analysis.

As the data have a hierarchical structure (multiple alters per ego), we cannot treat the alters that belong to the same ego as independent observations. Instead, they have to be treated in clusters. For that reason, we use multilevel path analysis

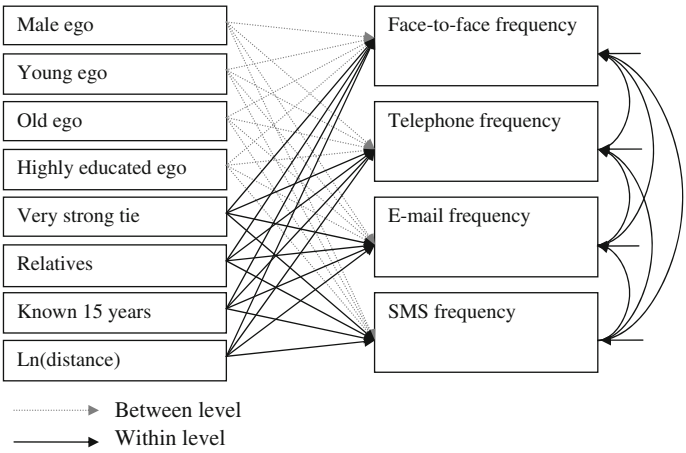

Fig. 1 Path diagram of the model

(Jöreskog and Sörbom 2001). Multilevel models recognize the existence of hierarchy in the data by allowing for residual components at each level. In this study, a two-level model is estimated, which allows for within- and between-respondents variation in contact frequency and which includes residuals at the respondent level and the ego-alter link level. The respondent residuals, often called 'cluster effects', represent unobserved respondent characteristics that affect the outcomes for ego-alter links as they lead to correlation between outcomes for ego-alter links of the same ego. For an in-depth review of multilevel (structural equation) models, we refer to (Hox and Roberts 2010).

In our model, the respondents' personal characteristics gender, age and education are used to explain the between-level patterns. The ego-alter link characteristics (tie strength, type of relationship, duration of the relationship and geographical distance) are used to explain the variance at the within level. A similar analysis was executed by Frei and Axhausen (2009).

The path diagram of the model capturing the links between personal characteristics, ego–alter link characteristics and social interaction frequencies with different communication modes can be seen in Fig. 1. The pathways (arrows) in the path model represent the hypothesized effects. The variables on the right are endogenous variables, hypothesized to be influenced by the exogenous variables on the left. The gray arrows represent the links at the between (ego) level, and the black arrows represent the links at the within level (the ego-alter relationship). At the within level, links are also present between the endogenous variables.

6 Results

This section presents the results of the multilevel path analysis model, which was estimated using the statistical software package LISREL (Jöreskog and Sörbom 2001). A number of different model specifications were tested, with different

(transformations and levels of) explanatory variables. The best final model, identified based on the goodness-of-fit statistics, is presented here. The estimates of the model are shown in Table 2.

The coefficients represent increases or decreases in the number of interactions per year. The interpretation is therefore straightforward. However, the measurements were not very precise, as the number of interactions were measured in an ordinal fashion and recoded to the middle value of the category.

Figure 2 shows the significant effects at the within level (i.e. the ego-alter relationship). With regard to the endogenous variables, the results indicate positive relationships between the contact frequencies by different modes. Accept for the relationship between SMS and face-to-face contact frequency, all relationships are highly significant. Social network members who have high ICT-mediated contact frequencies are likely to have higher frequencies of face-to-face contact as well. This is in line with findings from earlier studies (e.g. Tillema et al. 2010; Frei and Axhausen 2009) and supports our hypothesis of complementarity. This indicates that, since the use of e-mail and mobile phones is still increasing, social trips, which are made for face-to-face contact, are likely to increase as well.

Regarding the exogenous variables tie strength is found to have a positive effect on the contact frequencies with all communication modes. This indicates that social

Table 2 Model estimates

From/to	F2F freq.		Telephone freq.		E-mail freq.		SMS freq.	
	Coeff.	*t*	Coeff.	*t*	Coeff.	*t*	Coeff.	*t*
Within level								
Intercept	21.052	4.874	14.030	4.938	5.861	3.374	2.199	1.872
Telephone freq.	0.411	16.060						
E-mail freq.	0.192	5.142	0.264	9.311				
SMS frequency	0.002	0.033	0.635	17.554	0.232	9.392		
Very strong tie	7.588	3.004	21.625	11.399	6.602	5.030	8.227	7.948
Relatives	−8.132	−3.049	13.549	6.657	−5.873	−4.164	1.203	1.068
Known 15 years	−22.651	−8.369	4.676	2.246	−3.705	−2.563	−1.039	−0.900
Ln(distance)	−12.193	−15.882	−3.620	−6.169	1.114	2.734	−1.407	−4.338
Error variance	3161.88	35.757	1877.38	35.827	908.88	35.850	578.59	35.807
R^2	0.266		0.255		0.055		0.033	
R^2 reduced form	0.158		0.119		0.023		0.033	
Between level								
Male	11.691	1.311	2.475	0.419	8.421	2.341	−1.075	−0.443
Young	38.916	2.607	8.437	0.853	8.044	1.336	8.240	2.027
Old	26.607	3.198	17.009	3.084	−4.292	−1.279	−2.822	−1.245
High education	11.307	1.605	14.608	3.128	9.173	3.230	6.268	3.268
Error variance	1636.82	6.650	689.57	6.417	250.56	6.276	105.87	5.857
R^2	0.143		0.129		0.148		0.158	
R^2 reduced form	0.143		0.129		0.148		0.158	

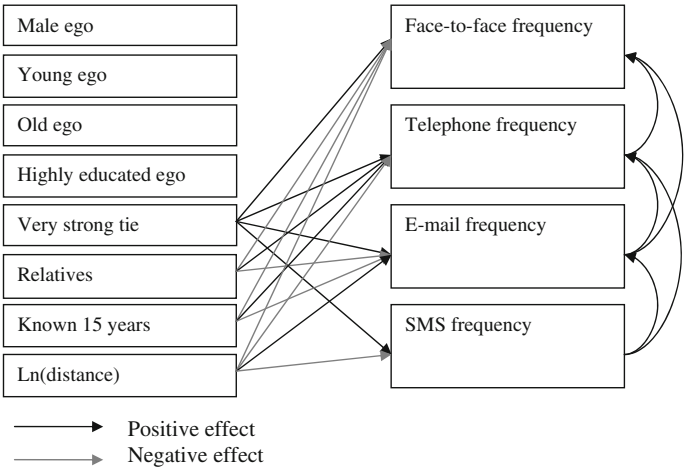

Fig. 2 Significant effects at within level

network members, who are relationally very close, interact more often than somewhat close network members, which is an intuitive finding, that is in line with other studies (e.g., Boase et al. 2006; Carrasco and Miller 2009; Tillema et al. 2010). The largest positive effect is found for telephone contact.

The type of relationship between ego and alter is also found to significantly affect contact frequency. Like Carrasco and Miller (2009), we found lower face-to-face contact frequencies between relatives, compared to friends. Therefore, increased trips may be expected as social networks become less family oriented and more friend oriented. In addition, relatives have lower e-mail contact frequencies and higher telephone contact frequencies compared to friends. Frei and Axhausen (2009) also found that relatives are contacted more often by telephone.

For the duration of the relationship, the results indicate that social network members who have known each other at least 15 years have substantially lower face-to-face contact frequencies compared to social network members who have known each other shorter. The contact frequencies by e-mail are also found to be lower than average for social network members who have known each other 15 years or more. However, they tend to have higher telephone contact frequencies.

As expected, distance has the highest negative effect on face-to-face contact frequency. Telephone and SMS contact frequencies are also found to decrease with increasing distances. These findings are in line with Frei and Axhausen (2009). In the case of e-mail contact, frequency distance is found to have a small positive effect, which was also found by Larsen et al. (2006).

At the between level, the effect of the characteristics of the ego were tested. The significant effects are shown in Fig. 3. With regard to gender, male egos are found to have higher e-mail frequencies with their social network members. This partly supports our hypothesis that the forerunners with regard to e-mail still have higher contact frequencies for this mode. For the other communication modes, the gender effects were not significant. These findings are similar to Frei and Axhausen (2009).

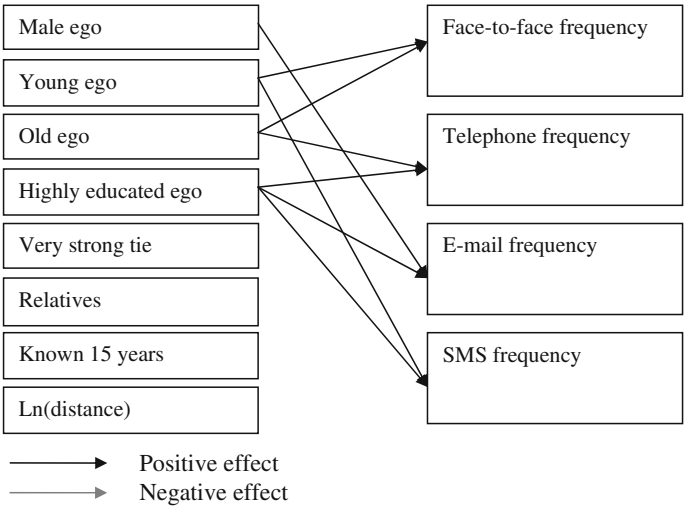

Fig. 3 Significant effects at between level

We also found age to significantly affect communication frequency with social network members. We found that the youngest and the oldest age cohorts are both likely to have higher face-to-face contact frequencies with their social network members. This is in line with Carrasco and Miller (2009), whereas Frei and Axhausen (2009) found a negative coefficient for the oldest age cohort. The youngest age group also has higher SMS frequencies, whereas the oldest group has higher telephone contact frequencies. This indicates that the older generation tends to hold on to the mode they are familiar with, whereas the younger generation is faster in adopting the newer modes.

Finally, we tested the effect of education level on the frequency of social interactions with the different modes. In contrast to Frei and Axhausen (2009) who only found a positive coefficient for e-mail, our results indicate that higher educated egos tend to have higher contact frequencies with all three mediated communication modes. This again supports our hypothesis that the forerunners in the use of ICT still have higher ICT-mediated contact frequencies with their social network members.

The *R*-squares in Table 2 indicate that the explanatory power of the exogenous variables is strong in the case of face-to-face contact frequency and telephone contact frequency and modest for e-mail and SMS contact frequency.

Based on Table 2, it can be calculated that 34% of the unexplained variation in face-to-face contact frequency is associated with respondents (between-level). For telephone, e-mail and SMS, these percentages are 27, 22 and 15%, respectively.

Table 3 shows the goodness-of-fit measures of the model. In general, the goodness-of-fit measures of the model are adequate. The value of Chi square divided by the model degrees of freedom is 1.187. Rules of thumb (e.g., Golob 2001; Washington et al. 2003) suggest that for correct models, this measure should be smaller than 2 or at least smaller than 5, but preferably around 1. Another goodness-of-fit measure is the root mean square error of approximation (RMSEA),

Table 3 Goodness-of-fit of the model

Degrees of freedom	387
Full information ML chi square	459.707
Chi square/degrees of freedom	1.187
Root mean square error of approximation (RMSEA)	0.0118
90% Confidence interval for RMSEA	0.00664; 0.0158
P-value for test of close fit (RMSEA < 0.05)	1.000

which should preferably be between 0.02 and 0.05 (e.g. Washington et al. 2003). Our model has a RMSEA of 0.012.

7 Conclusion and discussion

This paper has analyzed the frequency of social interaction by different communication modes (face-to-face, telephone, e-mail and SMS) between social network members. Based on social network data collected in 2008 in the Netherlands among 116 respondents, a multilevel path analysis model was estimated. At the between level, characteristics of the ego (gender, age, education level) explain the frequencies, and at the within level, characteristics of the ego-alter relationship (the geographical distance between their homes, tie strength, duration and type of relationship) serve as explanatory variables.

Overall, the findings are largely consistent with our hypotheses and with earlier findings in the literature and offer further insights into understanding social travel behavior. At the level of the ego-alter relationship (within level), we found positive relationships between the contact frequencies by different modes, supporting our hypothesis of complementarity. Moreover, we found that relational closeness (strength of tie) has a positive effect on contact frequency with all modes. The contact frequency was found to decrease as costs (related to distance) increase. Corresponding to our hypothesis and findings from other studies, we found geographical distance to have a strong negative effect on face-to-face contact frequency, a smaller negative effect on telephone and SMS frequency and a small positive effect on e-mail contact frequency. The duration of the relationship (how long ego and alter have known each other) and the social category (relative or friend) are also found to affect contact frequency. Relatives and network members who have known each other at least 15 years were found to have lower face-to-face and e-mail contact frequencies and higher telephone contact frequencies than average.

At the level of the ego (between level), we hypothesized that the earlier adopters of ICT's (young, highly educated men) would still have higher ICT-mediated contact frequencies with their social network members. This hypothesis is partly supported. In contrast to Frei and Axhausen (2009) who only found a positive coefficient for e-mail, our results indicate that higher educated egos tend to have higher contact frequencies with all three mediated communication modes. Men

were found to have a positive coefficient for e-mail frequencies, and younger people have higher SMS contact frequencies than the older cohorts.

With regard to face-to-face contact, we found higher frequencies for the youngest and the oldest cohorts. This is in line with Carrasco and Miller (2009), while Frei and Axhausen (2009) found a negative coefficient for the oldest age cohort. In addition, the oldest group has higher telephone contact frequencies, suggesting that the older generation tends to hold on to the mode they are familiar with, whereas the younger generation is faster in adopting the newer modes.

Our results are relevant for transport policy. The finding of complementarity between the different communication modes is important. It indicates that, since the use of e-mail and mobile phones is still increasing, face-to-face interactions, requiring social trips, are likely to increase as well. Policy makers should therefore reckon with increasing (social) travel. Moreover, ICT's are important for the maintenance of social networks that are becoming more geographically spread. Although the frequency of face-to-face communication (and trips) decreases with geographical distance, long-distance trips may increase as new ICT's are now providing better and cheaper ways to maintain strong social relationships over long distances. Finally, our results show that the oldest age group has a higher face-to-face contact frequency than average. Therefore, social travel demand is likely to increase as the number of senior citizens in our society is growing (Van den Berg et al. 2010).

Although the analyzed links can help to better understand social travel behavior, a number of aspects deserve further research. Since our dataset is relatively small (116 respondents), the number of explanatory variables in our model was restricted. For that reason, we recoded some categorical variables into continuous or binary variables even though this meant a loss of information.

Moreover, there are several factors that may affect communication frequencies between social network members that were not included in this study because of the small sample size. First, household characteristics such as income and household type were collected but not included in this paper. The same goes for social network composition. Third, the effect of gender- and age similarities between ego and alter (homophily) on communication frequency might give further insight into contact frequencies. Spatial factors (available meeting places, urban density) may also play a role in the frequency of social interaction. Moreover, the main purpose (or content) of the social interactions was not taken into account in this study, whereas this is likely to affect communication frequency (Tillema et al. 2010).

In addition, interaction effects between geographical distance and relational distance and the duration of the relationship might be examined. Related to this is the topic of social network dynamics, which is now starting to appear in our field of research (Sharmeen et al. 2010). Communication frequency with social network members changes over time, as ties become stronger or weaker or even end, for instance after a lifecycle event such as changing home location. This is a topic that deserves further research.

Finally, the literature indicates that the relationship between social network distances and communication frequencies with different modes might differ substantially between different cultures. Although our findings are highly in line

with findings from Zürich (Frei and Axhausen 2009), this does not imply that results of other socio-cultural and spatial contexts will be similar as well. Therefore, similar analyses from other countries (outside Europe) would be desirable.

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