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A Comparative Study of Contact Frequencies Among Social Network Members in Five Countries

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Abstract
As face-to-face and ICT-mediated social interaction patterns are relevant to explain (social) travel behavior, the objective of this paper is to study comparatively the factors that influence social interaction frequency via different communication modes. The analysis is based on seven recent data collections on personal social networks from Canada, Chile, Switzerland, the Netherlands, and Japan. A multilevel-multivariate mixed model that explicitly accounts for the hierarchical nature of the data is used to jointly analyze contact frequency patterns across all samples. We show the existence of very consistent associations across samples between individual and relational characteristics and social interactions such as age, network size, distance and emotional closeness. At the same time, for other characteristics such as gender and relationship type, among others, effect patterns were less clear, differences that might be explained by intrinsic contextual characteristics as well as methodological differences among studies.

Keywords: Social networks, personal networks, social interaction, communication frequency, social activity travel behavior.

1. INTRODUCTION

Social activities are responsible for a substantial share of trips *(1)*. These social trips are influenced by new ways of social interaction made possible by the rise of new information and communication technologies (ICT). From a transportation perspective, the study of both face-to-face and ICT-mediated interactions is of importance since these changing communication patterns might affect demand dynamics on urban environments and transportation systems. To study this, data collection efforts have been made in Toronto, Canada *(2)*, in Zurich *(3, 4)*, and Switzerland nationwide *(5)*, in Eindhoven, the Netherlands *(6)*, in Concepción, Chile *(7)* and in the Greater Tokyo Area, Japan *(8)*, among others. In all seven studies, the personal networks approach has been used to capture information on individuals (egos) and their social network members (alters). Analyses from each of these studies have indicated that incorporating social network characteristics is crucial in studying social activity-travel behavior. However, there might be substantial differences between countries and cultures in terms of communication patterns, social activity and travel behavior. The aim of this paper, is therefore, to study comparatively the factors that influence social interaction frequency among social network members via different communication modes in five different countries on three continents.

The rest of the paper is structured as follows. The next section discusses the theoretical framework. Section 3 summarizes data collection efforts and its respective descriptive statistics. Section 4 describes methods and results of the statistical model used. The final section discusses the key findings of this study and future avenues of research.

2. THEORETICAL FRAMEWORK

Social networks and travel

In general, social networks research in the transportation field can be classified into two streams: (i) the relationship between social influences and activity travel decisions, and (ii)

the relationship between social networks and social-activity travel *(9)*. The discussion below will be largely focusing on the second stream of research, as it is the most relevant to the analysis presented in this article.

To analyze social networks and social-activity travel, researchers have largely relied on the social networks approach, developed and used for decades in sociology. Particularly relevant to this study is the egocentric approach, in which personal network members (alters) are elicited for the given individuals (egos), through the use of name generators, that is, questions designed to help egos elicit the names of these alters *(10)*. Using this approach, several data collections efforts have been carried out *(2–8, 11, 12)*

To collect more information on each ego-alter relationship, additional questions (name interpreters) are used. These questions may include age and gender of the alter, to assess homophily (the tendency to interact with people similar to you). Other questions include tie strength, duration, and relational roles. Social network data collection in the transportation field also include geographical distance between the homes of egos and alters and contact frequency by different modes (face-to-face, telephone, SMS, email, SNS), as these are important aspects of social activity-travel behavior. An in-depth comparison of the distance patterns between social network members in Toronto, Zurich, Eindhoven, Switzerland, and Concepción is reported in Kowald et al. *(13)*. In addition to adding two new datasets, this article will complement the study by Kowald et al. *(13)* by analyzing social interaction frequency in different socio-cultural contexts.

Factors influencing communication frequency

To maintain their social networks, people need to communicate and meet each other. This contact can include face-to-face meetings as well as contacts mediated by different ICT tools. Previous studies have shown that for leisure or social activities, the effect of ICT is generally complementary, in that ICT use might generate new travel by stimulating the demand for new activities *(14–19)*.

Communication modes and frequencies, however, vary among individuals and relationships. Past research has indicated that contact frequencies are influenced by individual and household characteristics, time constraints, and availability (and costs) of mobility and communication tools.

Being young, highly-educated and male has been associated with higher contact frequencies with ICT-mediated modes such as e-mail and SMS *(15, 17)*. Household income has been associated with higher face-to-face interactions *(6, 20, 21)*, a rather intuitive findings given larger budgets to spend on interactions. On the other hand, the presence of children in the household has been associated with shorter out-of-home, face-to-face social activities *(20)*, and face-to-face interaction frequencies *(6, 22)*, likely as a result of time-budget constraints associated with childrearing.

With respect to access to mobility tools Banister and Bowling *(23)* found that elderly people with access to a vehicle (and people with access to adequate local transport) were likely to undertake more (face-to-face) social activities. On the other hand, Farber and Páez *(24)* found that people who are more automobile-reliant tend to participate in fewer social activities.

Social network characteristics have also been associated with communication frequencies. People with larger networks have been found to have more social interactions *(20, 25)*. Other studies, however, have suggested that communication frequencies might actually be reduced in order to maintain larger social networks *(26)*.

Regarding ego-alter relationships, emotional closeness has been positively associated with interaction frequencies irrespective of modes *(17, 27)*, while in terms of relational roles, lower face-to-face and telephone contact frequencies between work mates, and higher telephone contact frequencies between relatives have been reported *(15)*. Van den Berg et al. *(17)* also found higher telephone contact frequencies between relatives, and lower face-to-face and email frequencies compared to friends.

In terms of homophily, analyzing contact frequency by different modes, Carrasco *(18)* only found a significant effect for gender homophily on face-to-face interaction frequency. Sharmeen et al. *(22)*, analyzing the frequency of face-to-face social interaction, found a positive effect for gender and education level homophily. They found however a negative effect for age homophily. Parady et al. *(19)* found negative effects for both age and gender homophily on face to face and ICT contact propensity.

Another important variable is the geographical distance between egos and alters. In spite of the development of new ICT tools and decreasing prices for telecommunication, geographical distance is still an impediment for interaction in the post-Internet era *(28)*. Perhaps the most consistent finding in the literature is the negative effect of distance on face-to-face interaction frequency *(3, 11, 17, 19, 29, 30)*. These studies also found a negative effect of distance on telephone contact frequencies, except for Boase et al. *(30)* who found no relationship. On the other hand, email contact frequencies have been found to increase with geographical distance by all studies except for Frei and Axhausen *(15)* who found no significant relationship.

The literature shows that the study of face-to-face and ICT mediated communication and the link with social activity-travel has received some interest in recent years. Although these studies have indicated a number of factors that influence social interaction behavior, the review has also shown that communication patterns differ among countries and cultures. Therefore, an in-depth comparison of the factors that influence the frequency of interaction through various communication tools in different socio-cultural contexts will increase our understanding of the maintenance of social networks and related social travel demand. As such, the analysis presented in this article is guided by the following research questions:

1. What are the differences in social interaction patterns between societies and nation-states?
2. What role does distance play in these patterns?
3. How are personal and network characteristics associated with social interaction patterns?
4. To what extent are these associations contextual- or culture-specific, or consistent across societal and cultural backgrounds?

3. DATA COLLECTION

Toronto, Canada - TOR

As part of the "Connected Lives Study", data were collected between May 2004 and April 2005 in the East York area of Toronto, Canada. The study consisted of two stages: a survey of a random sample of 350 people from East York, and interviews of a sub-sample of 87 respondents (86 valid responses). The interviews were used to elicit respondents' social networks. Respondents were asked to name the people who live outside their household, with whom they felt very close and somewhat close. "Very close" alters 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" alters consisted of "more than just casual acquaintances, but not very close". Data on alters' age, gender, type of relationship, and home location was collected. Contact frequency by mode was measured on an ordinal scale. See Hogan et al. *(2)* and Carrasco et al. *(31)* for more information.

Zurich, Switzerland (1) – ZUR (1)

In Zurich, Switzerland, social networks data were collected between December 2005 and December 2006. A random sample of respondents was recruited by telephone. The data collection itself consisted of a written questionnaire containing socio-demographic and travel related questions and a face-to-face interview to collect information on social networks. To elicit very close social network ties, a similar name generator was used as in the Connected Lives Study in Toronto. A second name generator asked for persons with whom the respondents plan to and actually spend leisure time. Data on 307 respondents was collected. Data on alters' relationship type and duration, and home location was collected. Contact frequency by mode was measured on a metric scale. For more information, see Axhausen and Frei *(3)*

Eindhoven, The Netherlands - EIN

Between January and June 2008, social network data were collected in Eindhoven and a number of surrounding villages. The data were collected as part of a larger study that consisted of a two-day social interaction diary and a paper-based questionnaire to capture the respondents' social networks. The social interaction study involved 747 respondents. The social network questionnaire was completed by a subsample of 116 respondents. The name generating questions used in this study are similar to those in Toronto. Respondents could record up to 25 very close and 40 somewhat close social network members. Data on alters' age, gender, type of relationship, and distance between home locations of ego and alter was collected. Contact frequency by mode was measured on an ordinal scale. For more information, see van den Berg et al. *(6)*.

Concepción, Chile - CCP

In Concepción, Chile, characteristics of social activity travel and personal networks were collected between August 2008 and April 2009. Data about personal networks were collected through semi-guided interviews with 241 respondents in four distinctive neighborhoods. The same name generators were used as in Toronto. Data on alters' gender,

age, type of relationship and home location was collected. Contact frequency by mode was measured on an ordinal scale. For more information, see Carrasco and Cid-Aguayo *(7)*.

Switzerland - SWI

In Switzerland, social networks data was collected between January 2009 and March 2011. In this study, snowball sampling was used. A stratified random sample of the Zurich population was used to recruit 40 initial respondents. In a paper-based questionnaire, respondents were asked to record the alters with whom they make plans to spend free time. In addition, a second name generator was used, asking about other people with whom important problems are discussed. The elicited social network members were then asked to fill out the social network questionnaire as well. After five iterations a total of 743 responses were collected. The attributes collected for each alter included age, gender, type and duration of relationship and home location. Contact frequency by mode was collected on a metric scale. For more information, see Kowald and Axhausen *(5)*.

Zurich, Switzerland (2) – ZUR (2)

A second social network survey in Zurich, Switzerland was conducted as part of a larger mobility survey in 2017. The survey consisted of two parts: a first part focusing on mobility behavior, mobility tool ownership, etc. The second part focused on social networks. For the second part of the survey, data on 1,536 respondents was collected. The attributes collected for each alter include age, gender, type and duration of relationship and home location. Contact frequency by mode was collected on a metric scale. For more information, see Guidon et al. *(4)*.

Greater Tokyo, Japan - TYO

In the Greater Tokyo Area (the Tokyo metropolis and the prefectures of Saitama, Chiba and Kanagawa) a personal networks survey was conducted in early 2019 on 1000 randomly sampled residents of six municipalities in the Greater Tokyo. The survey mediums were web and paper. The name generators used to elicit network members were similar to the ones used in the Switzerland data. Data on 217 respondents was collected. The attributes collected for each alter included age, gender, employment and marital status, type and duration of relationship, tie strength, and home location. Contact frequency by mode was collected on an ordinal scale. For more information, see Parady et al. *(8)*.

4. DESCRIPTIVE STATISTICS

General statistics of each survey location are presented in Table 1. Statistics from Canada, The Netherlands, Switzerland and Japan show relatively small differences in wage level and transportation costs, although the city of Zurich exhibits much higher wage levels and transportation costs. In the case of Concepción, Chile, wage levels are considerably lower.

Table 2 summarizes ego characteristics for each dataset. Although the table is self-explanatory, some differences among samples are worth highlighting. In particular, differences in internet and mobile phone access are likely related with the year the surveys were conducted, which explains the low market penetrations rates in the Toronto sample, and

Zurich (1). Although internet and mobile access was not measured in the Zurich (2) and Greater Tokyo samples, given that these surveys are very recent, it can be expected that access is very high.

Table 1: Country/city specific statistics

Variable	TOR[a]	ZUR[b]	EIN[a]	CCP[a]	SWI[a]	TYO[c]
Population (1,000s)	5,500	394	213	292	7,900	36,131
Population density	3,972	4287	2,407	1,318	188	2,664
Wage level Gross (Base: New York=100)	74.2	131.1	77	21.2	115.1	79.2
Wage level Net (Base: New York=100)	80.4	141.8	72.7	24.3	124.2	85.3
Bus/Tram/Metro (US$, 10 km trip ticket)	2.4	3.8	2.6	0.7	2.7	2.3
Taxi (US$ per 5km)	8.2	27.6	17.2	7	21.2	17
Train (US$, 200 km single ticket)	45.4	73.4	31.2	11.7	44.8	32.9
Average cost of fuel per liter (US $)	0.89	2.0	1.72	1.06	1.22	1.6
Average Mid-Price Car (US $)	19,933	45,200	21,140	11,416	22,240	26,300
Tax on Car (US $/Year)	64	426	289	210	255	495

Source: UBS, Wealth Management Research (2006, 2012, 2015, 2017)
[a] Wage level and transport costs compiled from 2006 data at country level
[b] Wage level and transport costs compiled 2012, 2015 data for Zurich City; population data from 2012
[c] Wage level and transport costs compiled from 2012, 2017 data for Tokyo Metropolis; population data from 2015

Table 2: Survey information and socio-demographic characteristics of the respondents

	TOR	ZUR (1)	ZUR (2)	EIN	CCP	SWI	TYO
Year of the survey	2004-5	2005-6	2017	2008	2008-9	2009-11	2019
Survey medium	Paper/ Interview	Paper/ Interview	Web/ paper	Paper	Paper/ Interview	Paper	Web/ paper
Number of respondents	84	265	1,536	106	241	426	217
Variable	**Sample (%)**	**Sample (%)**	**Sample (%)**	**Sample (%)**	**Sample (%)**	**Sample (%)**	**Sample (%)**
Male	39.8	42.3	50.4	31.1	39.8	41.1	54.4
Young (<30)	9.8	19.6	12.6	7.5	24.1	5.9	12.4
Middle (30-60)	69.5	44.2	56.9	59.4	58.5	73.5	52.5
Old (>60)	20.7	36.2	30.6	33.0	17.4	20.6	35.0
Living with partner	61.9	48.3	85.3	72.6	58.1	80.3	55.8
Child(ren) under 18	46.4	-	-	34.0	61.8	36.6	20.7
Secondary education or lower	18.3	7.9	16.8	17.0	44.8	1.6	30.9
Technical education	28.0	70.2	42.7	34.0	24.5	48.6	23.0

	TOR	ZUR (1)	ZUR (2)	EIN	CCP	SWI	TYO
University education	53.7	21.9	40.5	49.0	30.7	49.8	46.1
Low HH-income	29.4	24.5	36.8	36.8	43.8	10.1	22.4
Medium HH-income	41.2	47.9	37.5	25.5	25.1	39.2	57.9
High HH-income	29.4	27.5	25.7	37.7	31.1	50.7	19.7
1 or more cars	-	63.4	84.7	83.0	56.4	89.0	57.4
Season ticket	-	38.9	64.9	42.5	-	82.9	-
Internet access	79.8	67.9	-	90.6	63.9	97.9	-
Mobile phone access	42.3	65.7	-	94.3	86.3	95.8	-
	mean	**mean**	**mean**	**mean**	**mean**	**mean**	**mean**
Age	50.3	50.7	50.5	51.6	42.8	50.1	50.1
Work hours	22.5	-	40.0	14.6	21.8	-	-
Years in current location	12.8	-	20.7	13.3	16.4	25.4	-

Table 3 summarizes the social network characteristics in each dataset and contact frequencies by mode. In terms of social network size, networks in the Toronto, Eindhoven, Concepción and Switzerland samples are quite similar, while networks in the Zurich (1), Zurich (2) and the Greater Tokyo samples are considerably smaller. Although socio-cultural factors might partly explain these differences, there are several methodological factors that might also affect the number of elicited alters, such as the name generators, survey mediums (i.e. in-person interview, self-response paper, or self-response web) and sampling methods used.

In terms of alter characteristics, the distribution of alters across age groups shows similar patterns to the distribution of the respondents' age, except for the Concepción study where the share of alters in the youngest age class is higher than the share of egos in that class. The Zurich (1) study did not include questions on alters' sex and age. Regarding relationship type, average shares of immediate family in the network vary between 13.4% and 32.5%, being the lowest in the Switzerland sample. The average shares of extended family range between 11% and 25 %, with higher shares in Eindhoven (25.1%) and Concepción (23.6%). In terms of relationship duration, the Concepción sample has a relatively large proportion of 'new' ego-alter relationships (known each other less than one year). This may be related to the larger shares of young egos and alters in the sample. Finally, regarding the distance between home locations of ego and alter the results show different patterns for each dataset as well. The proportion of local contacts (<2 km) range between 17.9% and 30.1%. Toronto shows a relatively large share of long-distance social ties (>100 km), whereas this share is lowest in case of Switzerland (6.8%), followed by the Greater Tokyo (8.7%).

Interaction frequency is summarized in terms of three communication modes: face-to-face, by telephone, and via Internet. Internet includes communication means such as e-mail, short-messaging services (SMS), and for the two most recent datasets (Zurich (2) in 2017 and Greater Tokyo in 2019), also social networking services (SNS), and video chats. Regarding face-to-face contact, in the Concepción sample more than half (55.1%) of the ego-alter pairs meet each other weekly, whereas this share is roughly one third for Toronto, Zurich (2), Eindhoven and the Greater Tokyo (24.3% to 32.4%), 19% for Zurich (1) and only 8.2%

for Switzerland. In the Swiss dataset the largest share of ties meets less than once a month. There is also great variation in the share of ego-alter pairs that meets less than once a year, with lowest values in the Eindhoven sample (1.3%) and Zurich (2) showing the highest percentage at 35.2%.

Table 3: Characteristics of personal networks

	TOR	ZUR (1)	ZUR (2)	EIN	CCP	SWI	TYO
Number of alters	1,019	3,156	19,231	2,452	5,038	6,982	1,448
Mean network size[a]	23.8	11.9	15.1	23.9	20.9	21.6	9.9
Personal network variables	**Sample (%)**	**Sample (%)**	**Sample (%)**	**Sample (%)**	**Sample (%)**	**Sample (%)**	**Sample (%)**
Very close	54.0	52.4	88.7	43.0	51.3	28.9	38.0
Somewhat close	46.0	47.6	11.3	57.0	48.7	71.1	62.0
Male	42.1	-	45.7	41.4	45.9	43.1	40.9
Young (<30)	11.8	-	14.5	13.0	32.2	9.2	17.3
Middle (30-60)	65.3	-	54.0	53.7	52.9	67.2	45.3
Old (>60)	22.9	-	31.5	33.3	14.9	23.6	32.7
Immediate family	25.4	18.3	32.5	18.8	20.2	13.4	21.8
Extended family	11.0	12.7	6.8	25.1	23.6	11.1	11.3
Friend or other	63.6	69.0	60.8	56.1	56.2	75.5	66.9
Known <1 year	-	0.6	0.4	1.4	14.6	2.0	3.9
1-10 years	-	36.7	25.7	37.4	25.8	28.5	32.5
>10 years	-	62.7	73.9	61.2	59.6	69.5	63.6
Distance < 2km	19.3	26.0	30.1	17.9	36.1	24.6	29.7
Distance 2 – 30km	42.9	43.2	44.7	47.6	41.3	54.1	45.4
Distance 30 – 100km	9.5	12.4	13.9	17.3	2.4	14.5	16.2
Distance > 100km	28.3	18.4	11.3	17.2	20.2	6.8	8.7
Contact frequencies by mode	**Sample (%)**	**Sample (%)**	**Sample (%)**	**Sample (%)**	**Sample (%)**	**Sample (%)**	**Sample (%)**
Face-to-face							
Weekly	32.4	19.0	24.3	28.8	55.1	8.2	27.9
Monthly	25.1	25.5	21.1	31.0	24.9	27.6	25.5
Less than monthly	31.5	44.5	19.2	38.9	14.4	57.8	44.1
Less than yearly	11.0	11.0	35.3	1.3	5.7	6.4	2.6
Telephone							
Weekly	35.9	13.0	14.4	16.1	34.5	6.5	10.7
Monthly	32.2	29.9	16.5	30.2	20.0	20.6	16.2
Less than monthly	18.1	34.8	9.5	43.1	15.4	52.1	31.6
Less than yearly	13.7	22.2	59.6	10.6	30.1	20.8	41.5
Internet							
Weekly	16.4	4.3	25.3	4.8	12.5	3.5	27.3
Monthly	17.4	10.0	16.4	19.3	5.3	12.1	23.6
Less than monthly	8.5	18.1	14.1	26.7	5.1	35.7	26.5
Less than yearly	57.7	67.5	51.0	49.2	77.2	48.8	22.6

[a] Values exclude isolates (egos who did not report any alters). Small differences between networks sizes reported in this table and values reported in individual studies are due to the difference in the number of observations used.

With respect to telephone and internet contact frequencies, patterns not only differ by country but also by survey year. For the two most recent datasets, a considerable increase in weekly internet contact frequency can be observed (>25%). Similarly, these samples exhibit the largest shares of no contact by phone less than once per year (> 41%). These differences highlight the increasing market penetration of internet-based communication in recent years, and the move away from phone-based contact.

Figure 1 shows the mean face-to-face, telephone and Internet interaction frequencies for egos and alters with up to 100km distance between them for each of the seven datasets. This is of importance for the analysis, as the dominant part of all ego-alter distances in each dataset is shorter than that. The results show that for all datasets the face-to-face interaction frequencies decrease with increasing geographical distance between homes of ego and alter. Regarding telephone and internet interaction frequencies the results in Figure 1 show no clear relation between frequency of interaction and geographical distance in the 100km range, which is expected given the low marginal costs of these modes given distance. Similarly, Figure 2 shows mode-specific communication frequencies for distances of up to 10,000 km. The plot for face-to-face meetings clearly shows a decreasing trend for all datasets with increasing distance. On the other hand, telephone and internet-based contact frequencies are largely unaffected by distance.

Figure 3 shows the mode specific market shares by distances of up to 10,000 km. All three communication modes are clearly affected by increases in distance, and patterns are very similar among all datasets, with some clear temporal differences. The shares of face-to-face meetings are dominant for distances of up to 10 km and stay very important even at long distances of 1,000 km and above. However, the share of face-to-face interactions clearly decreases with increasing distance in all data sets. For the older datasets (all datasets except Zurich (2) and Greater Tokyo), at distances of around 10 km, similar telephone contact shares can be observed, increasing up to the 100 km range, where they flatten. For the most recent datasets, a considerable drop in phone market share is observed with both curves almost flat, and below a 30% share irrespective of distance. On the other hand, market shares of internet-based communication modes increase consistently with increasing distances, with considerable differences in share for the most recent datasets. In case of the Greater Tokyo sample, at 10 km the market share is almost 50%.

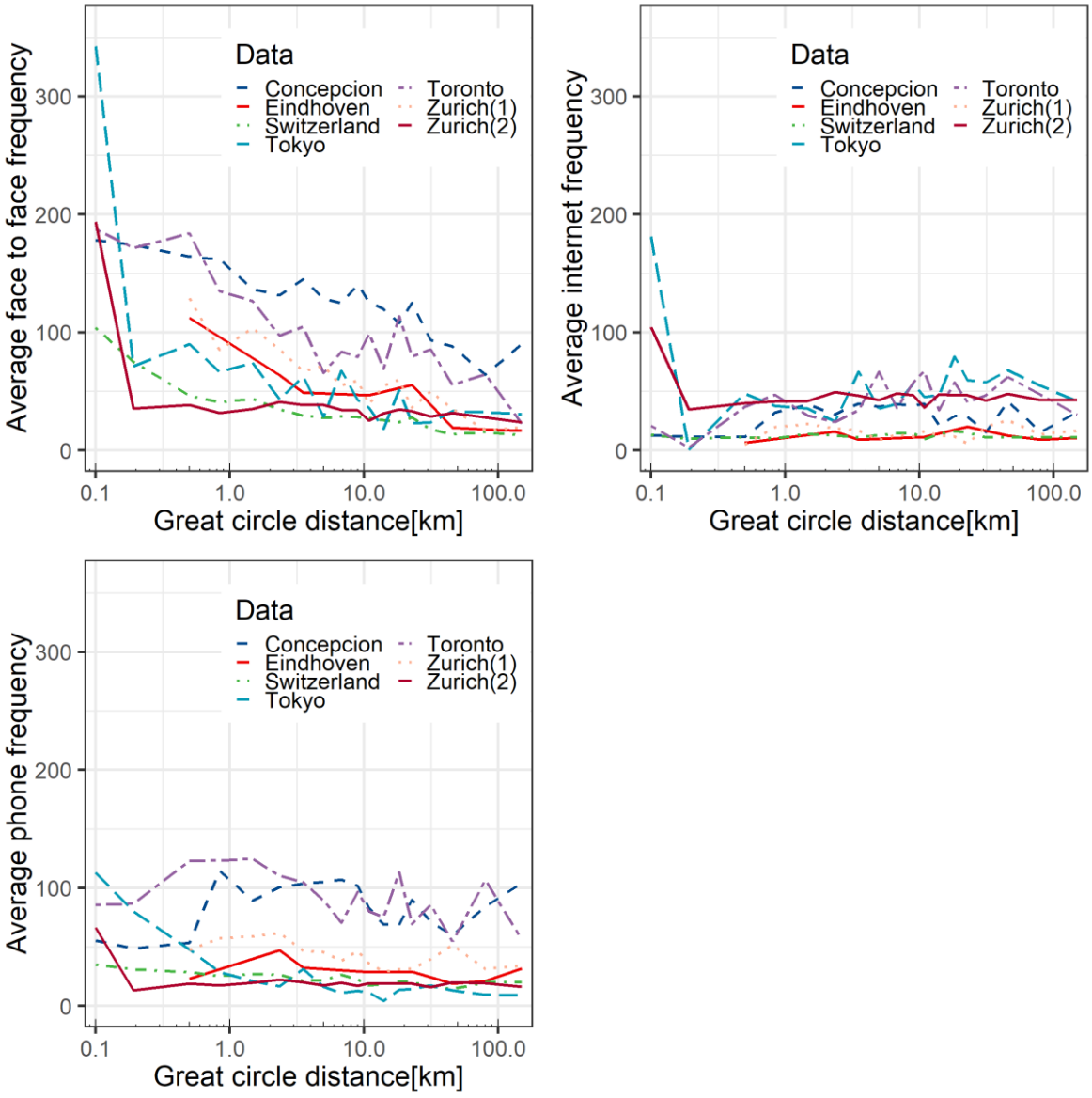

Figure 1 Yearly average interaction frequency by geographical distance of up to 100 km

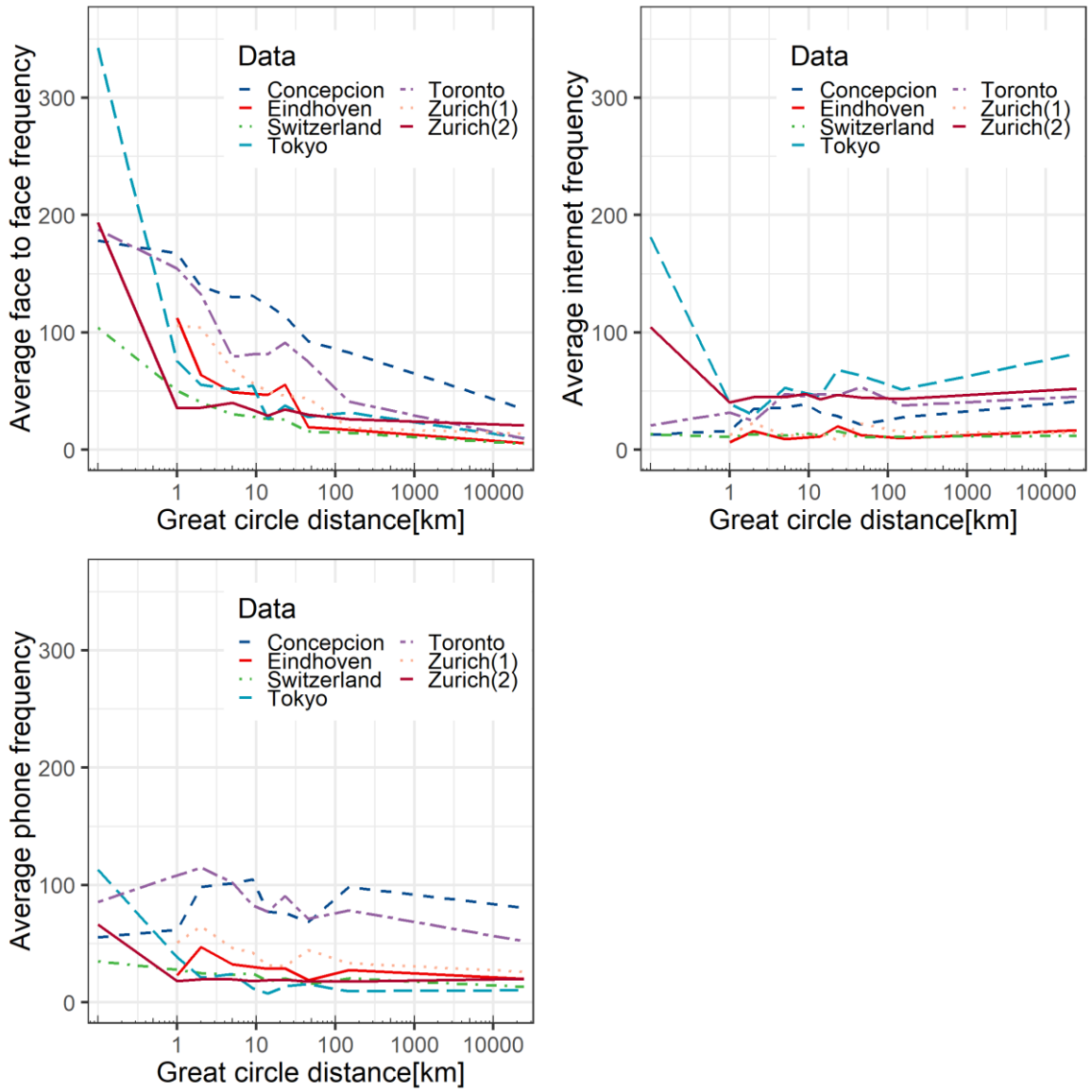

Figure 2 Yearly average interaction frequency by geographical distance of up to 10,000 km

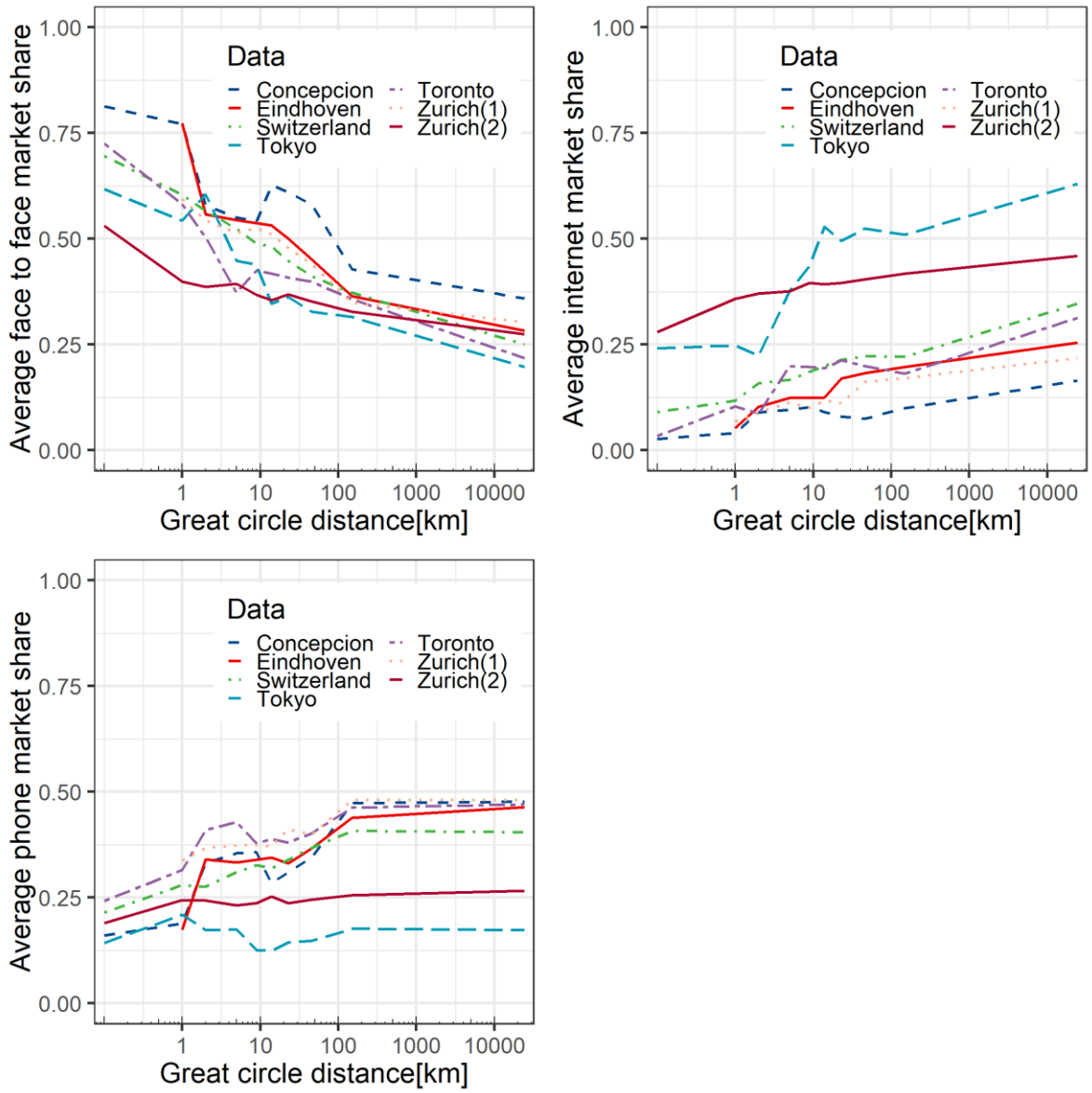

Figure 3: Mode specific market shares by geographical distance

5. MODEL BASED COMPARISONS AND RESULTS

To further evaluate the effects on communication frequencies and social travel, a multilevel regression model of yearly contact frequencies by mode is estimated. Multilevel linear regression modelling is used given the hierarchically clustered nature of the data. Note that these regression techniques require models to have complete case observations without missing values, as such, only observations with complete information are used for estimation. This also restricts the potential set of explanatory variables to variables that can be found in all seven datasets.

The datasets studied in this paper can be structured in three levels. Level 1 includes information on the characteristics of each alter and individual ego, level 2 includes the ego's socio-demographic as well as aggregated personal network characteristics, level 3 includes information about the study area where each data collection took place. In this analysis we use random intercepts and slopes to account for intrapersonal and interpersonal variations as well as correlation among contact modes. A specific characteristic of our study is the right skewed distribution of the dependent variables, because mode-specific communication frequencies between egos and alters include predominately low and only few (very) high values. The residual maximum likelihood estimator (REML) was used for model estimation.

A logarithmic transformation was employed to address the skewed distance and communication-frequency distribution in each dataset. Distances with zero km were recorded due to rounding and aggregation, considering that not all data bases are geocoded at the household level, but to higher level units such as blocks and street corners. In order to avoid infinite values and the loss of observations, an empirically calculated constant was added to the smallest 2% of all distances in each dataset. Table 4 presents a comparative analysis of effects on log yearly contact frequencies by mode. For legibility reasons only coefficients significant at least at the 0.1 level are reported.

Regarding ego-level variables, a higher education degree is associated with higher internet contact frequencies, although the coefficients are not significant for the Switzerland, Zurich (1) and Greater Tokyo samples. This positive association might be a result of more geographically dispersed networks. Kowald et al. *(13)* reported positive associations between higher education and greater distances between contacts, arguing that higher education both enables and demands more travelling in professional life and might result in a more diverse geographical biography. As such, these ties are likely maintained through low-cost internet-based communication.

The effect directions among significant age coefficients is consistent across all samples given contact modes. On average, people in age cohorts of 30 and over tend to have lower face-to-face contact frequencies, than their "under 30 years old" counterparts. This effect can be explained by the fact that younger cohorts tend to have larger discretionary time budgets, due to factors such as not having children, etc. No significant effects, however, are observed in the Concepción and Greater Tokyo samples. The clearest age pattern, however, is that of internet contact frequency, where the older the cohort, the larger the magnitude of the effect. This indicates a decreasing willingness to adopt new technologies.

Household income was positively associated with higher face-to-face frequencies in the Toronto, Eindhoven and Zurich samples, consistent with findings from the literature that suggests higher monetary budgets might facilitate physical interaction. Larger networks are negatively associated with contact frequencies irrespective of mode, although in some cases the coefficients are not significant. Although effect magnitudes are not very large, this supports the hypotheses that to some extent, larger networks impose heavier burdens on individuals to maintain ties, which results in lower contact frequencies *(26)*.

In terms of ego-alter relational characteristics, mixed associations are observed regarding relationship type. These effects, however, need to be interpreted with care because of the interactions with distance and emotional closeness. More specifically, these

coefficients capture the effects of "somewhat close" relations at a 1km distance, compared against "somewhat close" non-relatives. While these effect directions differ among datasets and contact modes, the significant effects of emotional closeness are very consistent. With the exception of the Zurich (1) sample, emotional closeness is positively associated with contact frequencies irrespective of mode, with differences in magnitude given relationship type. Furthermore, when looking at effect magnitudes, emotional closeness has relatively larger effects on phone contact frequencies, suggesting that people are willing to incur in higher costs for communication with emotionally closer members of their networks. In the particular case of the Greater Tokyo, emotional closeness is only significant for internet contact with immediate family.

Distance is negatively associated with face-to-face contact, with variations in magnitude given relationship type. Phone contact frequencies also tend to decrease with increasing distances. Contact with non-relatives in Concepción is the exception, where the phone might serve as a substitute for face-to-face contact, given increasing distances. A clearer substitution pattern, however, is observed for internet contact. With the exception of Zurich (2), increasing distances are associated with higher non-relative contact frequencies. This was also the case for contact with relatives in Concepción, Switzerland, Toronto and Zurich (2) samples. On the other hand, in the Greater Tokyo area, people tend to have lower internet contact with relatives given increasing distances, that is, no substitution effect is observed. Given that blood ties are more likely to be maintained regardless of distance *(13)*, it is plausible that in the Greater Tokyo case, egos only use internet communication to maintain non-relative ties, which might be more sensitive to distance.

Although, the findings above suggest the existence of some consistent associations between individual and relational attributes with contact frequencies irrespective of socio-cultural contexts, there were several variables for which no clear patterns were observed. At the ego level, the associations between education with face-to-face and phone contact, gender with face-to-face and internet contact, and household income with ICT contact in general, were not clear. At the ego-alter level, the differences observed among relationship types, as well as effect magnitude variations given relationship type also exhibited diverse patterns.

Some results might be explained by context-specific socio-economic factors. For example, economic affluence might be more crucial a factor in facilitating ICT communication in the Concepción case than other contexts, which might help explain the association between higher incomes and higher phone and internet contact frequencies. This would, however, not explain the negative coefficient observed for phone contact in Zurich (1), and for internet in Switzerland, or the positive coefficients observed for internet contact in the Zurich (2) sample.

Methodological differences in terms of sampling, survey medium, question formulation, etc., as well as cultural factors might also account for observed differences. The precise source of these variations remains, however, an open question, since it is very difficult to precisely discriminate between these effects from these data alone.

Table 4: Multilevel-multivariate model of contact frequencies by mode - standardized coefficients

Fixed effects	**Dataset**							**Contact modes**	
	CCP	**EIN**	**SWI**	**TOR**	**ZUR1**	**ZUR2**	**TYO**	**Phone**	**Internet**
Intercepts	1.98	1.96	1.95	2.09	1.69	1.24	1.47	-1.31	-1.80

	Face to face							**Phone**							**Internet**						
	CCP	**EIN**	**SWI**	**TOR**	**ZUR1**	**ZUR2**	**TYO**	**CCP**	**EIN**	**SWI**	**TOR**	**ZUR1**	**ZUR2**	**TYO**	**CCP**	**EIN**	**SWI**	**TOR**	**ZUR1**	**ZUR2**	**TYO**
Dataset x contact mode	-	-	-	-	-	-	-	-		0.97		0.83			-				0.38	1.63	1.65
Ego characteristics																					
Education level																					
Secondary or lower (r)																					
Technical degree	0.11							0.27							0.32						0.33
University degree or higher						-0.07								-0.26	0.47	0.38		0.41		0.09	
Gender																					
Female (r)																					
Male			0.07	-0.16		0.05													0.18	-0.14	
Age																					
Under 30 (r)																					
30 to 60		-0.20	-0.29	-0.39	-0.17	-0.16		0.14					0.28		-0.19			-0.53	-0.26	-0.20	
Over 60		-0.28	-0.31		-0.16	-0.21							0.26	0.42	-0.43	-0.43	-0.28	-1.08	-0.53	-0.69	-0.81
Household income																					
Low income (r)																					
Medium income								0.27									-0.20			0.16	
High income		0.12		0.20	0.13	0.05		0.55				-0.28			0.31		-0.11			0.18	
Network size	-0.01	0.00*	0.00*		-0.01	-0.01		-0.01		-0.01			-0.01		-0.01			-0.04		-0.01	
Ego-alter relational characteristics																					
Relationship type																					
Non-relative (r)																					
Extended family		-0.26	-0.40			-0.27	0.48		0.25	-0.61		0.23		0.50	-0.22		0.11	-0.43		-0.17	
Immediate family	-0.17		-0.29		0.45	0.27	0.63	-0.15	0.46	-0.41		0.60	0.40	0.86	-0.18	0.21		-0.31	0.20		0.38
Emotionally close																					
Non-relative	0.08	0.07	0.26	0.17	-0.05	0.31		0.39	0.33	0.37	0.73	-0.15	0.46		0.16	0.27	0.28	0.12	-0.07	0.55	
Extended family	0.16	0.33	0.24	0.20	-0.20	0.28		0.41	0.29	0.52	0.62		0.51			0.21	0.19	0.56	-0.18	0.43	
Immediate family	0.31	0.39	0.24	0.23		0.58		0.80	0.57	0.49	0.74	-0.20	0.71			0.21	0.12	0.40		0.68	0.31
Log of distance																					
Non-relative	-0.27	-0.34	-0.44	-0.36	-0.31	-0.10	-0.28	0.04		-0.15	-0.12	-0.04			0.10	0.16	0.05	0.18	0.12		0.09
Extended family	-0.31	-0.30	-0.28	-0.27	-0.32	-0.12	-0.62	-0.05	-0.11	-0.10	-0.11	-0.11		-0.21	0.04		0.05				-0.16
Immediate family	-0.28	-0.42	-0.33	-0.30	-0.43	-0.35	-0.54		-0.19	-0.15	-0.14	-0.05		-0.17	0.08			0.07		0.04	-0.21

Random Effects					**Goodness of fit statistics**	
Groups	**Var.**	**S.D.**	**Correlation**			
Ego (n=2636)						
Face-to-face	0.05	0.21				
Internet	0.26	0.51	0.12			
Phone	0.19	0.43	0.23	0.42		
Ego-alter (n=31495)						
Intercept	0.10	0.32				
Residual	0.34	0.58				

Test	**AIC**	**Likelihood ratio test (p-value)**
None	198,440	reference
Ego	202,558	9990.3 (<0.01, df=5)
Ego-alter	208,421	4119.9 (<0.01, df=1)
Intra-class correlation :		
Adjusted	0.31	
Conditional	0.19	

Number observations	94485
REML criterion	197710.30
Marginal R-square	0.37
Conditional R-square	0.56

* Coefficient is smaller than -0.01. (r) indicates the reference category

In terms of random effects, their significance was tested via a single-term-deletion likelihood ratio test. That is, for each test, one random effect is eliminated from the model and the likelihood ratio test calculated. All random effects were statistically significant. Furthermore, the positive correlations between modes suggests, as reported in the literature, that face to face and ICT modes are complementary rather than substitutes. However, when accounting for the effect of distance discussed above, this complementarity tends towards substitution for internet-mediated contact given increases in distance.

Intraclass correlation levels also support the multilevel structure used in this analysis.

Finally, regarding the limitations of this study, it is important to note that since the model required complete case observations without missing values, only variables available to all datasets could be incorporated. As such, homophily effects, which have been well documented in the literature could not be evaluated.

6. CONCLUSIONS

In recent years, there has been an increasing awareness of the importance of the relation between social networks and travel. Face-to-face and ICT mediated social interaction patterns are of interest to transportation researchers, as changes in these interaction patterns might impose new demands on urban environments and transportation services. This subject, however, has until recently received little attention. This article compared social interaction frequencies by mode among seven datasets from five different countries. It complements the study by Kowald et al. *(13)* on the relation between social network distance patterns with personal network and relational characteristics and shows that these characteristics are also strongly associated with social interaction patterns.

Analysis of social interaction against distance showed very similar patterns across samples, with face-to-face frequencies showing high sensitivity to distance. In terms of modal share, a clear substitution effect was observed between face-to-face contact and ICT across all samples given increasing distances. For the older datasets (before 2012), the telephone dominated modal shares at distances over 100 km. On the other hand, for the more recent surveys (after 2017), a clear transition in ICT preference from phone to internet-based modes was observed.

A Multilevel-multivariate mixed regression analysis results showed the existence of very consistent associations between individual and relational characteristics and social interactions irrespective of socio-cultural context, such as age, network size, distance and emotional closeness.

Face-to-face and ICT contact were found to be complementary, a relation that tends towards substitution for internet-mediated contact given increases in distance.

While consistent associations across samples were indeed found, for ego-level characteristics such as gender and ego-alter level characteristics such relationship type, among others, effect patterns were less clear. These differences might be explained not only by socio-economic and cultural factors, but also by methodological differences in terms of sampling, survey medium, question formulation. While discriminating between these effects is difficult, it is clear that intrinsic contextual characteristics play an important role and need further understanding.

Regarding future research, similar to the study by Calastri et al. *(12)*, new data collection efforts should explicitly measure travel behavior and companionship in a disaggregate manner, in addition to the social network and interaction characteristics measured in this study. This would allow researchers to move beyond descriptive models of social interaction patterns towards the explicit incorporation of social network characteristics into different dimensions of travel behavior such as joint activity generation, companion choice and/or joint activity destination choice.

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AUTHOR CONTRIBUTIONS

- GP, KT and NH were involved in the collection of, and provided the Greater Tokyo Area data
- AF and KWA were involved in the collection of, and provided the Zurich (1) data
- SG, MW and KWA were involved in the collection of, and provided the Zurich (2) data
- MK, and KWA were involved in the collection of, and provided the Switzerland data
- JCA and BW were involved in the collection of, and provided the Toronto data
- PVDB, TA and HT were involved in the collection of, and provided the Eindhoven data
- JCA were involved in the collection of, and provided the Concepción data
- GP, AF, and MK conducted the statistical analyses
- GP, AF, MK and PVDB wrote the manuscript
- All authors provided comments and revisions to the analysis results, drafts and approved the final version

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