Published in final edited form as:

Adv Life Course Res. 2015 June ; 24: 10–20. doi:10.1016/j.alcr.2015.04.001.

Inter-generational Contact From a Network Perspective

Christopher Steven Marcum^{a,*} and Laura M. Koehly^a

^a National Institutes of Health, Bethesda, MD, USA, 20892

Abstract

Pathways for resource—or other—exchanges within families have long been known to be dependent on the structure of relations between generations (Silverstein, 2011; Fuller-Thomson et al., 1997; Agree et al., 2005; Treas and Marcum, 2011). Much life course research has theorized models of inter-generational exchange—including, the ‘sandwich generation’ (Miller, 1981) and the ‘skipped generation’ pathways (Chalfie, 1994)—but there is little work relating these theories to relevant network mechanisms such as liaison brokerage (Gould and Fernandez, 1989) and other triadic configurations (Davis and Leinhardt, 1972; Wasserman and Faust, 1994). To address this, a survey of models of resource allocation between members of inter-generational households from a network perspective is introduced in this paper. Exemplary data come from health discussion networks among Mexican-origin multi-generational households.

Keywords

Networks; Generations; Family Communication

1. Introduction

After more than a half-century of two-generation households being the norm for American families, demographic forces have given rise to an increase in multi-generational households (Fuller-Thomson et al., 1997; Harrell et al., 2011). A combination of new waves of immigration from Asia and Latin America, expanded longevity, and increasing variance in dependence during advanced age, has driven an uptake in three- and four- generation households. Even among whites, whose household structures have trended toward increasingly single-generation since the middle of the 19th Century (Ruggles, 1996; 2007), there has been a recent rise in grandparents living with their grandchildren and adult children since the start of the Great Recession (Kochkar and Cohn, 2011). From 1940 to 1980 the share of Americans living in multi-generational arrangements had been declining from 25% to 12%, only to gradually begin to rise again after 1980 (Taylor et al., 2010). By 2012, the Census estimated that 5.1 million households (~ 5.6%) were multi-generational,

© 2015 Published by Elsevier Ltd.

* Corresponding author chris.marcum@nih.gov (Christopher Steven Marcum).

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

which was up from 4.8 million in 2009 (Lofquist, 2012). This means that roughly 17% of Americans live in such multi-generational households today.

This demographic trend poses an opportunity for social scientists to reflect on the structure of family relations from a multi-generational network perspective. In particular, the last several decades have given rise to many geronto-logical and life-course theories that address a variety of pathways for resource and communication to flow from one generation to another. In this paper, we review network structures consistent with many of these theories and, following Agree et al. (2005), outline an analytic strategy to evaluate those theories given network data.

Taking a network perspective on inter-generational relationships sheds light directly on the interpersonal patterns of relationships within families by measuring exchange flows between household members. This is in contrast to alternative approaches that may rely on assumptions about inter-generational relationships by indirect observations, such as inferring that resources flow from grandparents to their grandchildren based only on observing grandparent-headed multi-generational households (Casper and Bryson, 1998). Moreover, aggregating these patterns to family (or network) level statistics facilitates comparative analysis of the prevalence of different patterns of exchange within and between families (Park et al., 2013).

The balance of this paper is outlined as follows. First, we consider the definition of a generation, resolving on one that incorporates both social and biological relationships. Second, we review the relevant literature on gerontological theories on inter- and intra-generational interaction and tie that literature to related processes and structures from social network analysis. Third, we use data on health discussion networks among Mexican-origin multi-generational families to evaluate several structural models of contact between and within generations using network analysis.

2. Generation as a Socio-Biological Construct

While gerontologists have implied consensus on what constitutes a generation—a matter settled years ago in the field—there are competing definitions of generation in the broader scientific literature and it is useful to review them here because they may be useful to a broader audience. Biologists, especially geneticists, consider the concept of a generation as strictly involving the hierarchy of lineages based on pedigree within families. This is a micro view, focusing in on families and bloodlines and mainly relevant for understanding family health history and Mendelian trait heritability. Demographers, on the other hand, take a more macro view, and operationalize generations as consisting of all members of a particular range of ages spanning some window—often, the window defined as the mean age of mothers at the birth of their children (Shryock et al., 1980, pg.527). Even more generally, sociologists—and some economists, historians, and anthropologists—think of a generation as all people born within a window of historic import. This definition is aligned with the life course perspective in sociology as it resonates well with the notion that shared experiences bring people together as they navigate life (Elder Jr. and Johnson, 2002; Ryder, 1965).

This life course approach to the definition of generation provides a generalized framework from which many alternatives may be derived. This includes popular branding of generations (The Greatest Generation, Generation Y, Millennials) (Barrett and Montepare, 2015) as well as empirical treatments, such as those employed in the international migration literature (1st generation, 2nd generation, 0.5 generation) (Rumbaut, 2004; Treas, 2015).

When it comes to the role that generation plays in shaping social relations, it is useful to think of generation structures in a nested, or multilevel manner. Individuals are nested within networks, which are in turn nested within broader social contexts (say families, neighborhoods, and societies) or what Gans and Silverstein (2006) call social-ecological spheres of development. Membership in a generation, is one such sphere, and the inherent correlation between generational membership and the age-structure provides a particular social context that shapes baseline interaction between and within generations as detailed by Blau's (1977) theory of social structure.

Intuitively, as Easterlin (1978) pointed out in his 1978 presidential address to the Population Association of America, the age-structure constrains between-and within-generation interaction based on the availability of living persons in one versus another generation. Leaving aside the age-grading of institutions that insulates cohorts from one another (Heinz and Marshall, 2003), a largess in the share of the population in one generation, such as the baby-boom following wwii in the United States (Easterlin, 1961), naturally increases the likelihood of interaction between members of that generation with all others. Similarly, if there are fewer members of a certain generation (e.g., the cohort of Russian men who died in wwii), then people of other generations have fewer opportunities to interact with them (e.g., are less likely to know their grandfathers, or have older male neighbors to befriend). At the same time, people in a smaller generation have fewer like-aged alters and a smaller opportunity pool for generation-assortative mixing. As a corollary, a cohort largess might lower the likelihood of out-group interaction just as a cohort dearth might increase such interactions (Blau et al., 1982).

Although some cohorts and generations are larger than others when they reach midlife, every group declines in size eventually. Under normal conditions, older people are at greater risk than younger people of losing their same-age peers due to mortality (Antonucci and Akiyama, 1987). Compared to younger people, older people have fewer opportunities to interact with same-age peers, whether maintaining current ties or seeking out new ones. Following Blau's theory of group size and group mixing rates, then, we would expect that relative inter-generational mixing rates would be higher than intra-generational mixing rates for the older population. For example, older adults will spend more time with their children than with their siblings.

Finally, it's not just life and death that shapes the baseline potential for inter-generational interactions. Group size is also affected by population displacement, such as migration. Migration results in two different dimensions that affect inter-generational relations in what Park and Myers (2010) call a "double-cohort" process: generational members who migrate are insulated from those who do not, and those that do migrate become the first in a new succession of generations. The experiences and linked-lives shared by members 1st, 2nd, and

further generations have been known to strongly shape both intra- and inter-generational relations over the tandem life courses within foreign-origin families (Silverstein and Attias-Donfut, 2010).

3. Multi-generational Relations

We've established that membership in a generation is an important sphere of social interaction that is shaped by both shared-experiences and the age-structure (Elder Jr. and Johnson, 2002). Now, we move onto propositions about the structure of interactions between and within generations from a network science perspective based on important gerontological theories. Throughout, we identify links between network science and gerontology.

First, it is useful to review the network concepts that we'll be drawing from here. We define a social network as a set of actors and the relationships (or ties) between them (Wasserman and Faust, 1994). When actors direct actions from one to another, we say that the network is directed. Transfers, exchanges, and communications—and most other relations of interest to life course scholars studying generational contact—are directed relations. Ties always reflect a single type of relationship, though networks may be multiplex (that is, have more than one type of relationship incident on the set of actors).

Within a network, both actors and ties may have attributes, or covariates. Here, we are interested only in the presence or absence of a directed tie, and the generational membership of the actors. Pairs of actors in a network are called dyads, and triples of actors are called triads. Both of these “local” structures (Holland and Leinhardt, 1975; Faust, 2007) are used in our approach.

In directed networks, there are three possible types (or isomorphism classes) of dyads: 1) a mutual, where person i sends a tie to person j and person j reciprocates by sending a tie to person i ; 2) an asymmetric, where i sends a tie to j (or vice versa) but j does not reciprocate by sending a tie to i ; and, 3) a null, where there are no ties present between persons i and j . The frequency of each combination in a network is called the dyad-census, the elements of which are labeled M_{mutual} , $A_{asymmetric}$, and N_{null} , respectively. There are also sixteen triadic isomorphism classes, which represent the unique configurations of mutuals, asymmetrics, and nulls possible in a triad. The dyad and triad censuses may tell us much about the structure of relations within a social system (Holland and Leinhardt, 1975; Faust, 2007)—more nulls may suggest greater isolation and more mutuals may suggest greater reciprocity, for example. As our models are based on social interactions that depend on the generational position of an actor, we employ the more comprehensive labeled versions of these concepts in the development of our statistics based on gerontological theory.

Much of the literature on intra- and inter-generational contact focuses on about nine different pathways for resources to flow. Figure 1 summarizes these as models using triads that are colored by generation. Light gray nodes represent members from the oldest generation, dark gray nodes are from the middle generation, and black nodes represent the youngest generation in a multi-generational social system. Arrows represent directed interactions (i.e., from members of one generation to another). Importantly, we preserve

only the order of generations and not the exact membership in this theoretical construct to allow for the fact that some multi-generational households lack members from one or more of the pedigree tiers. We now review each model by turns.

Miller's (1981) "sandwich generation" originally described the economic and social burden many baby-boomers would feel as they coped with tandem demands from their aging parents and young children. In the strict interpretation, the focus is on actors in the middle of the generation structure (say, second generation in a three generation family) and ties (i.e., resources) are sent out to actors in generations immediately above and below the focus. Alternatively, we recognize that from a social process perspective, this is really a special case of a more generalized structure where the assumption that the burden must fall on the middle is relaxed, and allowed to fall on any generation that sends ties to members of at least two other different generations. In the archetypal system with three generations, the structural model of a sandwich generation would be consistent with the "021D" (0 mutual dyads, 2 asymmetric dyads, and 1 null dyad) triad isomorphism class (Holland and Leinhardt, 1975; Wasserman and Faust, 1994), albeit with generation-labeled nodes. This structure is typified by, $A \leftarrow B \rightarrow C$, where resources or other ties are sent out from generation B to the others.

We also consider the reverse of the generalized sandwiched generation structure as a "needy generation structure" whereby resources are directed from at least two other generations toward a different, focal generation. Here, the corresponding triad isomorphism class would be "021U", represented by, $A \rightarrow B \leftarrow C$. Examples of this model are typified by both the provision of support in families with dependent elders and the provision of care in families with infants (Wolff, 2001).

Following a gerontological tradition that characterizes the role of parents in mediating communication, access, and resource flows between grandparents and grandchildren, we also consider two "mediated structures" (Robertson, 1977; Thompson and Walker, 1987; Silverstein et al., 1998). Consonant with the two available directions these are upward and downward mediated structures, respectively. These mediated flow models of inter-generational contact are related to the "liaison" brokerage role (the two-path $A \rightarrow B \rightarrow C$) as formalized by Gould and Fernandez (1989) in their study of transaction networks. Actors who occupy this role stand between members of two different groups—here, we label the groups such that the generational mediation two-path follows the proper direction; from younger-to-older or older-to-younger, respectively, with a middle generation representative occupying the liaison role in both cases.

Sometimes, though, parents (here, the middle generation) are not fully engaged. We also propose two "skipped generation" structures: the downward skipped generation structure, whereby older generations send ties to younger generations but bypassing their immediate decedents and the upward skipped generation structure, whereby the direction of the path is reversed. A recent study commissioned by the AARP found that the most common form of multi-generational household is a grandparent-headed household where adult children and grandchildren also reside (Harrell et al., 2011). In these households, the skipped-generation structure is consistent with grandparents bypassing the authority of their children to interact

with their grandchildren (downward) and also grandchildren seeking permission directly from the householder (upward). The most extreme example of skipped generation relations exist in families that lack members of the intermediate generation—such as in households consisting of grandparents acting as guardians of their grandchildren (Pilkauskas, 2012; Chalfie, 1994). Here, though, we only consider scenarios where middle generations could potentially mediate but do not, a model that is represented by the generation-colored “012” triad.

Of course, a survey of gerontological models of inter-generational exchange in multigenerational social contexts would not be complete without treatment of generational solidarity (Silverstein and Bengtson, 1997). We propose a model of generational solidarity whereby actors send ties to members of their own generation, rather than sending to others. Such a structure is consistent with the network construct of social “homophily,” which resonates with the old adage “birds of a feather flock together” (McPherson et al., 2001). Such generational homophily is commonly observed in a liation, friendship, and mate selection networks where similarity in age is optimal for maintaining partnerships throughout the life course a la Kahn and Antonucci's (1980) convoy model.

Complementing the generational solidarity model, we also consider a model of generational conflict or competition. Here, representatives from a particular generation avoid sending ties to their generational constituents. Unlike homophily, contact in the generational competition model is characterized by disassortative mixing between generations. This structure is, perhaps most famously, theorized in developmental psychology and family economics studies as “sibling rivalry” (Morduch, 2000; Parke, 2013; Sutor et al., 2013). Note that the structural configuration is conflictual in name-only, and is general to non-conflict scenarios featuring disassortative contact, such as situations when members of younger generations seek wisdom from their elders (Ardelt, 2000).

Finally, inter-generational exchange may be a relatively pluralistic enterprise and have an equitable social structure. Such structures are likely to emerge whenever actors are equally likely to exchange within and between generations, such as during family meals or on gift-giving holidays. The “inter-generational solidarity model” captures this form of equitable generational exchange, whereby representatives of a particular generation have contact with representatives of each of the other generations present in a social system. Borrowing from the triadic isomorphism classes, again with generation-labeled nodes, the uniform model is consistent with the fully mutual “300” class and may (given relevant relations) reflect strong solidarity and reciprocity.

Obviously, there are other pathways for generational contact that can be represented by network features. In fact, for the minimal case of three generation systems, we might consider the labeled triad census to be the census of all triadic configurations that correspond to contact models of interest. This, however, would require an enumeration and theoretical overview of $2^6 = 64$ labeled triads (Wasserman and Faust, 1994, pg.560-562), not all of which are described in the literature on inter-generational exchange. Thus, we stop here for brevity and for theoretical relevance to the existing literature.

4. Empirical Example: Health Communication in Mexican-origin Multi-generational Families

Hispanic families constitute one of the major sources of growth in multi-generational households in the United States with the largest share residing in Arizona, California, Hawaii, Puerto Rico, and Texas (Lofquist, 2012; Harrell et al., 2011; Kochkar and Cohn, 2011). Much of the recent rise in the prevalence of these families, particularly in the Western U.S., is due to the arrival of older members of established Mexican-origin families (called the “point 5 [0.5] generation by Treas and Torres-Gil (2009)), whereas the initial migrating pioneers in these families tended to be young, healthy, men (Massey and Espinosa, 1997). As the prospects for full integration into mainstream society (i.e., through assimilation and acculturation) are strained by old age (Treas and Torres-Gil, 2009), these families may need to rely on brokering communication between generations to understand and access information and resources (Treas, 2015).

One of the challenges faced by new arrivals is brokering the language gap between the family's native language and the English used by the dominant institutions of the host society, such as the U.S. medical complex. As such, multi-generational families rely on communication brokering to relay health information. The pattern of the brokerage has been shown to be that of an older-generation family member communicating their health concerns to a younger-generation family member who then passes along this information to medical professionals and vice versa (Tyyskä, 2013; Torres, 2000; Haffner, 1992). As a precondition for brokering information between family members and outside parties, family members must resolve on a discussion pattern from within, in an *a priori* manner—i.e., to establish roles, clarify message content, and build knowledge base—the failure to do so may result in the broker lacking sufficient knowledge of family health history to effectively communicate concerns (Goergen et al., 2012).

Here, we focus on describing the within-family pattern of communication through the lens of intra- and inter-generational contact at the population-level. Specifically, we compare which models of generational contact discussed above are active in the health communication networks in Mexican-origin families, over and above the differences we would expect to arise from the size of each generation (Blau, 1977). This analysis is both exemplary of our network perspective on inter-generational relations and provides insight into the important arena of family health discussions in the Mexican-origin population.

5. Data

Our empirical example data are drawn from the Risk Assessment for Mexican Americans (RAMA) project (Koehly et al., 2011), a family-based study using family health history information to promote communication about family risk of common, complex diseases with heritable and environmental risk factors (including diabetes, cancer, and heart disease).

Participants from Project RAMA were recruited from a population-based cohort of Mexican American households launched in 2001 by the Department of Epidemiology at The University of Texas M.D. Anderson Cancer Center. Households were initially recruited into

the Mano-a-Mano Mexican American Cohort Study (MACS) via probability random-digit dialing, door-to-door recruitment, intercepts and networking approaches. All were of Mexican heritage and resided in the Houston, TX area. A detailed description of the cohort has been previously published (Wilkinson et al., 2005). Mexican origin adults who participated in MACS provided informed consent, and completed an interview-administered survey in their home in either Spanish or English. As part of this interview, participants enumerated their household composition. A total of 1,927 multigenerational households meeting the composition criteria for the current study were identified from the cohort database.

To recruit participants from this sub-sample into Project RAMA, we randomly called eligible households with at least 3 co-resident adults: two biologically related and representing two different generations and two “socially” related. Of the 1,254 households contacted, 907 did not meet eligibility criteria and 185 refused to participate. A final total of 497 adults from 162 multi-generational households were recruited in 2008-2009. Participants completed an in-home baseline survey in English or Spanish and two follow-up phone surveys approximately 3- and 10-months later. Information from participants was collected on a wide variety of social and health topics, including a network module asking about the relationships between respondents and their broader personal network members. The present study focuses on the baseline health communication in the network data.

The baseline network data consist of a sample of the complete set of health communication interactions. Three focal-actor representatives from each family were asked to report on (among other things) their health discussion networks by answering the following two questions: 1) with whom do you often discuss health concerns, and 2) who discusses their health concerns with you. Respondents could nominate anyone and basic social and demographic data was gathered on each communication partner (i.e., age, sex, relationship to respondent). This design collected directed, ego-centric networks with a high level of overlap within families.

6. Methods

The sampling design limits our ability to know about relationships between non-focal actors from observation. However, since our focus is on learning about relationships between generations in aggregate, we can leverage the different generation structures observed across families to infer a distribution of possible relationships at large. We accomplish this by network inference methods and simulation, as described in the next section. We use network simulation methods to examine the distribution of multigenerational contact models. The approach is describe in detail in Section 6.1.

We are inclined to take a hybrid approach to defining generation. Here, we mean members along a common branch of a pedigree *and* cohort members born within the same ten year interval. This definition blends the sociological definition with the biological such that within-cohort friendships and all sibships both get counted in the same generation. This definition is broad enough to encompass social family relations as well (e.g., adoptees,

fictive-kin, in-laws, and spouses). By *multi*-generational, we mean more than two generations present in a social system, such as a family or household.

By *generation structure*, we mean the ordered frequency distribution ($f(\text{Generation})$) of membership in each generation; thus, our definition fits within the broader “age-structure” construct commonly used in the social sciences (Ryder, 1965).

6.1. Network Inference and Simulation

If we had complete network data, we would proceed with directly counting the network structures consistent with the patterns of intergenerational contact that we are interested in measuring in each family. However, the nature of these data only allow for us to simulate network structures given our observations within families and compare them to what is possible given the age-structure of the family; this type of simulation is standard practice in network science (Marcum et al., 2012; Moss and Edmonds, 2005; Breslau et al., 2000; Halpin, 1999). The inferential procedure used in the network simulation is novel but simple. A detailed algorithm is provided in the Appendix, though the method is also reviewed here. First, for each family's network, we calculate the mixing-matrix on the generation membership attribute. This matrix is of order $m \times m$, where m is the number of generations. The rows index the senders and the columns index the receivers of ties, aggregated by generational membership. Each row-by-column pair represents the count of ties sent from one generation to another (Del Valle et al., 2007). Naturally, the diagonal of this matrix represents within-generation, or intra-generational, ties. This mixing matrix is then divided by the outer-product of the generation structure (i.e., the frequency distribution of generations in a network— $f(\text{Generation})$)¹, which is also used to derive the expected mixing rates. The resulting $m \times m$ matrix represents the fraction of ties sent to those possible—the mixing-rate matrix (Newman, 2003).

We then integrate over the set of these mixing-rate matrices to get the average, which is projected back onto each original network and used as tie-probabilities to draw Bernoulli graphs as described in Newman (2003). Specifically, we draw from a mixing-rate conditioned uniform random graph distribution (for details, see the **rgnmix** routine in Butts (2008)). This distribution is a mixture of Bernoulli trials conditional on the underlying between and within-generation mixing rates. The approach is a straightforward generalization of the Erdős and Rényi (1959) family of network inference models. Our resulting networks are thus conditioned on 1) the size of each family, 2) the generation structure of each family, and 3) the probability that members of each generation send ties to one another (which is likewise conditional on our sampling scheme). We conduct this procedure separately for families with three and four co-extant generations. One hundred networks are generated at each iteration of the algorithm (via Gibbs sampling), which become the data for our subsequent analysis, discarding duplicated networks.

¹Because the network questions did not allow for self-ties (an actor could not nominate his or herself as a discussion partner), we reduce the diagonal of this matrix by the generation structure and therefore the total within-generation tie volume ($tr(M')$) is reduced by $\sum f(\text{Generation})$.

The average mixing rates are depicted in Figure 3. Sending actors are (aggregated by generation) represented on the y-axis and receiving actors are represented on the x-axis. Darker blocks indicate higher volume of ties sent and received between the corresponding sender-receiver generational pair. Consistent with Blau's observations on mixing between and within generations (Blau, 1977), this figure takes variance in generation size into account. Thus, the mixing rates reflect generation-structure adjusted tie probabilities.

6.2. Analysis

Measurement of the generational contact structures depicted in Figure 1 and discussed in Section 3 is straightforward from a network science perspective. Because of its familiarity, simplicity, and intuitive interpretation, we borrow our measurement strategy from that motivating network density—i.e., the ratio of extant ties to possible ties in a network that can be interpreted as the network tie-probability. In review, greater network density indicates greater connectivity in a network, whereas lower network density indicates greater sparseness and often disconnection and structural isolation in a network (Wasserman and Faust, 1994). In particular, we follow the strategy of Agree et al. (2005), who base their inter-generational transfer measures on the familiar density statistic. As such, our measures have similar interpretations—greater values mean that a higher percent of the particular form is observed, indicating greater consistency with the respective theory.

We simply count the number of features in a network that are consistent with each of the nine models of inter-generational contact. These counts are then divided by the number of *possible* features to facilitate comparisons between networks and models. The resulting network-level indices are “density-like” to the extent that they are the ratio of extant to possible features in the same way that network density is the ratio of extant to possible ties. In our analysis here, we compare the observed and expected distributions of these indices by taking their simple difference.

One of the limitations of this strategy is that the indices should not necessarily be interpreted as probabilities for the purpose of excluding one model over $f(\text{Generation})$. Another as they are not all mutually exclusive and caution is advised on that regard. For example, in a three actor network, the generational competition model (where actors avoid sending ties to members of their own generation) may be implied in the skipped-generation model (where actors send ties upward or downward while avoiding the middle generation). Another limitation is that the distribution of possible indices relies strongly on the observed generation structure. For instance, in a minimal multi-generational network with three actors (one representative from each generation), only one of the labeled triads could be observed and it will be equal to its expectation. This limitation is the same for other statistics on such small networks, such as brokerage (Gould and Fernandez, 1989). As mentioned, we dropped such cases from our analysis. We also aggregate our network results to help alleviate this bias.

7. Results

From the RAMA data set, there were 104 families with at least three coextant generations and 80 unique generation structures (77%). Sixteen (15%) of the families had four coextant

generations. Figure 2 plots the average generation structure for three (in gray) and four (in black) generation families, respectively. A single family had five coextant generations, which we excluded as an outlier. We also excluded 17 three generation families with only 3 members.

Descriptive statistics from the distribution of mixing-matrix conditioned health communication networks for three and four generation families in the RAMA dataset are reported in Table 1. Three generation families were slightly smaller than four generation families (with $n \simeq 11$ versus 14, respectively), but they contained similar frequencies of health communication at around 20 edges each. On average, these networks were relatively sparse as indicated by the low network densities (and the four generation families were more sparse than the three generation families, which is consistent with the size and edge count results). Also consistent with low density, the average dyad census was rich in nulls and low on mutuals and asymmetrics.

The simulation results are presented in Table 2 with 95% credibility intervals and depicted in Figure 4, which plots the distribution of differences between observed and expected “density-like” indices for each of the nine generational contact models reviewed here. We find evidence that the needy, upward mediation, both skipped-generation models, and generational competition are all at play to a greater extent than expected in our networks for both three and four generation families. By contrast, the sandwich and downward mediated models do no better than what we could expect given the generation structure. The results for inter-generational and generational solidarity differ between three and four generation families—with the latter being different than expectation for three generation families and the former being different for four generation families.

8. Discussion

Economists, life course sociologists, and gerontologists have long recognized that the pattern of intra- and inter-generational exchange is an important feature of social life. The flow of resources, communication, and support depend on the structure of relations between and within generations. With the recent upswing in the prevalence of multi-generational families in the United States, understanding these patterns is of particular import. Concurrently, the growing availability of network data on these families avails an opportunity to link gerontological perspectives on social contact with network measurement and analysis (Ashida and Heaney, 2008; Ersig et al., 2011; Litwin and Shiovitz-Ezra, 2011). To that end, we reviewed nine models of contact in multi-generational social systems and measured them using a network approach in this paper.

Our empirical example came from the health communication networks in multi-generational Mexican-origin households. We found that both three and four generation families direct inter-generational health communication toward one generation more than expected, as suggested by the positive needy-generation model results. At the same time, health communication tends to leave out the middle-generations in these families as the strong positive results for the pair of skipped-generation models demonstrates; though if the middle is involved, it tends to be consistent with a pattern where they broker communication from

younger to older, as suggested by the weakly positive upward-mediated contact model results. In general, these results resonate with past qualitative findings that suggest Mexican-origin families often rely on the youngest generation to broker health information with the outside world (Tyyskä, 2013; Valdés, 2008; Love and Buriel, 2007; Valenzuela Jr., 1999; Haffner, 1992). Our results advance this literature by shedding light, quantitatively, on how the conversational preconditions for young interpreters arises within these families.

One of the primary applications of using network data and network structures to model inter-generational exchanges within families is to identify typologies of multi-generational family systems (Park et al., 2013; Litwin and Stoeckel, 2013; Litwin and Shiovitz-Ezra, 2011). A family system with a mixture of upward and downward skipped-generation structures may be very different from a system where only upward or downward structures prevail, for example. This may reflect the difference between a reciprocal relationship between grandparents and grandchildren, on the one hand, and a usurping of resources, on the other. Thus, it may be empirically useful to categorize families by the various combinations of contact models present. From an interventionist perspective, characterizing multi-generational families based on these models of contact may shape specific targets to disseminate health information, as in our empirical example. Families that are predominantly characterized by skipped-generation health communication networks—such as the Mexican-origin families in our analysis—would be well-suited for grandchild and grandparent targets, where middle-generation members would be less optimal on that front.

Finally, while our focus in this paper was on the relationships between individuals in families, our structural models are appropriate for studying both macro- and micro-sociological relations. In the former, we might consider the inter-generational social contract as an example (Bengtson, 1993; Marcum and Treas, 2013). In the United States, this involves resource flows (in the form of taxes) from the working-aged population to their younger and older generation consorts. Naturally, one might characterize this arrangement as a macro version of the “sandwich generation” structure. We leave it to future research to differentiate other macro and micro processes alike based on our typology and approach.

Acknowledgments

We would like to thank the anonymous reviewers and Dr. Judith Treas, who offered useful feedback on drafts of this manuscript. This research is funded by the National Institutes of Health Intramural Research Program (grant number Z01HG200335 to LMK). The authors have no conflicts of interest.

Appendix

The algorithm for our empirical analysis is detailed in this appendix. We implemented the algorithm using the open-source and cost-free statnet packages for the **R** statistical programming environment (Handcock et al., 2008).

1. Set G , the vector of the number of actors in each network.
2. Calculate $f(G)$ the generation structure frequency distribution:

$$f(G) = f_n = \frac{m_n}{\sum G},$$

where m_n is the count of actors n in generation m .

3. Calculate $E(M)$, the expected mixing-rate matrix from $f(G)$:

$$E(M) = f(G) \otimes f(G),$$

(this is an $m \times m$ matrix). Reduce $\text{diag}(E(M))$ by $f(G)$ to discount self-ties or loops.

4. Calculate $O(M)$, the observed mixing-rate matrix from the set of networks:

$$\sum_{lm} g_{lm} = 1, \quad \sum_m g_{lm} = a_l, \quad \sum_l g_{lm} = b_m,$$

where a_m and b_m are the fractions of the ties incident between nodes in each generation m for all networks g (this is an $m \times m$ matrix).

5. For every network of size G_n , draw two sets of 100 random networks from a mixing-rate matrix conditioned graph distribution using $O(M)$ and $E(M)$, respectively, to condition on the observed and expected generational mixing via Gibbs sampling, discarding duplicate graphs.
6. For each matched pair of observed and expected random mixing-rate matrix conditioned graphs generated in 5), calculate the distribution of generational exchange features depicted in Figure 1.
7. Take the difference of each pair of observed and expected features calculated in 6).

References

- Agree EM, Biddlecom AE, Valente TW. Intergenerational transfers of resources between older persons and extended kin in Taiwan and the Philippines. *Population Studies*. 2005; 59(2):181–195. [PubMed: 16096197]
- Antonucci TC, Akiyama HH. Social networks in adult life and a preliminary examination of the convoy model. *The Journal of Gerontology: Psychological Sciences*. 1987; 42:519–527.
- Ardelt M. Antecedents and effects of wisdom in old age: A longitudinal perspective on aging well. *Research on Aging*. 2000; 22(4):360–394.
- Ashida S, Heaney CA. Differential associations of social support and social connectedness with structural features of social networks and the health status of older adults. *Journal of Aging and Health*. 2008; 20(7):872–893. [PubMed: 18815414]
- Barrett AE, Montepare JM. "it's about time": Applying life span and life course perspectives to the study of subjective age. *Annual Review of Gerontology and Geriatrics*. 2015; 35(1):55–77.
- Bengtson, VL. Is the "contract across generations" changing? effects of population aging on obligations and expectations across age groups.. In: Bengtson, VL.; Achenbaum, WA., editors. *The Changing Contract Across Generations*. Aldine de Gruyter; New York: 1993. p. 3-24.
- Blau PM. A macrosociological theory of social structure. *The American Journal of Sociology*. 1977; 83(1):26–54.

- Blau PM, Blum TC, Schwartz JE. Heterogeneity and inter-marriage. *American Sociological Review*. 1982; 47:45–62.
- Breslau L, Floyd S, Heidemann J, Estrin D, Fall K, Yu H, Xu Y, Varadhan K, Helmy A, McCanne S, et al. Advances in network simulation. *Computer*. 2000; 33(5):59–67.
- Butts CT. Social network analysis with sna. *Journal of Statistical Software*. 2008; 24(6)
- Casper, LM.; Bryson, KR. Co-resident grandparents and their grandchildren: Grandparent maintained families.. Population Division Working Paper 26, The United States Bureau of the Census; Washington, DC. 1998.
- Chalfie, D. Technical report, American Association of Retired Persons. Washington, D.C.: 1994. Going it alone: A closer look at grandparents parenting grandchildren..
- Davis, JA.; Leinhardt, S. The structure of positive interpersonal relations in small groups.. In: Berger, J., editor. *The Structure of Positive Interpersonal Relations in Small Groups*. Vol. 2. Houghton Mifflin Company; Boston: 1972. p. 218-251.
- Del Valle SY, Hyman J, Hethcote HW, Eubank SG. Mixing patterns between age groups in social networks. *Social Networks*. 2007; 29(4):539–554.
- Easterlin RA. The American baby boom in historical perspective. *The American Economic Review*. 1961; 51(5):869–911.
- Easterlin RA. What will 1984 be like? socioeconomic implications of recent twists in age structure. *Demography*. 1978; 15(4):397–432. [PubMed: 738471]
- Elder, GH., Jr.; Johnson, MK. The life course and aging: Challenges, lessons, and new directions.. In: Settersten, RA., Jr., editor. *Invitation to the Life Course: Toward New Understandings of Later Life*, chapter 2. Baywood; New York: 2002.
- Erdős P, Rényi A. On random graphs. i. *Publicationes Mathematicae*. 1959; 6:290–297.
- Ersig AL, Hadley DW, Koehly LM. Understanding patterns of health communication in families at risk for hereditary nonpolypoid colorectal cancer: examining the effect of conclusive versus indeterminate genetic test results. *Health Communication*. 2011; 26(7):587–594. [PubMed: 21512927]
- Faust K. Very local structure in social networks. *Sociological Methodology*. 2007; 37(1):209–256.
- Fuller-Thomson E, Minkler M, Driver D. A profile of grandparents raising grandchildren in the United States. *The Gerontologist*. 1997; 37(3):406–411. [PubMed: 9203764]
- Gans D, Silverstein M. Norms of filial responsibility for aging parents across time and generations. *Journal of Marriage and Family*. 2006; 68(4):961–976.
- Goergen, AF.; Wilkinson, AV.; Koehly, LM. Barriers to family health history knowledge within immigrant families of Mexican origin in Project Rama.. Presented at the Annual Meeting of the Society of Behavioral Medicine; New Orleans, LA.. 2012.
- Gould RV, Fernandez RM. Structures of mediation: A formal approach to brokerage in transaction networks. *Sociological Methodology*. 1989; 19:89–126.
- Haffner L. Translation is not enough. interpreting in a medical setting. *Western Journal of Medicine*. 1992; 157(3):255–259. [PubMed: 1413765]
- Halpin B. Simulation in sociology. *American behavioral scientist*. 1999; 42(10):1488–1508.
- Handcock MS, Hunter DR, Butts CT, Goodreau SM, Morris, Martina. statnet: Software tools for the representation, visualization, analysis and simulation of network data. *Journal of Statistical Software*. 2008; 24(1):1–11. [PubMed: 18612375]
- Harrell, R.; Kassner, E.; Figueiredo, C. Fact Sheet. Vol. 221. AARP; 2011. Multigenerational households are increasing..
- Heinz WR, Marshall VW. *Social Dynamics and the Life course: Transitions, Institutions, and Interrelations*. Aldine de Gruyter. 2003
- Holland, PW.; Leinhardt, S. Local structure in social networks.. In: Heise, D., editor. *Sociological Methodology*. Jossey-Bass; San Francisco: 1975.
- Kahn, RL.; Antonucci, TC. Convoys over the life course: Attachment, roles, and social support.. In: Baltes, P.; Brim, OG., editors. *Lifespan development and behavior*. Vol. 3. Academic Press; 1980. p. 253-286.

- Kochkar, R.; Cohn, D. Fighting poverty in a tough economy, Americans move in with their relatives. Report. Pew Research Center; 2011.
- Koehly LM, Ashida S, Goergen AF, Skapinsky KF, Hadley DW. Willingness of Mexican-American adults to share family health history with healthcare providers. *American Journal of Preventive Medicine*. 2011; 40(6):633–636. [PubMed: 21565656]
- Litwin H, Shiovitz-Ezra S. Social network type and subjective well-being in a national sample of older americans. *The Gerontologist*. 2011; 51(3):379–388. [PubMed: 21097553]
- Litwin H, Stoeckel KJ. Confidant network types and well-being among older europeans. *The Gerontologist*. 2013; gnt056:1–11.
- Lofquist, DA. American Community Survey Briefs 11-03. United States Census Bureau; 2012. Multigenerational households: 2009–20011..
- Love JA, Buriel R. Language brokering, autonomy, parent-child bonding, biculturalism, and depression: A study of Mexican American adolescents from immigrant families. *Hispanic Journal of Behavioral Sciences*. 2007; 29(4):472–491.
- Marcum CS, Bevc CA, Butts CT. Mechanisms of control in emergent interorganizational networks. *Policy Studies Journal*. 2012; 40(3):516–546.
- Marcum, CS.; Treas, J. The intergenerational social contract revisited: Cross-national perspectives.. In: Silverstein, M.; Giarusso, R., editors. *Kinship and Cohort in an Aging Society: From Generation to Generation*. Johns Hopkins University Press; Baltimore: 2013. p. 293-313.chapter 14
- Massey DS, Espinosa KE. What's driving Mexico-U.S. migration? a theoretical, empirical, and policy analysis. *AmeJouSoc*. 1997; 102(4):939–999.
- McPherson M, Smith-Lovin L, Cook JM. Birds of a feather: Homophily in social networks. *Annual Review of Sociology*. 2001; 27:415–444.
- Miller DA. The 'sandwich' generation: Adult children of the aging. *Social Work*. 1981; 13:419–423.
- Morduch J. Sibling rivalry in africa. *The American Economic Review*. 2000; 90(2):405–409.
- Moss S, Edmonds B. Sociology and simulation: Statistical and qualitative cross-validation1. *American journal of sociology*. 2005; 110(4):1095–1131.
- Newman ME. Mixing patterns in networks. *Physical Review E*. 2003; 67(2):026126.
- Park J, Myers D. Intergenerational mobility in the post-1965 immigration era: Estimates by an immigrant generation cohort method. *Demography*. 2010; 47(2):369–392. [PubMed: 20608102]
- Park NS, Jang Y, Lee BS, Ko JE, Haley WE, Chiriboga DA. An empirical typology of social networks and its association with physical and mental health: A study with older korean immigrants. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*. 2013:gnt065.
- Parke, RD. Families in life-span perspective: A multilevel approach.. In: Hetherington, EM.; Lerner, RM.; Perlmutter, M., editors. *Child Development in Life-Span Perspective*. Lawrence Erlbaum Associates; New York: 2013. p. 159-190.
- Pilkauskas NV. Three-generation family households: Differences by family structure at birth. *Journal of Marriage and Family*. 2012; 74(5):931–943. [PubMed: 24014117]
- Robertson JF. Grandmotherhood: A study of role conceptions. *Journal of Marriage and Family*. 1977; 39(1):165–175.
- Ruggles, S. The effects of demographic change on multigenerational family structure: United States whites 1880-1980.. In: Bideau, A.; Perrenoud, A.; Lynch, K.; Brunet, G., editors. *Les systems demographiques du passe*. Centre Jacques Cartier, Quebec; Lyons: 1996. p. 21-40.
- Ruggles S. The decline of intergenerational coresidence in the united states, 1850 to 2000. *American Sociological Review*. 2007; 72(4):964–989. [PubMed: 21562613]
- Rumbaut RG. Ages, life stages, and generational cohorts: Decomposing the immigrant first and second generations in the United States. *International Migration Review*. 2004; 38(3):1160–1205.
- Ryder NB. The cohort as a concept in the study of social change. *American Sociological Review*. 1965; 30:843–861. [PubMed: 5846306]
- Shryock, HS.; Siegel, JS.; Larmon, EA., editors. *The methods and materials of demography*, volume 1–2. US Govt. Print. Off.; Washington, D.C.: 1980.

- Silverstein, M. Intergenerational transfers in social context.. In: Binstock, RH.; George, LK.; Cutler, SJ.; Hendricks, J.; Schulz, JH., editors. Handbook of Aging and the Social Sciences. sixth edition. Academic Press; 2011. p. 165-179.chapter 10
- Silverstein, M.; Attias-Donfut, C. Intergenerational relationships of international migrants in developed nations: the United States and France.. In: Dannefer, D.; Philipson, C., editors. The SAGE Handbook of Social Gerontology. Sage; London: 2010. p. 177-189.
- Silverstein M, Bengtson VL. Intergenerational solidarity and the structure of adult child-parent relationships in American families. American Journal of Sociology. 1997; 103(2):429–460.
- Silverstein, M.; Giarrusso, R.; Bengtson, VL. Intergenerational solidarity and the grandparent role.. In: Szinovácz, M., editor. Handbook on Grandparenthood. Greenwood; 1998. p. 144-158.chapter 10
- Suitor JJ, Gilligan M, Johnson K, Pillemer K. Caregiving, perceptions of maternal favoritism, and tension among siblings. The Gerontologist. 2013; 6(25)
- Taylor, P.; Passel, JS.; Fry, R.; Morin, R.; Wany, W.; Velasco, G.; Dock-terman, D. A Social & Demographic Trends Report 752. PewResearchCenter; Washington, DC.: 2010. The return of the multi-generational family household..
- Thompson L, Walker AJ. Mothers as mediators of intimacy between grandmothers and their young adult granddaughters. Family Relations. 1987; 36(1):72–77.
- Torres JB. Communication patterns and direct social work practice with latinos in the U.S. Human Behavior and the Social Environment. 2000; 3(2):23–42.
- Treas J. Incorporating immigrants: Integrating theoretical frameworks of adaptation. Journals of Gerontology: Social Science. 2015; 70(2):269–278.
- Treas, J.; Marcum, CS. Diversity and family relations in an aging society.. In: Settersten, RA., Jr.; Angel, JL., editors. Handbook of Sociology of Aging, Commemorating the 30th Anniversary of the ASA Section on Aging and the Life Course. Springer; 2011. chapter 6
- Treas J, Torres-Gil F. Immigration and aging: The nexus of complexity and promise. Generations. 2009; 32(4):11–17.
- Tyyskä, V. Communication brokering in immigrant families: Avenues for new research.. In: Chuang, SS.; Tamis-LeMonda, CS., editors. Gender Roles in Immigrant Families, Advances in Immigrant Family Research. Springer; New York: 2013. p. 103-116.chapter 7
- Valdés, G. Expanding Definitions of Giftedness: The Case of Young Interpreters from Immigrant Communities. Taylor & Francis; New Jersey: 2008.
- Valenzuela A Jr. Gender roles and settlement activities among children and their immigrant families. American Behavioral Scientist. 1999; 42(4):720–742.
- Wasserman, S.; Faust, K. Social Network Analysis: Methods and Applications. Cambridge University Press; Cambridge: 1994.
- Wilkinson AV, Spitz MR, Strom SS, Prokhorov AV, Barcenas CH, Cao Y, Saunders KC, Bondy ML. Effects of nativity, age at migration, and acculturation on smoking among adult houston residents of mexican descent. Journal Information. 2005; 95(6)
- Wolff FC. Private intergenerational contact in France and the demonstration effect. Applied Economics. 2001; 33(2):143–153.

Figure 1.
Models of Generational Contact in Multi-Generational Networks

Figure 2.
Average Generational Structure ($f(Generation)$) in RAMA Communication Networks

Figure 3.
Observed and Expected Mixing Rates in Three and Four Generation RAMA Health Communication Networks

Rows and columns index each sending and receiving generation, respectively. The shading of each cell represents relative tie volume, with darker values indicating greater tie volume. The off-diagonals represent inter-generational communications and the diagonals represent intra-generational communications.

Figure 4. Distributions of Differences Between Observed and Expected Relative Frequencies of Selected Models of Contact in Multi-generational RAMA Communication Networks
The box-and-whisker plots the distribution of differences between observed and expected relative frequencies of the contact models for three (dark gray) and four (light gray) generation RAMA communication networks. An horizontal line is drawn at $y = 0$. Whiskers extend to 1.5 times the interquartile range from the box.

Table 1

Descriptive Statistics of RAMA Health Communication Networks

	3 Gen		4 Gen	
	Mean	SD	Mean	SD
N		87		16
Size	10.57	7.58	14.44	6.91
Edges	19.95	29.98	22.36	21.77
Density	0.12	0.06	0.09	0.03
Dyads				
% Mutuals	0.02	0.03	0.01	0.01
% Asymmetrics	0.21	0.11	0.16	0.05
% Nulls	0.77	0.12	0.83	0.05

Data come from 100 draws of the distribution of generational mixing matrix conditioned health communication networks in the RAMA sample via Gibbs sampling.

Table 2

Differences Between Observed and Expected Relative Frequencies of Selected Models of Contact Multi-generational RAMA Communication Networks with Approximate 95% Credibility Intervals

	Three Generation			Four Generation		
	2.5%	97.5%		2.5%	97.5%	
Sandwich	0.004	−0.003	0.016	0.003	−0.001	0.010
Needy	0.088	0.052	0.137	0.038	0.022	0.050
Downward Mediated	0.005	−0.025	0.040	0.007	−0.017	0.025
Upward Mediated	0.023	−0.012	0.068	0.034	0.022	0.056
Downward Skipped	0.353	0.280	0.436	0.161	0.139	0.179
Upward Skipped	0.392	0.327	0.466	0.136	0.110	0.169
Intergenerational Solidarity	0.038	0.000	0.077	0.003	0.001	0.004
Generational Solidarity	0.003	−0.085	0.144	0.056	0.011	0.095
Generational Competition	0.210	0.121	0.283	0.090	0.045	0.120