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Frequent and/or Durable? The Predictive Impact of Initial Face-to-Face Contacts on the Formation and Evolution of Students' Developmental Peer Network Relationships

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Abstract

Despite the relevance of relationships to others acting towards advancing a person's career for individual career development, there is little research on how developmental relationships emerge and evolve over time. This two-year longitudinal study analyses the predictive impact of frequency and duration of initial face-to-face social interaction among newcomer students measured via RFID technology. Results from stochastic actor-oriented models suggest that the more frequent and durable initial contacts were at the first encounter, the more likely actors will create a developmental relationship, supporting proximity and mere-exposure-effect theory. Moreover, they show long-term effect tendencies of initial contacts' frequency on the network's evolution.

Keywords

Developmental Network Formation, Developmental Network Evolution, Peer Network, Face-to-Face Proximity, Stochastic Actor-Oriented Model

1. Introduction

Social network research has shown that besides and beyond individuals' human capital (e.g., personality, skills, knowledge), individuals' social capital (i.e., networks of social relationships) predicts career-relevant outcomes. For example, personality was found to predict job performance and career success through social network position (Fang et al., 2015; Thiele, Sauer, & Kauffeld, 2018). For

individual career development, connections to people who are actively interested and supportive in promoting one's career (i.e., developmental network relationships) have especially been shown to be critical (Cummings & Higgins, 2006).

In the early career stage of university, the association between social network parameters and performance has also been shown, revealing that central students get better grades because of their superior access to information, knowledge, and social support (e.g., Baldwin, Bedell, & Johnson, 1997; Gašević, Zouaq, & Janzen, 2013; Rizzuto, LeDoux, & Hatala, 2009; Thiele, Sauer, & Kauffeld, 2018). Here, the developmental relationships to fellow students bundle into one of the most influential social networks at this career stage due to exchanging peer knowledge and relevant information as well as providing psychosocial support and advice (see also Rodkin & Ryan, 2012).

Given the impact of social networks, it is crucial to understand how and why they emerge and evolve (Jackson, 2014, 2005) because this may yield important strategic implications for the actors of such relationships (Higgins, Chandler, & Kram, 2007, Scandura & Williams, 2001). However, the antecedents of developmental relationships have not received as much empirical attention as their consequences have (Dobrow, Chandler, Murphy, & Kram, 2012; Higgins et al., 2007; Cummings & Higgins, 2006). Social interaction seems to be a key factor for relationship formation (Brass, 2012, Reis, Maniaci, Caprariello, Eastwick, & Finkel, 2011). Nevertheless, little is known about the quantity of such interaction and how it should be shaped when the entire social network is just emerging. In this study, we want to focus on the interaction of a newly composed group of people in order to explore how the frequency and duration of initial contacts comparatively explain the emergence and evolution of developmental social relationships. Within this study, we estimate the likelihood of any two students of a students' cohort forming and/or maintaining a developmental peer network relation as a function of their initial contact length and frequency, complemented by typical structural network and actor attribute effects with respect to a network's emergence and its evolution. In doing so, we contribute to social and developmental network research along several dimensions: first, rather than the common cross-sectional examination of social networks (Cummings & Higgins, 2006), we observe the students' network from its emergence over almost two years within three data waves. This enables us to analyze the networks' formation as well as its evolution and to compare which factors take effect at which point in time. Second, because research has shown that self-reports on specific interactions are not very accurate (Bernard, Killworth, Kronenfeld, & Sailer, 1984, Quintane & Kleinbaum, 2011), we examine contact frequency and contact duration by using radio frequency identification (RFID) technology in order to detect and record face-to-face contacts. Third, we employ an actor-oriented network approach on longitudinal data of a complete network. Thus, we enlarge the focus on one focal actor (ego), usually implemented in developmental network research, by integrating the developmental peers' (alters) perspectives.

2. The Predictive Impact of Initial Face-to-Face Contacts on the Emergence and Evolution of Developmental Peer Networks

Relationships to people who are interested in and acting towards a person's career advancement form a developmental network (Higgins & Kram, 2001). The support and assistance derived from those relationships are a crucial factor for that person's career development (Allen, Eby, Poteet, Lentz, & Lima, 2004) because they can enhance various career-related outcomes, such as perceived career success (van Emmerik, 2004), work satisfaction (Higgins, 2000), and salary level (Murphy & Kram, 2010). The social circles from which such developmental relationships can stem from are manifold and hierarchically diverse (e.g., family, peer group, work teams, senior colleagues, and supervisors; Higgins & Kram, 2001). Each of them is connected to different kinds of developmental support, fulfilling different sub-functions, that is, psychosocial support (e.g., friendship, acceptance, or endorsement), career support (e.g., coaching, exposure, or sponsorship), and role modeling (for a review of developmental networks, see Dobrow et al., 2012). In the early phase of career development, (i.e., the period of studying), particularly the relationships between peers are of developmental importance (Murphy & Kram, 2010; Sacerdote, 2001) because students have no classic supervisors, colleagues, or subordinates. Rather, the peer group composes the biggest pool of possible developmental relationships. Peers hence represent a combination of non-work and work contacts, providing a variety of developmental support functions for one another: career support as well as psychosocial support within friendships and learning groups, and role modeling (see also Rodkin & Ryan, 2012). In doing so, peers are likely to become receiver (protégé) and sender (developer) of developmental support, both simultaneously and reciprocally. In this study, we thus focus on the subset of peer developmental network relationships.

Concerning developmental networks in general, there are some empirically supported individual-level (e.g., protégés' gender and developmental stage) and contextual-level (e.g., formally assigned vs. informal mentoring and organizational culture) network antecedents (see Dobrow et al., 2012, for a review). The (conscious or unconscious) choices to form and/or maintain relationships to peers by selecting them as friends, advisors, and collaborators are, to a large extent, influenced by the similarity of attributes actors share with their affiliates. That is, they are likely to either select peers with similar demographic and personal characteristics (e.g., gender, age, race, but also education, occupation, and intrapersonal values) or to socialize with each other and become similar over time (Ryan, 2001). In social network research, social similarity attraction is called homophily and has been found in various types of network relationships (friendships, peers, support, etc.; for a review, see McPherson, Smith-Lovin, & Cook, 2001). Theory suggests that personality also may play a role in network formation, such that extroverted, conscientious, and open people are more

proactive in interactions with very diverse others (Dougherty, Cheung, & Florea, 2008). Moreover, developmental initiation expressed by development-seeking behaviors, with the aim to enhance skills, knowledge, task performance, or learning (e.g., information seeking, help seeking, initiating behaviors) is assumed to increase the likelihood of situations in which developmental relationships start (Higgins, Chandler, & Kram, 2007).

In general, social network change (i.e., formation, termination, or maintenance of social network relationships) is assumed to be based on the current networks' structure and its actors' attributes as empirical studies continuously report the tendency for networks to show certain structural characteristics, such as reciprocity or transitivity, and actor-specific characteristics, such as homophily (Stokman & Doreian, 2013). Both types of characteristics can be explained by familiarity, such that actors are more familiar with one another when they are physically or socially close, for example, because they are friends of friends (transitivity), or similar (homophily) to each other. Familiarity creates opportunities for interaction, which, in turn, leads to attraction (Denrell, 2005; Reis et al., 2011). Accordingly, the initial interactions and contacts between the actors are apparently crucial for creating and maintaining developmental relationships.

Social psychology has emphasized that spatial and temporal proximity fosters (developmental) social relationships, referred to as the proximity effect. For example, physical proximity has been found to predict information seeking (mediated by knowing about the other person's expertise and availability, or access to that person, Borgatti & Cross, 2003) and friendships (Back, Schmuckle, & Egloff, 2008). This process is generally referred to as the Mere-Exposure Effect (Zajonc, 1968, 2001), which states that repeated exposure of a novel stimulus results in liking that stimulus, and explains why proximity (i.e., familiarity) leads to attraction and subsequent relationships. The Mere-Exposure Effect has been widely studied in different contexts and regarding different stimuli, such as images, music, commercials, and persons (see Montoya, Horton, Vevea, Citkowicz, & Lauber, 2017, for a recent meta-analysis). For example, a study in which the stimulus was a human being revealed a linear increase of perceived familiarity, attractivity, and similarity to women merely and frequently exposed to subjects within student lessons, and a greater reported chance to befriend and work together with them (Moreland & Beach, 1992). Beyond mere exposure, frequent face-to-face interactions produce positive relationships (Ebbesen, Kjos, & Konecni, 1976). "Although interactions may be initially coincidental, repeated interaction is not. Repeated interaction leads to social structure […]" (Brass, 2012: p. 678), such that the degree to which people interact with one another leads to their interpersonal attraction. Moreover, the longer people interact, the more they are attracted to each other through interpersonal processes (i.e., perceived responsiveness and increased comfort and satisfaction during the interactions). Interpersonal attraction, in turn, increases their probability to form or maintain a relationship (Reis et al., 2011). Building on these results, we assume that the frequency and the duration of initial interaction will affect the creation of deve-

lopmental relationships.

Hypothesis 1: The (a) frequency and the (b) duration of actors' initial face-to-face contacts between students increases their likelihood of forming a developmental network relationship.

Further, we assume that this impact of initial interaction will persist over time. Each additional interaction with a person raises the sample of (positive and negative) experiences with her/him, which results in the current impression of her/him. However, the likelihood of future interactions is increased with positive first impressions and high perceived social skills of the other person. By contrast, negative initial impressions lead to the avoidance of further interaction and are thus more stable than positive ones (Denrell, 2005). Hence, we propose that the degree of initial interactions among students facilitates their future interactions, relationship formation, and maintenance. Moreover, social network research has emphasized that although there is a substantial amount of change over time in (developmental) relationships, there also is an inner core of relationships that are rather stable (e.g., Cummings & Higgings, 2006). Over time, actors form relationships to others at a decreasing rate, probably because they do not perceive any more additional benefit compared to the cost of forming a new tie (Currarini, Jackson, & Pin, 2009) or because they gradually exhaust the pool of potential alters in specific social groups (Tarbush & Teytelboym, 2017). Accordingly, we assume that despite a good portion of network change, part of the former relationships predicted by initial interactions will persist over time and/or new relationships will be formed on the basis of initial interactions.

Hypothesis 2: Over time, the (a) frequency and the (b) duration of actors' initial face-to-face contacts between students increases their likelihood of forming/maintaining a developmental network relationship.

3. Method

Sample and Procedure

We followed a cohort of undergraduates (total N = 73; 17.8% male; age at the time of wave 1: M = 22.56, SD = 7.2, range = 18 - 59 years) during their first semester until the end of their forth semester of psychology bachelor studies. During the three data waves, some students joined or left the group because of lateral entry or study dropout, respectively (cf. Table 1: joiners and leavers). Data were collected via RFID technology (wave 0 - 1) and paper pencil questionnaires (wave 1 - 3). The first data wave took place during the mandatory one-week introductory course prior to the start of the degree program, which aimed to provide the newcomers with relevant information about the university, the program's contents, and the lecturers, as well as the chance to get in touch with one another. Hence, the course included plenary sessions mixed with open sessions and breaks. The single events of the course happened at different locations, depending on their purpose (e.g., conveniently, the university library was introduced at the library itself). However, 75% (equals 19 out of 24 hours) of all

Table 1. Subsample descriptives in the three data waves.

	Wave		
	0 - 1	2	3
	Start of 1. Semester (introductory course)	End of 2. Semester	End of 4. Semester
Joiners (+) compared to prior wave		+5	+0
Leavers (−) compared to prior wave		−2	−7
Number of students in cohort (N)	68	71	64
male	16.2%	16.9%	17.2%
mean age at time of wave 1 (SD, range)	22.2 (5.9, 18 - 47)	22.1 (6.6, 18 - 59)	21.5 (5.0, 18 - 47)
Number of students not participating	0 (0%)	1 (1.4%)	1 (1.6%)

Note. Total $N = 73$. Students not participating at wave 2 and 3 exmatriculated at the respective subsequent semester, and were no longer attending lectures by the time of data collection.

the events took place in a separate building, which was technically equipped with RFID technology for the purpose of this study. All students volunteered for wearing active RFID tags while they were staying at the equipped facility of the introductory course (wave 0 - 1). We combined the tags with the students' name badges in order to ensure unambiguous assignment over the five single days of the introductory course. At the end of each day, participants returned the badges so that their batteries could be renewed for the consecutive day. At the end of the introductory week (wave 1), we asked the students to fill out paper pencil questionnaires. Nine months later (i.e., at the end of the second semester; wave 2) and another year later (i.e., at the end of the fourth semester, wave 3), we collected data at the closing event of a seminar held in the respective semester. Participants signed a consent form, which informed them about confidentiality and anonymity, as well as data security and their opportunity to discontinue participation at any time without consequences. Additionally, students were credited for their participation in the study with test-person credits, which they needed to collect during their studies for their degree. Table 1 provides information about the subsamples at each wave. The total number of students ever belonging to the cohort was recorded between wave 0/1 and wave 2 (68 + 5 joiners = 73), was reduced instantaneously (73 − 2 leavers = 71) and again till wave 3 (71 − 7 leavers = 64).

Measures

We measured face-to-face contacts during the consecutive days of the introductory week (wave 0 - 1) and the developmental peer relationships among the students at data waves 1 to 3.

Face-to-face contacts. Within the introductory week (wave 0 - 1), we applied RFID technology from the SocioPatterns consortium[1] (Barrat et al., 2008) and a variant of the MYGROUP (Atzmueller et al., 2014) system to detect and record

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[1]http://www.sociopatterns.org/.

close-range face-to-face proximity of individuals wearing RFID tags. RFID technology has been applied for automatic identification of items in the areas of, for example, transportation, supply chain, agriculture, healthcare, and security (Ahsan, Shah, & Kingston, 2010; Nambiar, 2009). Above that, RFID tags provide the unique feature of measuring face-to-face proximity between people wearing them (Barrat et al., 2008). Face-to-face proximity can be considered as a proxy for actual interaction and can be used to model a social network in different settings, for example, in schools (e.g., Pachucki, Ozer, Barrat, & Cattuto, 2014), at workplaces (e.g., Brown, Efstratiou, Leontiadis, Quercia, & Mascolo, 2014), and at congresses (e.g., Atzmueller, Doerfel, Hotho, Mitzlaff, & Stumme, 2012). Similarly, we used face-to-face proximity as a proxy for actual interaction (that is, verbal and non-verbal contacts) between the students. RFID tags send out proximity sensing signals and tracking signals. Radio packets with proximity signals are exchanged between tags and can therefore be used as a proxy for the close-range proximity of the corresponding tag wearers. In line with Cattuto et al. (2010), we rated a contact as a face-to-face contact if the tags (wearers) were facing each other with a maximal distance of up to 1.5 meters for at least 20 seconds. This is possible because the human body is impervious to radio frequency signals. Slightly more conservative than Cattuto et al. (2010), we defined contact to be persistent until the tags do not detect each other for more than 60 seconds. We determined the end of a contact with a rather large threshold of 60 seconds in order to capture short side-by-side or over-the-shoulder sequences of a contact as well. After detecting a contact, the tags sent specific signals to readers installed at fixed positions evenly spread all over the facility. Those signals contain the unique IDs of the sending and the detected tag and the time stamp of the contact. The readers transfer the signals to a server, where the information is stored and aggregated into a database. With respect to the accuracy of RFID tags from the SocioPatterns consortium, Cattuto et al. (2010) confirmed that if the tags are worn on the chest, very few false positive contacts are observed. They state that face-to-face proximity can be observed with a probability of over 99% given an interval of 20 seconds for a minimal contact duration. For further information about the functionality of the SocioPattern RFID tags, we refer to Barrat et al. (2008). With the RFID technology, we reached not only indoor areas, but also nearby places, such as the smokers' corner and the outer entrance area of the facility. For our analyses, we aggregated the contact duration and frequency over the whole week for each student dyad. In doing so, for each dyad, we received their overall contact frequency in times and their overall contact duration in minutes.

Peer relationships. At each of the measurement points (i.e., wave 1 - 3), we asked the students to select peers on a name list of all students currently belonging to the cohort with respect to (a) "whom you are friends with (i.e., friend)"; (b) "whom you would seek advice from (i.e., advisor)"; and (c) "whom you would like to work together with (i.e., collaborator)" from their current point of

view. On each of the three response occasions, a few students did not fill out the network questionnaire seriously and selected very many others or (almost) the whole cohort as friends (0 - 1 student did), advisors (1 - 6 students did) or collaborators (1 - 5 students did). We followed the approach employed by Light, Greenan, Rusby, Nies, and Snijders (2013) to avoid any destabilization of the iterative estimation algorithm for the simulation which is implemented in the here-used stochastic actor-oriented models (see also section *Analytic Strategy* as well as Huisman & Steglich, 2008). That is, we handled every outgoing choice of those extreme nominators as missing, and only considered data of peers not chosen and ingoing ties to extreme nominators by others as valid. Quadratic assignment procedure (QAP; Krackardt, 1987) tests showed graph correlations of the friend, collaboration, and advice network at each of the various data waves, ranging between 0.52 - 0.76. As peers provide support in various work and non-work roles, we combined those networks into one developmental peer network for each data wave, such that a relationship tie is present if it was present in either of the single networks.

Analytic Strategy

In our analyses, we examined (a) the formation and (b) the evolution of the students' developmental peer network. We conducted our analyses using stochastic actor-oriented modeling (e.g., Snijders, 2001; Snijders, van de Bunt, & Steglich, 2010), which is implemented in the R package SIENA (Simulation Investigation for Empirical Network Analysis; Ripley, Snijders, Boda, Vörös, & Preciado, 2016). These models consider changes in a social network over time resulting from choices made by the single actors in the network, which, in turn, depend on their structural position in the network as well as on their own and the others actors' attributes (e.g., Snijders, 2001; Snijders et al., 2010). Originally, stochastic actor-oriented models were constructed for analyzing longitudinal network data to examine the networks' evolution and to evaluate its' dynamics. Therefore, the first observation of the empirical network is used as the starting basis for the evolution process ending in the last observation. In this study, however, we applied them to model both the evolution of the network and its prior emergence (formation), for which the starting basis would consist of no tie because people did not know each other before, by following the approach of Snijders and Steglich (2015). They showed how stochastic actor-oriented models can be applied on a single observation of a network without an empirical data starting basis. SIENA is very robust toward handling missing data (up to 20%), which occurs naturally in social networks. In order to permit meaningful simulations, missings that come from not participating are imputed such that they equal the last observed tie (i.e., either 1 = present, or 0 = not present) or equals 0 if there was no earlier observed tie (i.e., not present). Contrarily, missings resulting from composition change (i.e., missings from joiners and leavers) are not imputed. The simulations only account for those actors at the observation moments in which they were part of the network. For details and recommendations

on the cross-sectional usage of the models and their application in SIENA, we refer to Snijders and Steglich (2015) and Ripley et al. (2016), respectively.

In order to model (a) the formation and (b) the evolution of the network in a comparable way, we used the effects recommended for the cross-sectional usage identically within both models (e.g., *gwespFF* [$\alpha = 0.69$] for transitivity). Furthermore, in both models, we controlled for alternative effects, which could possibly explain the network dynamics of our primer interest. For example, the effect of contact duration and frequency accounting for peer relationship formation and maintenance may be confounded with peer selection resulting from social proximity (e.g., tendencies for affiliating to an alter's alter) or other structural reasons (e.g., tendencies for popular actors to attract more incoming ties because of their current popularity), or resulting from demographical attributes of the individual actor in relation to those of the other actors (e.g., tendencies for preferring same-gender or coeval peers as affiliates). Thus, we included structural effects (e.g., transitivity, indegree popularity), and demography effects (e.g., gender and age homophily) as predictors of developmental peer network dynamics.

4. Results

Descriptive Overview

Table 2 shows basic descriptive results for the initial contacts of the students and the peer network for each data wave. We determined an overall average contact frequency of 3.3 times between the students' dyads, ranging from 0 to 95 times, and an average contact duration of 8.7 minutes, ranging from 0 to 376.3 minutes (i.e., 6.3 hours). On average, students' individual developmental peer network consisted of 7 peers at the first wave, 14 peers at the second wave, and 13 peers at the third wave.

Table 3 provides information on the occurring developmental peer tie changes in the subsequent data waves. The Jaccard indices (Jaccard, 1900) have shown that 25% of the peer relationships were stable in the first period and 37%

Table 2. Initial contacts (RFID) and peer network descriptives.

	Wave		
	0 - 1	2	3
Initial contacts			
Average frequency	3.28	-	-
Average duration (min)	8.71	-	-
Peer network			
Density	0.10	0.19	0.18
Average degree	7.04	13.77	12.63
Number of ties	495	976	845

Note. $N = 68$ at first wave, 71 at second wave, 64 at third wave.

in the second period (see also Snijders et al., 2010), indicating that there is a substantial amount of change (which is also reflected in the distance measure).

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The results of the converged SIENA models are presented in Table 4. The

Table 3. Descriptives of the network changes between subsequent data waves.

	Period	
	Wave 1 → Wave 2	Wave 2 → Wave 3
Peer network		
0 → 0	3827	3528
0 → 1	666	374
1 → 0	197	398
1 → 1	283	457
Jaccard	0.25	0.37
Distance	729	643

Note. $N = 68$ at first wave, 71 at second wave, 64 at third wave; 0 = absent tie, 1 = present tie; (0 → 0) 1 → 1 = stable (non-existing) tie, 0 → 1 = new tie, 1 → 0 = dissolved tie. Jaccard = index of stability of the successive networks. Distance = number of ties that differ between successively observed networks.

Table 4. Results of the SIENA models.

	Formation Model		Evolution Model	
	Estimate	Standard Error	Estimate	Standard Error
Reciprocity	1.66***	0.31	1.42***	0.41
Transitive triplets	1.00***	0.11	1.56***	0.14
Transitive recipr. triplets	−0.26	0.23	0.02	0.23
Indegree popularity	−0.04	0.16	−0.02	0.05
Outdegree popularity	−0.25*	0.12	−0.35***	0.05
Outdegree activity	0.01	0.04	0.01	0.04
Gender (female) alter	−0.14†	0.08	−0.16*	0.08
Gender (female) ego	−0.08	0.09	0.09	0.09
Gender (female) similarity	0.17*	0.07	0.10	0.08
Age alter	0.01	0.01	0.03***	0.01
Age ego	0.01	0.01	0.05***	0.01
Age similarity	1.52***	0.40	1.95***	0.34
Initial contact frequency	0.03**	0.01	0.01†	0.01
Initial contact duration (min)	0.01**	0.003	−0.001	0.002

Note. $N = 68$ at first wave, 71 at second wave, 64 at third wave. Rate and density parameters are not shown. Reciprocity = tendency to reciprocate tie. Transitive triplets = tendency towards triadic closure (nomination of alters' alters; gwespFF [$a = 0.69$]). Transitive recipr. triplets = tendency for reciprocity within triads (gwespFF [$a = 0.69$] × reciprocity). Indegree popularity = tendency of actors with high indegrees to attract further nominations. Outdegree popularity = tendency of actors with high outdegrees to attract further nominations. Outdegree activity = tendency of actors with high outdegrees to send out further nominations. X Alter = tendency of actors with high values on attribute X to attract further nominations. X Ego = tendency of actors with high values on attribute X to send out further nominations. X Similarity = tendency for X-related homophily. Gender is a binary variable coded 1 = female, 0 = male. †$p < 0.1$. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

estimated parameters are to be interpreted as log-odds ratios (Ripley et al., 2016).

In Hypothesis 1, we assumed that (a) the frequency and (b) the duration of students' face-to-face contacts will significantly increase the likelihood of them forming a developmental network tie. We found evidence for contact frequency, displayed by a significant estimate of $\theta = 0.03$, $p = 0.003$, and contact duration, displayed by a significant estimate of $\theta = 0.01$, $p = 0.002$, to predict developmental network tie formation. Thus, Hypotheses 1a and 1b are fully supported. That is, the more often students have face-to-face contact right at the beginning of their studies, the more likely they will create a developmental peer relationship. Precisely, with a single contact, the likelihood of creating a relationship increases by 3% ($e^{0.03} = 1.03$ times more likely), and with recurring contacts, e.g., for ten times recurring contacts ($e^{10*0.03} = 1.35$), the likelihood of creating a relationship increases by 35%. Moreover, the longer students stay in face-to-face contact right at the beginning of their studies, the more likely they will become developmental peers: This likelihood increases by 1% ($e^{0.01} = 1.01$ times more likely) with a contact lasting for one minute. For longer contacts, the likelihood will increase even more (e.g., for a 15 min contact it will be ($e^{15*0.01} = 1.16$) 16% more likely to create a network tie).

In Hypothesis 2, we proposed that the aforementioned effects would continue over time, assuming that the likelihood that students maintain or form developmental peer network ties to fellow students is significantly greater the (a) more frequent and (b) longer they had face-to-face contact right at the beginning of their studies. Our analyses show marginal significant evidence for contact frequency, $\theta = 0.01$, $p = 0.064$. Hence, the likelihood of maintaining or creating a developmental peer relationship to a fellow student during the first four semesters tends to increase by 1% ($e^{0.01} = 1.01$) with a single contact right at the beginning of the studies, and will increase even more for recurring contacts, for example, for ten times recurring contacts ($e^{(10*0.01)} = 1.11$) 11%. Thus, we partially support Hypothesis 2a. However, we found no significant evidence for contact duration, $\theta = 0.00$, $p = 0.734$. That is, the duration of initial face-to-face contacts does not have an impact on network evolution. Thus, we cannot support Hypothesis 2b.

Beyond the focal effects, we controlled for potential structural and demographical factors on predicting network formation and evolution. Several of these prove to be significant in both the network formation and the network evolution model, or in either of them. In terms of network structure, for both network formation and network evolution, we observe significant reciprocity effects, $\theta = 1.66$, $p < 0.001$ and $\theta = 1.42$, $p < 0.001$ respectively. Reciprocity describes the tendency to reply to a tie within dyads, which in this study means the tendency to seek developmental support from those being supported by oneself. Furthermore, we find a significant tendency towards triadic closure, expressed by significant transitive triplets effects, $\theta = 1.00$, $p < 0.001$, and $\theta = 1.56$, $p <$

0.001, respectively. Moreover, we observe significant outdegree popularity effects, that is, tendencies to nominate others who nominate few developmental peers, θ = −0.25, *p* = 0.043, and θ = −0.35, *p* < 0.001, respectively.

Concerning demography, in both models, we found (marginally) significant gender alter effects, that is, tendencies to nominate males as developmental others, θ = −0.14, *p* = 0.091, and θ = −0.16, *p* = 0.042, respectively, and highly significant age homophily effects, θ = 1.52, *p* < 0.001, and θ = 1.95, *p* < 0.001, which describes tendencies to nominate coeval others. Only for network formation did we find evidence for gender homophily (θ = 0.17, *p* = 0.013), whereas only for network evolution, we observed the tendency for older students to attract further nominations from others, θ = 0.03, *p* < 0.001 (age alter effect), and also to send out further nominations, θ = 0.05, *p* < 0.001 (age ego effect).

In order to estimate the model fits of the formation and evolution model, we compared the empirical peer network with the 5000 networks that were simulated within the SIENA models (see Figure 1). The specified models perform better in capturing the actual social mechanisms when the deviation between empirical and simulated networks is small (goodness of fit; Snijders et al., 2010). As can be observed in Figure 1, the empirical distribution (solid line) is located within the simulated distributions (violin plots) for most degree values and triad types, which implies an acceptable to good fit of our models.

5. Discussion

Within the present study, we examined the influence of students' initial contact frequency and duration on both their developmental relationship formation and its evolution. Those peer relationships are a career-relevant subset of a person's developmental network (a type of social network basically consisting of all the relationships to people who are interested in and acting towards this person's career advancement; Higgins & Kram, 2001). Our aim was to objectively measure initial interactions between students of one cohort and find out about the short- and long-term impact those interactions have on developmental peer relationships (i.e., friendship, advice, and collaboration ties). Therefore, we used RFID-technology to measure close-range face-to-face proximity (i.e., verbal and non-verbal interaction) of newcomer students during their introductory week at university. To evaluate the RFID and three-wave longitudinal self-report network data, we applied stochastic actor-oriented modeling and controlled for alternative effects.

With partial support of our hypotheses in which we assumed the frequency and the duration of initial contacts to impact both the short-term emergence and the long-term evolution of developmental peer relationships, our results have indicated that the frequency and the duration of initial contacts have a strong short-term impact on relationship formation. Moreover, they show tendencies that the impact concerning frequency (but not duration) persists over time. That is, relative to a random choice of developmental peers, students initially
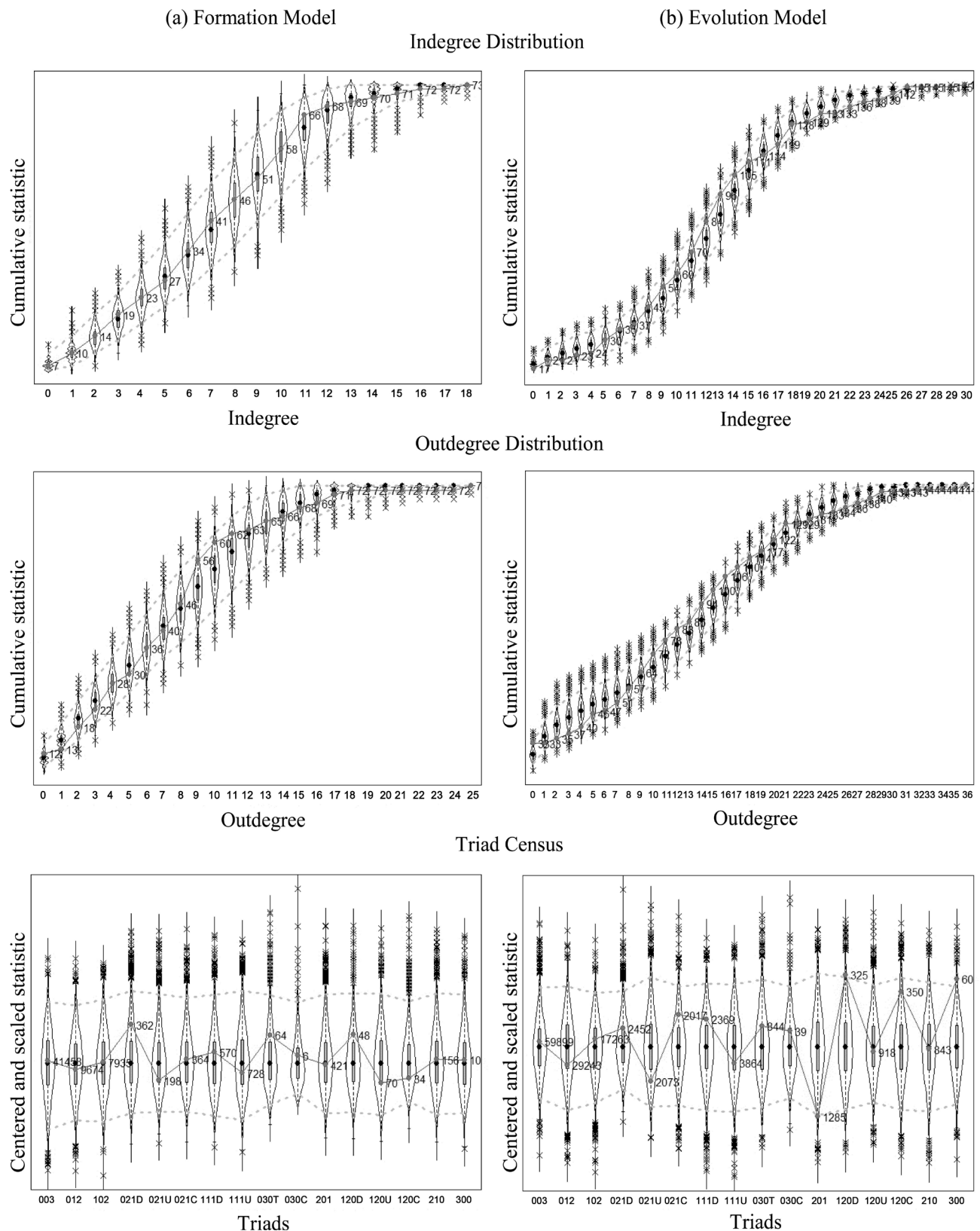
(a) Formation Model (b) Evolution Model

Indegree Distribution

Outdegree Distribution

Triad Census

Figure 1. Goodness of fit assessed on the basis of 5000 simulations. Distributions of incoming (indegree) and outgoing (outdegree) relationships, as well as types of triads (triad census). The solid line represents the empirical distribution, the violin plots represent the simulated distributions, $N = 68$ at first wave, 71 at second wave, 64 at third wave.

interacting frequently and durably are also more likely to affiliate to one another at the beginning of their studies. Also, students initially interacting frequently are, by trend, also more likely to maintain or form such relationships over time during the course of subsequent semesters. Note that the initial interaction we measured does not necessarily imply active conversation between specific students, but simple standing together. Likewise, the size of the effects is rather huge, considering that they refer to single occurrences (frequency) and minutes (duration): a single interaction increases the likelihood of initially forming a developmental peer relationship to a fellow student by 3%, a single minute of interaction increases it by 1%. Moreover, the probability of students maintaining or emerging those developmental peer network ties in the long run is at least marginally increased by 1% with a single initial interaction between the students. Of course, applied to recurring and longer contacts, the size of these effects will be dramatically higher (e.g., a 5-times recurring contact or a 15-min lasting contact increases the likelihood for initially forming a network tie by 16%).

We observed our results while controlling for structural and demographical characteristics typically found in network studies and shown to be influential (see also Veenstra, Dijkstra, Steglich, & van Zalk, 2013). Valid for both the formation and the evolution of the network, the examined student peer relationships tend to be reciprocal. Hence, students provide and receive support reciprocally from each other. Moreover, the examined network shows stable tendencies towards triadic closure. That is, students tend to connect to their peers' affiliates (e.g., friends of friends become friends). Furthermore, they tend to nominate those fellow students for a developmental relationship who, by themselves, nominate only few others. Such behavior can be explained with the consideration of costs and benefits of forming a new tie (e.g., Jackson, 2005), such that students might assume most benefits in asking those for developmental support, who are themselves not (in need of) support. Concerning typical demographical homophily, our results support the stable tendency to affiliate with similarly aged others. Despite the typical tendency to affiliate with same gender others, which we find only in terms of initial network formation but not when it comes to the maintenance of relationships, our mostly female students also tended to seek developmental support from male peers, thereby also supporting findings from Ibarra (1992). In line with mentoring research, this networking behavior is highly beneficial because such relationships (i.e., male mentor, female mentee) provide the highest amounts of career development functions (Sosik & Godshalk, 2000). Lastly, while controlling for age-homophile relationships, the evolution of the examined developmental peer network is characterized by tendencies for older students to seek further developmental support and also to be further asked for developmental support from others.

Theoretical & Practical Implications

In line with previous network research (e.g., Back et al., 2008; Borgatti & Cross, 2003; Moreland & Beach, 1992; Reis et al., 2011), our results support the

idea that proximity (i.e., face-to-face contacts) leads to the formation of social relationships via attraction through familiarity. Our results are crucial for explaining how networks emerge and evolve. Building on previous research, our results shed light on how initial contacts can influence social networks as they emerge as well as over time. By examining relationships in the framework of an entire student cohort's network, we extend our understanding of developmental networks and demonstrate that developmental peer relationships tend to be reciprocal. This indicates that those relationships imply equal measures of give-and-take. Thus, peers' (alteri) ego perspectives are worth being included in the data collection (see also Dobrow et al., 2012; Steglich, Snijders, & Pearson, 2010).

The results of this study are also important for prospective students, educators, career counselors, and faculties concerned with the career development of people in the early career stage of higher education. Generally, initial face-to-face contacts are crucial for the formation of developmental network ties and, thus, for developmental support. Up to this point, this has not been surprising. According to our results, however, the quality of these contacts seems be important. First, in line with Watzlawick's and colleagues' axioms of communication (Watzlawick, Beavin, & Jackson, 1967), saying that interpersonal communication is omnipresent, happens intentionally as well as unintentionally, and defines relationships, our results indicate that both active conversations and passive standing together without directly speaking to one another (i.e., mere exposure) lead to relationship formation. Second, the frequency of initial face-to-face contacts apparently is even more important than their duration. This applies not only for initial relationship formation but also marginally for their long-term maintenance. According to Denrell (2005), there might be a positivity bias in impressions of people frequently interacted with, such that people are likely to initiate recurring interactions with people they have a positive first impression of. Beyond that, the likelihood that false negative initial impressions can be corrected are increased with more different opportunities of social situations in which people can sample experiences and develop their first impressions of others. Given the career-developmental benefit of such relationships (e.g., Cummings & Higgins, 2006), these two aspects yield several implications for ideal networking behavior: people in newly composed groups profit from portioning their time trying to repeatedly (and maybe also durably) get in contact with a great many others instead of intensively interacting with just a few in order to build a large individual developmental peer network. In this process, actively speaking to someone is not necessarily required. Joining a conversation of others, standing alongside and exposing oneself frequently to others without actively pushing the discussion is sufficient to foster relationship formation. Even if the relationship is created by the passive actor, for example, such that he/she asks a more active person for collaboration, it is very likely that this relationship is eventually reciprocated. In this connection, considering the results of Shipilov,

Labianca, Kalnysh, & Kalnysh (2014), high amounts of individually driven career networking increase individuals' network range much more than networking in organized structured activities with the explicit purpose of networking, which follows a negative curvilinear shape (i.e., moderate amounts of structured networking yields most positive outcomes). Beyond that, following our results, initial tie formation can open the gates for additional ties in the future (e.g., to friends of friends). Hence, engaging in networking right at the beginning also comprises long-term benefits. These findings should encourage organizers of introductory events to carefully think about how to arrange such events: Introductory events should not only aim to provide information but also time for (unstructured) networking. Moreover, as much as possible, they should allow for free mingling with people, facilitating frequently changing contacts. For example, bar tables without seats could enhance free mingling more than seated. People can more easily choose to leave for or join another conversation without bothering with getting up from a comfortable position, leaving, or searching for an abandoned seat and offending those left behind.

The covariate results of our study should furthermore encourage minorities: The salient minorities in our sample, which encompassed a psychology student cohort, are men and older students. Despite possible fears of not catching up with the typical student of the cohort, they play an important role in the peer network. Male students are continuously attracting further nominations for developmental peer relationships, which holds benefits in particular for female protégés, as mentioned above. At a later stage, when the network evolves, older students come to the fore. Not only do they enlarge their network range by seeking developmental support, they also attract others to ask them for developmental support. Hence, the perceived value of older students seems to increase over time because, for example, during the course of studying, they might contribute the experience they gained in their former job to solve study tasks, and are thus perceived to have general, professional, and methodical competence.

Directions for Future Research

Although we applied sophisticated statistical analyses to our longitudinal data, which was collected via self-reports as well as objective technology, this study faces some limitations, which provide directions for future research. First, we measured developmental peer relationships by asking the participants to select peers with whom they are friends, with whom they would like to work together, and from whom they would seek advice. We phrased these two questions subjunctively to be able to capture developmental network ties from the beginning of the cohort's existence, when people had not actually worked together yet. Thus, we cannot distinguish between, for example, actual advice seeking from intended but still hypothetical behavior. Thus, future research could measure developmental relationships in a peer cohort incorporating a mutual perspective by asking participants about their actual developmental support seeking/support

providing behavior. Moreover, although it is common to aggregate across different content networks (e.g., Burt, 1997), future research could analyze the multiplexity of the single networks (i.e., friendship, advise, collaboration), as we did when we merged into a single developmental network. Given that multiplex developmental relationships from the work- and non-work context (e.g., friend and coworker) are positively associated with career and psychosocial support in the organizational context (Barthauer, Spurk, & Kauffeld, 2015), their examination regarding students' peer developmental networks could reveal fruitful implications for the actors of such networks. On the basis of the QAP-test results, which suggested that there is a substantial overlap of the three, the modeling and analysis of such multiplex networks (Kanawati, 2015; Mucha, Richardson, Macon, Porter, & Onnela, 2010) could examine the co-evolution of those networks in more detail. Furthermore, including descriptive information in the network yielding attributed multiplex networks (Kanawati, 2015) is a further direction for the extended structural analysis and mining of descriptive patterns (Atzmueller, Doerfel, & Mitzlaff, 2016).

Second, although with our measurement of initial contacts via RFID technology we were not able to detect contacts that took place during leisure time (i.e., in the evenings) of the data collection period, which could have been influential, measuring contacts with objective technology has a tremendous advantage. Surveys are, indeed, seen as efficient and time saving. However, they bear the risk of recall bias (Bernard, 2013). Recall bias in self-reports has been found in many social network studies (e.g., Marin, 2004; see also Brewer, 2000, for a review). In case of social interaction, recall errors arise if informants forget to report contacts, or if they report contacts they did not actually have, as they tend to unconsciously rate the social significance of their ties (Quintane & Kleinbaum, 2011). Precisely, about 50% of specific interaction self-reports contain some inaccurate information (Bernard et al., 1984).

Third, we examined the linear relationship between proximity (i.e., interpersonal interaction) and network emergence and evolution, indicating that the more people interact with one another, the higher their probability to connect. However, a recent meta-analysis on the Mere-Exposure Effect has shown that there is a negative quadratic (i.e., inverted U-shape) relation between exposure frequency and liking, such that liking for a specific stimulus decreases after a certain amount of exposures, resulting from habituation (Montoya et al., 2017). Despite our assumption that a linear model will display the data better than a quadratic one, as the contacts we measured were unforced such that people could have left or joined conversations self-determinedly, for example, in case of boredom (in contrast to the participants of the Mere-Exposure Effect studies), future research should examine the shape of the relationship.

Moreover, future research should examine the contact pattern after the introductory events and its impact on the networks' evolution. Although the frequency and duration of initial contacts apparently determine much, especially

for initial network emergence, it would be interesting to learn how subsequent contacts should be shaped to maintain ties, and find answers to the following questions: Is contact frequency more important than contact duration? In which temporal intervals must contacts occur in order to optimally align one's network? Are peer developmental relationships influenced by effects of boredom or habituation through too many contacts in the long run?

6. Conclusion

This study is the first to examine the impact of face-to-face interaction frequency and duration on developmental peer networks' emergence and evolution. By applying stochastic actor-oriented modeling on three-wave network data, thereby incorporating a mutual and longitudinal perspective, we contribute to open questions on developmental networks. Our findings highlight the importance of initial contact frequency and duration for network formation and the minor importance of contact frequency for its evolution. With our study, we improve our understanding of how actors' dyadic characteristics and individual networking behaviors determine relationships.

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