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Digital communication and tie formation amongst freshmen students during and after the pandemic

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ABSTRACT

This study examines the network evolution among sociology freshmen students during and after the Covid-19 pandemic as a natural experiment on the impacts of digitalised communication. The first surveyed cohort (N = 42) began their studies under lockdown in October 2020, when all classes were taught online (lockdown cohort). The second cohort (N = 66) started one year later when the lockdown measures were released partly and most classes were taught in a hybrid mode (hybrid cohort). We use Stochastic Actor-Oriented Models (SAOM) for model estimation; missing relations due to actor non-response are multiply imputed using SAOM-based procedures. The findings show (1) that the network among students of the lockdown cohort developed slower and reached a lower density at the end of the first term, (2) that the probability of triadic closure was significantly lower in the lockdown than in the hybrid cohort and (3) that in both cohorts, students have a stronger tendency to get acquainted if they share classes, but (4) that shared classes were more important for tie formation during lockdown. We conclude that digital communication will mitigate the opportunities to make new acquaintances and friends.

1. Introduction

Digitalisation has thoroughly changed peoples' lifestyles and will do so in the future. Besides digital services that make life easier, digital communication has only started to shape our social relationships. However, during the Covid-19 pandemic, nearly everybody had to rely exclusively on digital communication to stay in touch with friends and family. Though maintaining yet-existent ties was challenging to many, establishing new ties was even harder. Hence, analysing social network evolution during the pandemic can be viewed as a natural experiment that shows how networks would develop if communication were (almost) exclusively digital. Therefore, we compare the network evolution among a small cohort of freshmen students who started their studies at a German university during a strict lockdown (winter term 2020/21) to a cohort of freshmen who started after the lockdown (winter term 2021/22) in the same track at the same university.

Finding new acquaintances and friends is an important task at most major life course trajectories. For many freshmen students, the end of school and the beginning of their undergraduate studies is accompanied by the search for new fellows with whom they can exchange social resources regarding their studies: information, help, companionship and solidarity in the new situation. Moreover, going to university for many freshmen means moving to a new city, away from their families and established network of friends. Because very few freshmen have known each other before, we can describe the network evolution from its beginning. This is particularly important, because students recruit study partners from their existing friends at university, and these social resources have been identified as important for their academic success (Stadtfeld et al., 2019).

Recent findings have shown that students' interactions significantly decreased after only two weeks of lockdown (Elmer et al., 2020). For students who even started their undergraduate studies in a fully online scenario, opportunities to meet, interact and make friends are presumably even worse. Typically, individuals do not choose their friends and acquaintances randomly. On the one hand, there is a strong preference to connect with others who are similar to oneself in various traits – the so-called homophily principle. On the other hand, finding potential friends depends on meeting opportunities which are typically facilitated by *foci of activity*. Feld (1981) conceptualizes foci of activity as social activities that are organised around some place or other entity and bring

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together people with particular characteristics. Foci may vary in the amount and structure of others who individuals can meet there (opportunities for contact), and they can vary in their capacity to provide opportunities to come into mutually rewarding interaction (opportunities for interaction, Stauder, 2014b; Stauder, 2014a). In non-pandemic times, university life consists of many foci of activity: the classes students attend, student activities like theatre or sports clubs, student councils, hang-outs at student cafés, and many more. During the pandemic, however, students' foci were reduced to digital classrooms. The less formal occasions to interact were all cancelled, and the digital classrooms reduced opportunities to get to know others and to interact "off-topic" to an absolute minimum. When the impact of the pandemic restrictions on public life began to peter out, many of these foci of activity were re-established.

Therefore, this study describes and analyses the network evolution among two cohorts of freshmen students in a small study track at a German university (about 30,000 students) during their first term. The first cohort started their studies in the winter term 2020/21. For them – the *lockdown cohort* – virtually all classes were taught online. The two possible modes were video calls or asynchronous online teaching via texts, tasks, and written feedback. For the lockdown cohort, all classes discussed in this paper were taught via weekly video calls. We compare the network evolution of this cohort with that of the freshmen of the following winter term 2021/22. This cohort could opt to attend lectures and seminars in physical co-presence. However, those who went through a Covid-19 infection or feared getting infected could also participate using a video call. We will refer to members of this cohort as the *hybrid cohort*. At the beginning of the term, only few students chose to join via video call. Due to increasing infection rates during winter, more students attended that way in the second half of the term.

The *first research question* we aim to answer is, whether the evolution of the student network was slower for the lockdown cohort than for the hybrid cohort and whether the density was finally lower.

One important social mechanism of tie formation is transitivity, the tendency to close open triads because individuals seek for cognitive balance in their networks to avoid psychological strain (Heider, 1946). This mechanism is a main driver of tie formation in educational settings next to reciprocity (Boda et al., 2020; Kitts and Leal, 2021; Louch, 2000). As Feld (1981) points out, transitivity is particularly to be expected when the triad is embedded in one or several shared foci of activity; and the more constraining these foci, the more likely is a closed triad. As the pandemic reduced the more informal foci in academic life and the opportunities for mutually rewarding interactions there to an absolute minimum and since online-classes might be less constraining than classes in physical co-presence, our *second research question* is whether transitivity was particularly mitigated in the pandemic.

Even if students during the lockdown are likely to have made fewer friends or did so at a slower pace during their first term than those who started their studies one year later, it is not immediately evident whether meeting places were less or even more important for tie formation: On the one hand, participating in the same virtual classrooms during the lockdown might have offered *poorer opportunities for interaction* than participation in co-presence. Against this backdrop, we can expect that attending the same classes is less important for tie formation among the lockdown cohort compared to the hybrid cohort. On the other hand, virtual classrooms were the *single remaining opportunities for contact* for members of the lockdown cohort, whereas students of the hybrid cohort could meet in classrooms and on informal occasions. Hence, although network evolution might have developed slower during the pandemic, taking the same class may have been even more important to make friends. Therefore, as its' *third research question*, this study will ask whether shared classes as formal meeting places impact friendship formation among freshman students and if so, whether this effect was less or even more pronounced for the lockdown cohort than for the hybrid cohort.

The present study contributes to the literature by observing a two-fold natural experiment. In contrast to Elmer et al. (2020), who identified changes within one cohort of students and between two cohorts at an advanced stage of their studies, we (1) compare a freshmen cohort under lockdown to one after lockdown. Therefore, we can observe (2) the two networks from their very beginning with almost no pre-existing ties. We find that the density of stronger relationships within the freshmen network in the lockdown cohort developed slower and reached a lower level than in the hybrid cohort. Moreover, we find that the tendency for triadic closure seems to be much stronger when in-person meetings are possible.

Our analysis then focuses on the role of foci of activity, namely classes. We emphasise that not every opportunity for contact is as well an opportunity for interaction. Opportunities for contact are only converted into opportunities for interaction if this is facilitated by the setting. Though we suspect that online classrooms do not foster interaction among students (Stauder, 2014a) and that the less formal occasions to socialise are more important for positively evaluated interactions, we find that the effect of attending the same class is more important for the lockdown cohort. Most probably, there simply are no other – more informal – opportunities for contact among students.

2. Prior research

Educational settings appear to offer an environment full of opportunities for interaction, and people are usually part of educational foci long enough to form strong ties like friendship. Therefore, students in schools and universities on average have significantly more friends than people in the labour force (Stauder and Kossow, 2014). This power of educational settings is particularly important because peer-network integration at university has been shown to impact academic success among Dutch students of the social sciences (Brouwer et al., 2016) and among Swiss engineering students (Stadtfeld et al., 2019). On a subgroup of the Swiss engineering students, an experiment was performed two months prior to the start of their first term, dividing them in small groups at an introduction event. The groups impacted friendship formation at the beginning of the term, but the effect petered out later (Boda et al., 2020).

With the emergence of the Covid-19 pandemic and the first lockdowns in April 2020 in Switzerland, the number of interactions dropped significantly for students enrolled in an engineering program, both within one student cohort (enrolled since 2017) and compared to an older cohort (enrolled since 2016). However, two weeks after the start of the Swiss lockdown, the number of friendships reported remained stable (Elmer et al., 2020). It remains an open question whether the lockdowns impacted the network formation among students in the long run. Especially those who began their studies under lockdown might have faced a severe lack of opportunities to get in contact and interact with their fellow students and therefore might have made fewer friendships or acquaintances than students who started their studies without these restrictions.

Homophily is the tendency to form ties with others who have identical or similar attributes as oneself. Literature shows that homophily is a main driving force of tie formation, for example by gender, ethnicity, or financial resources (Block and Grund, 2014). Local attributes, like sharing the same classroom, allow for interaction and identification, too, and hence, are subjected to the homophily principle. In schools, attending the same classroom has a high impact on friendship formation for children aged ten to 13 (Pink et al., 2020) as well as for adolescents in high school (Frank et al., 2013). As the younger students at school spend most of their day in class with more or less the same group, this effect should certainly be weaker at university than at school, but yet existent. However, the lockdown and social distancing measures prevented students from attending classes in physical co-presence from April 2020 for more than one year. It is an open – and concerning the social consequences of digitalisation, in general, a very interesting – question, whether sharing virtual classrooms has similar impacts on tie formation

as attending class in physical co-presence.

'Social distancing' during lockdown had severe impacts on students' psychological well-being all over Europe with a high prevalence of stress, anxiety, and depression (Oliveira Carvalho et al., 2022). For Germany, Werner et al. (2021) report a slight increase in depression and a medium increase in loneliness. Peer relationships seem crucial: 91 % of respondents feeling socially stressed reported that this was due to them no longer being able to meet their friends (ibid.: 6). A descriptive survey in the US found that loneliness in students was often reported as a consequence of loss of peer-contact during the pandemic (Birmingham et al., 2021).

In sum, all studies so far examined the impacts of social distancing and online teaching on the social network and psychological well-being of students who were already enrolled and, hence, had the opportunity to establish friendship ties before the first lockdown. To our knowledge, no existing study analyses the impact of contact restrictions on students who began their studies during the pandemic. We contribute to filling this research gap by studying the emergence of networks in two student cohorts not enrolled in their programs before the pandemic. In doing so, we also contribute to understanding the impacts of future digitalisation of communication.

3. Theoretical background

3.1. Opportunities for contact at the university

Ever since Verbrugge's (1977) seminal work, we know that there is no mating without meeting. In many cases, meeting places can be characterised as "foci of activity". Feld (1981) defines foci as social, psychological, legal, or physical entities around which joint activities are organised, such as workplaces, voluntary associations, hangouts, and families. Because social activities are organised around foci, individuals do not meet randomly. A focal activity attracts individuals possessing relevant attributes, thus enforcing similarity amongst participants regarding these attributes (Feld, 1981, 1982; Fischer et al., 1977; Marsden, 1990; Verbrugge, 1979). The university can be characterised as a focus which attracts students with specific traits. First and foremost, all of them hold the same educational level.

At closer sight, however, the university is not a single focus where students repeatedly meet with others. It consists of many "sub-foci" organising different social activities: Naturally, there are the classes students attend. In contrast to school, students at university can subscribe individually for various classes. Hence, two students of the same subject may attend different classes. Focus theory suggests that two individuals who participate in the same focus – in this work meaning the same class – have a higher possibility to interact and to get tied than two individuals who do not share a focus (class).

But student life does not only consist of classes: Students also learn together in self-organised groups or at the library, they engage in campus activities like theatre groups, sports clubs, political groups, and student councils. They also jointly wait for classes to begin, chat at student cafés, have lunch together, have the same way to the campus or classrooms, and many other foci.

3.2. Opportunities for interaction

The various foci of activity offer different opportunities to transform mere contact into positively valued interaction (Stauder, 2014a,b). Following Homans (1950), Feld claims that foci bring individuals together in a mutually rewarding situation, which can result in positively valued interaction and the formation of positive sentiments (Feld, 1981). (Stauder 2014a,b) suggests differentiating between opportunities for contact and opportunities for interaction. Opportunities for contact pertain to the amount and the social composition of regular contacts in an individual's foci of activity. Whether opportunities for contact transform into opportunities for interaction depends upon the potential of these foci to bring together individuals in a mutually rewarding situation.

All students take classes – though during the pandemic this does not necessarily mean physical co-presence. But even in the classic classroom situation, communication in classes is highly constrained: Students must discuss the subject in a regulated order. They do not mainly participate to socialise with fellow students, but to learn about the subject and to succeed in exams. In contrast, students' other activities on campus are less formalised. This makes it easier to find out who could be an interesting fellow to socialise with and to find out about shared interests and beliefs. Hence, the more informal foci may provide better opportunities for (positively valued) interaction.

Moreover, the more informal foci at university may foster opportunities for interaction via the transitivity mechanism: Two individuals who are each tied to a third individual have a high probability of linking to each other (Kossinets and Watts, 2006; Louch, 2000). This effect of transitivity is a particularly powerful source of contact opportunities if the triad is embedded in a shared focus of activity (Granovetter, 1973; Mollenhorst et al., 2008). Foci may vary in the extent to which they foster or inhibit transitivity. In particular, transitivity as a social mechanism within a focus is more likely when people can freely communicate with others, which is easier in more informal settings than in classrooms; and it is easier in physical co-presence than in virtualized settings. Under the regime of complete digital communication, informal meetings are typically 1:1-settings which are initialized by intention. While introducing two acquaintances to each other in an informal focus in co-presence happens more or less by occasion – like joining a conversation in a café or at a party –, under lockdown this is supposed to be an intentional act by the focal actor in most cases.

3.3. Hypotheses

Generally, in non-pandemic times, students can be involved in many different sub-foci around university life, the classes with the more rigid rules of communication being only one part of it. During the pandemic, however, students' foci were reduced to digital classrooms only. The less formal occasions to meet with their high potential for mutually rewarding interaction were all cancelled.

Moreover, communication in digital classrooms was even more restricted than in classes that take place in person: Depending on technical requirements, some students did or could not even use a camera or a microphone and only listened to what the teacher (and a few other students) said. Hence, the opportunities to interact "off-topic", to find out about other students, whether they may be suitable fellows or friends, and the occasions to introduce one's acquaintances to each other were reduced to an absolute minimum.

With all communication taking place via media during the pandemic, many freshmen students who might otherwise have moved out from their parents' homes and away from the social contacts in their hometown to start their studies, stayed at home and remained embedded in the old networks of school friends who faced the same situation.

In total, students who started their studies during lockdown in the winter term 2020/21 had reduced opportunities for contact with their fellow students. The opportunities for rewarding interaction in these remaining digital meeting places were very restricted because communication was not only regulated by the rules of the classroom but also due to reduced communication channels in the online situation. Moreover, with the condition of digital classrooms, no informal opportunities for contact and the reduced communication channels, the powerful mechanism of transitivity is supposed to be severely mitigated. The hybrid cohort, in contrast, had more opportunities for contact in the more informal foci of activity, could attend classes in person and had occasions for getting to know the acquaintances of their acquaintances. For all these reasons, we expect that ties formed slower in the lockdown cohort than in the hybrid cohort.

Therefore, we hypothesise that the density of the freshmen network

in the lockdown cohort reached a lower level at the end of the term than in the hybrid cohort (hypothesis 1) and that the network of freshmen in the lockdown cohort developed significantly slower (hypothesis 2). Moreover, we hypothesise that the tendency for triadic closure was severely mitigated for the lockdown cohort compared to the hybrid cohort (hypothesis 3).

Following the basic idea of focus theory, sharing the same classes should provide opportunities for contact and interaction – even though the less formal situations around classes might be more efficient in transforming opportunities for contact into mutually rewarding interaction. We hence hypothesise that participating in the same class increases the probability to become acquainted or befriended (hypothesis 4).

As opportunities for contact for the students of the lockdown cohort were exclusively restricted to (digital) class attendance, the distribution of students to classes might have shaped tie formation to a larger extent than for students of the hybrid cohort. Hence, we hypothesise that for the lockdown cohort, the effect of participating in the same class is stronger than for the hybrid cohort (hypothesis 5).

However, though digital classrooms may have the same function as classes in physical co-presence, they are qualitatively different: They may be less efficient in transforming opportunities for contact into opportunities for mutually rewarding interactions compared to classrooms in physical co-presence. Therefore, the basic mechanism of focus theory – sharing a focus promotes tie formation – may be *less effective* for such virtual foci. Hence, we alternatively hypothesise that for the lockdown cohort, the effect of participating in the same class was lower than for the hybrid cohort (hypothesis 6).

Note that hypothesis 5 builds on the argument that opportunities for *contact* are restricted to digital classes. In contrast, the competing hypothesis 6 is based on the idea that digital and conventional classrooms constitute qualitatively different foci, because the remaining opportunities for contact in digital classrooms only poorly transform into opportunities for *interaction*.

4. Data and methods

4.1. Data

The data of the two cohorts originated in two research seminars for master's students in Sociology. Social network data and individual attributes were collected in newly started bachelor freshmen cohorts of a study track at a large German university from November 2020 through February 2021 and November 2021 through February 2022. In 2020 (*the lockdown cohort*), 42 out of 63 enrolled freshmen students participated, in 2021 (*the hybrid cohort*) 66 out of 83 participated. Participation was counted as given if students agreed to take part in the study and provided the opportunity to their fellow students to identify them via a photo. Relational data and individual attributes were collected three times throughout the first term. Before the first data collection, profile pictures of the study participants were taken and consent forms were signed. These pictures were integrated into the online survey in which the students were first asked to identify whose first name they knew. In the reduced set of profile pictures of these known fellow students, respondents were asked to identify their acquaintances,[2] friends, and people they talk to about important issues (the core discussion network, Burt, 1984: 296, 331). As not all students in both cohorts participated in the study and provided their photos, some participants could not find all their acquaintances and friends in the survey. In the midterm surveys, we therefore asked the students how many of their contacts they were missing. More than two acquaintances and friends were missing only for four participants in the lockdown cohort and nine in the hybrid cohort.

Further, individual attributes were collected in the survey. Among others, these covered the participation in tutorial groups of "Introduction to Science" and "Statistics".[3] Due to the Covid-19-related contact restrictions in the autumn and winter of 2020/21, all classes and lectures were taught online for these students.[4] During the autumn and winter of 2021/22, students were free to attend either in person or via video chats in most classes. In both cohorts, some students did not participate in all three surveys. Therefore, missing data is imputed for elaborated analyses (see Appendix B).

4.2. Measuring ties and class participation

In the survey, we collected data about ties of different strength separately for both cohorts. In a network in which people have known each other for only a short time, only few friendships or core discussion relationships are already established. For the SAOM, we therefore cumulated responses and analysed a network of ties that are *at least* considered as acquaintances, but could also be even friends or someone with whom respondents talk about important things. In that way, we consider ties of medium to high strength of relationship. We treat the relationships as binary tie variables. Doing so provides us with enough computational power to conduct our analysis (Fig. 1 shows the density over time for the two networks).

Class participation was measured by self-reports as well. The two tutorials in our analysis were mandatory classes for all bachelor's students and recommended for the first term. Both tutorials were held in small groups (three groups in the lockdown and four groups in the hybrid cohort). Only very few students chose not to enrol in the tutorials in their first term. The students were asked about the weekly timeslot for the tutorial group they participated in and for the first name of their tutor (an advanced bachelor's, master's, or PhD student).

4.3. Analytical strategy

In the first, intuitive step, we will describe the density of the peer relationships (acquaintances including stronger relationships like friendships or core discussion ties) for both the lockdown and the hybrid cohort at the time of the three waves of the survey. We will thereby find evidence for hypothesis 1, that network density in the lockdown cohort reached a lower level at the end of the term than in the hybrid cohort. However, this description is limited: For the sake of intertemporal comparability, we had to constrict the description to those senders and recipients of a relationship who filled in all three surveys.

In the second step, we will draw on Stochastic Actor-Oriented Models (SAOM) for longitudinal social network data to analyse binary ties on the network of acquaintances (including friends and the core discussion network as outlined above).[5] SAOM objective functions are defined from a focal actor's perspective, and actors are assumed to have full control over their outgoing ties (Snijders, 1996; 2017). To estimate SAOMs, we use the RSiena package version 1.3.14.1 (Ripley et al., 2024). The entire data analysis was performed in R 4.3.0 (R Core Team, 2015).

In SAOM, any change is regarded as a decision by an actor and the

[2] The German term "Bekanntschaft" can literally be translated to "acquaintance", but colloquially it refers to a slightly stronger association between two individuals like fellowship or a weak friendship.

[3] Actually, the tutorial supported both the lecture on introduction to research methods and the statistic lecture. However, to keep things short, we will refer to this tutorial as the statistics tutorial.

[4] The single exception was one research day in the "Introduction to Science" course between the first and second survey, in which only 10 students participated on campus and all others online. Methodological analyses have shown that this single face-to-face meeting did not impact the long-term friendship formation.

[5] The Jaccard similarity was higher than 0.3 for all comparisons of subsequent waves in both cohorts, which is considered ideal for the application of SAOMs. However it is not a necessary prerequisite (Snijders, 2017: 359).

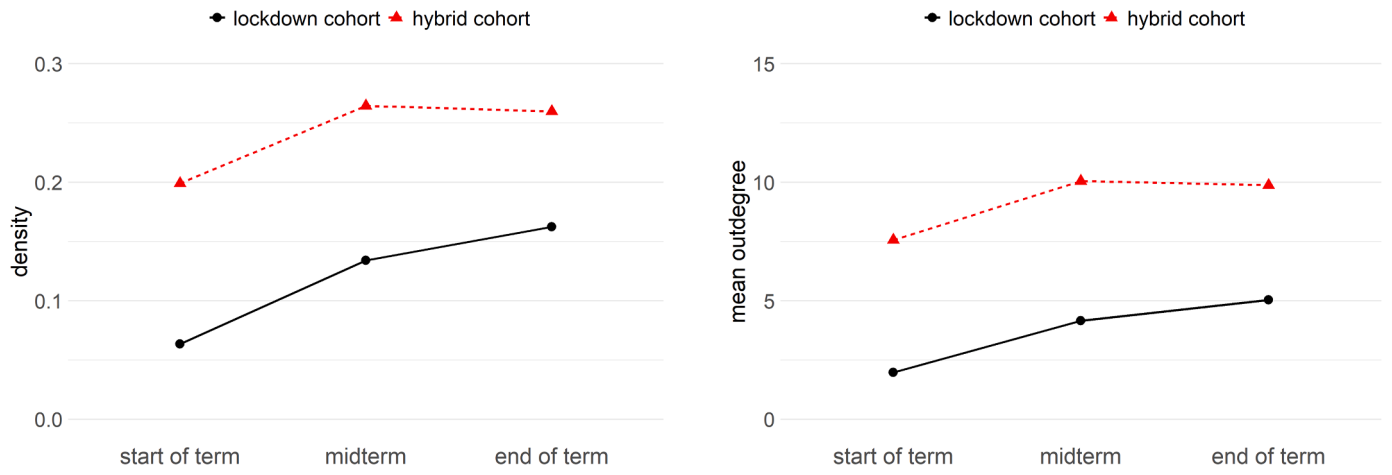

Fig. 1. Density (left) and average outdegree (right) of acquaintances-network (including stronger ties: friendships, core discussion ties) by cohort and time.

change between two observations of the same network is modelled as a series of so-called 'mini-steps'. In each mini-step, exactly one actor is selected based on the rate function and is supposed to either decide to add or remove one tie, or to change nothing ("null decision") based on the objective function (Snijders, 2017). We use a constant rate function, assuming that all actors are making decisions about connecting with fellow students at the same pace. The rate describes the average number of mini-steps actors were selected for between two observations. For all subsequent mini-steps all changes already made are taken into account when evaluating the options (Snijders, 2017).

The objective function is the core of the model. It models the probability for all possible decisions a selected actor could make, given an effect parameter θ and a network x:

$$f_i(\theta, x) = \sum_k \theta_k s_{ki}(x)$$

$\theta_k$is the effect parameter for effect k and $s_{ki}(x)$ is the network statistic for effect k from the perspective of the focal actor i, who was selected to choose an option in the respective mini-step. Only the structures in the personal network around the focal actor are taken into account for their decision. How this personal network is defined depends on how many tie steps from the focal actor's point of view are taken into account for the considered effect statistic (Snijders et al., 2010).

To test hypothesis 2 on the speed of development, we will compare the rate functions. Additionally, we evaluate the decisions actors make in the mini-steps to see if a higher rate occurred due to a higher share of null decisions and self-cancelling decisions (i. e, changes of ties that were previously changed in the same period). For hypothesis 3 on triadic closure, we include an effect of geometrically weighted edgewise shared partners (Hunter, 2007; Ripley et al., 2024). And hypotheses 4, 5, and 6 on the impact of sharing classes on tie formation are tested by including a matching "actor covariate effect" (sameX) testing for exact matches (Ripley et al., 2024). As a robustness check, we tested the effect of either shared tutorial group on acquaintanceship formation.

Social networks typically are not very dense and tend towards reciprocity. To control for common social structures, we include a density and a reciprocity parameter. As acquaintance and friendship decisions are impacted by gender in many contexts, we include effects for gender homophily as well as sender and receiver gender. As we seek to interpret the GWESP-parameter in terms of transitive closure, we control for indegree popularity, outdegree activity and indegree activity. To stabilise our model, we additionally control for out-isolates. Models are estimated for each cohort independently and compared afterwards.

A positive parameter effect can be interpreted in a way that actors choose to make a particular tie change that results in more of the structures expressed by the corresponding parameter statistic than the status quo (Snijders, 1996), for example more reciprocal relationships or more relationships between people in the same tutorial group.

While incomplete or missing participation of selected respondents in surveys is always a problem and can lead to biased results, the impact on data quality in network research is even greater: Unit "non-response" in survey-based networks results not only in missing data about the sender but also about the recipients (and non-recipients) of possible nominations. In our study, SAOM is also used to impute missing tie variables (see Appendix B). We use the Method of Moments (MoM) for the analysis models and the Maximum Likelihood Method (ML) for the imputation models and impute the first wave using a "Stationary SAOM" following the method suggested by Krause et al. (2018).[6] We impute the existence and non-existence of each missing relationship 50 times in each observed network. While we cannot impute relations for those freshmen students who did not consent to provide a photo to identify them in the survey, missing ties of those who allowed us to use their portrait pictures and were therefore identifiable for their fellow students are imputed, even if they did not participate in any wave of the survey. For those whose photo was available, the majority of the incoming relationships was observed. Imputing their outgoing relationships means not to neglect this available information. Thus, it allows us to estimate a network model with a realistic density.

We use the concept of relative importance (RI) of effects (Indlekofer and Brandes, 2013) to compare the strength of effects.[7] This concept allows for comparisons of the importance of effects within and between models as well as between different datasets (Indlekofer and Brandes, 2013). The importance of effects is calculated as the L1-difference between the choice probabilities in the evaluation function obtained by the model and the model excluding the statistic in question (e. g. same statistics tutorial group). It is interpreted as the direct contribution of that effect on i's choice (Indlekofer and Brandes, 2013). For each actor it is assumed separately that they are selected for the first mini-step after the respective observation (Indlekofer and Brandes, 2013). For the relative importance this is normalised so that the contributions of all effects add up to 100 %. In a next step the RI is averaged over all actors V

[6] As both networks are observed from the beginning and, hence are unusually sparse in the first observations, we included additional parameters in the imputation models that account for the disproportional occurrence of isolated nodes and those with low outdegrees. For the hybrid cohort we did not include the female sender and the gender homophily effects in the imputation model because the model did not converge with this specification and both effects were not significant in the analysis.

[7] In a previous version of this paper, we used probability ratios as suggested by Ripley et al. (2024): 14) and Snijders et al. (2010): 52) to compare the cohorts and came to the same conclusions.

in the network for each wave separately and over all imputations D:[8]

$$averageRI_{wave} = \frac{1}{D}\sum_{d=1}^{D}\left(\frac{1}{V}\sum_{v=1}^{V} RI\right)$$

5. Results

5.1. Intuitive description

In Fig. 1, the densities and average outdegrees of the network of acquaintances are described by cohort and timepoint during the first term. The acquaintance network considers all ties that are named as acquaintances or as stronger ties (friendships, core discussion ties). The left panel of Fig. 1 shows that network densities were significantly lower for the lockdown cohort compared to the hybrid cohort at all timepoints of observation. Note that the description in Fig. 1 is restricted to those senders and recipients of a relationship who filled in all three surveys. This finding provides evidence for hypothesis 1 that the density of the freshmen network in the lockdown cohort reached a lower level at the end of the term than in the hybrid cohort. The result is further supported by Table A3 in Appendix B, presenting differences in the network densities over time under different missing data treatments: deletion of missing actors, treating unobserved ties as missing and the multiple imputation method applied in the analyses in Section 5.2. Independently of the treatment of missing ties, the density within the lockdown cohort is lower than in the hybrid cohort. As the lockdown and the hybrid cohort consist of unequal numbers of students, we additionally compared the average outdegree in both cohorts. The right panel of Fig. 1 shows that students in the hybrid cohort nominated more acquaintances throughout the entire first term ($p < .001$ for all comparisons[9]).

5.2. Analytical results

Table 1 compares the SAOM results for the lockdown and the hybrid cohort. To measure how fast the two freshmen networks developed, we first look at the rate constants which represent the number of mini-steps each actor in a network was chosen for on average, meaning their chances to make a change between the respective first and second waves (period 1) and between the second and the third waves (period 2). In both periods, the network of the hybrid cohort developed at a significantly higher pace. While in the lockdown cohort each actor was chosen on average for 7.8 mini-steps in the first period, the average actor in the hybrid cohort was chosen for nearly 12 mini-steps (a z-test was performed, $p < .05$). In the second period the rate for the lockdown cohort decreased to approximately 6.4 mini-steps per actor and for the lockdown cohort to 10.4 mini-steps ($p < .001$). As null- and self-cancelling decisions are allowed in the SAOM, rate parameters can easily be inflated due to a bad model fit. An analysis of the individual chains in which the mini-steps were simulated[10] confirms that the difference in the rates between the cohorts is not due to a better model fit in the lockdown cohort: Actually, the share of null- and self-cancelling decisions was even slightly higher in the lockdown cohort than in the hybrid cohort (see Table A2).[11]

Table 1
SAOM analysis results, pooled estimates and standard errors for 50 imputations in each cohort.

	lockdown cohort	hybrid cohort
Effect	Estimate (SE)	Estimate (SE)
rate constant (period 1)	7.770 (1.777)	11.966 (1.016)
rate constant (period 2)	6.359 (0.825)	10.428 (0.771)
outdegree (density)	−0.335 (1.236)	0.250 (0.346)
reciprocity	2.675 (0.576)***	1.841 (0.119)***
triadic closure (GWESP FF, alpha =1.38)	0.616 (0.185)***	0.904 (0.069)***
indegree - popularity (sqrt)	0.315 (0.159)*	−0.373 (0.063)***
indegree -activity (sqrt)	−1.756 (1.002)	−0.722 (0.122)***
outdegree - activity (sqrt)	0.599 (0.364)	0.132 (0.059)*
out-isolate	2.446 (0.917)**	2.276 (0.659)***
same statistics tutorial group	0.471 (0.188)*	0.279 (0.102)***
same introduction to science tutorial group	0.253 (0.189)	0.301 (0.105)**
both tutorial groups in common	0.206 (0.323)	−0.272 (0.198)**
female receiver	−0.411 (0.220)	−0.373 (0.109)***
female sender	−0.604 (0.563)	−0.214 (0.116)
same gender	−0.030 (0.173)	0.103 (0.101)

Note: *** significant at .001 level, ** significant at .01 level, *significant at .05 level.

In period 2 (i. e., between the second and the third wave), the network evolution slowed down for both cohorts by a similar extend, most probably due to saturation effects.

In total, our findings support hypothesis 2 that the network of freshmen in the lockdown cohort developed significantly slower in both periods.[12]

Table 1 further presents our SAOM analysis results for the lockdown and the hybrid cohort, using the imputation procedures described above. The GWESP parameter (**g**eometrically **w**eighted **e**dgewise **s**hared **p**artners) informs about the tendency to close open triads, that is to get acquainted with the acquaintances of acquaintances.[13] Triadic closure was a significant driver of the network development in both cohorts (see Table 1). In both cohorts the GEWSP parameter is positive, meaning that students tend to become befriended or acquainted with contacts of their existing contacts. In the lockdown cohort, the effect estimate is lower than in the hybrid cohort. We draw on the concept of relative importance of effects as outlined above to compare the relevance the effects have in both cohorts. Fig. 2 compares the relative importance for the included effects for the lockdown and the hybrid cohort using the method proposed by Indlekofer and Brandes (2013). The standard errors were calculated over all actors in a network (within imputation) and all imputations of a network (between imputation) and were pooled by Rubin's Rule (Rubin, 1988). The significance levels reported in Fig. 2 for the cohort comparison were obtained by a z-test.[14] The full numerical results can be found in Table A4 in Appendix C. In all three waves, the lockdown and the hybrid cohort differ significantly with respect to the relative importance of triadic closure for network evolution. While the

[8] The RI of effects can vary greatly between actors due to their position in the network. In the results section we present results averaged over all actors. In Figure 3A in Appendix C a graphical representation of the RI for individual actors is included.

[9] We acknowledge that the independence assumption between the observed students within each cohort is violated. To validate our result, we calculated p-values again with permutation and yielded the same results.

[10] Due to restrictions in computation capacities, we repeated the analysis using a set of 5 imputed datasets to analyse the chains.

[11] In the first period, the share was about 39 % for the lockdown cohort and 31 % for the hybrid cohort. In the second period, the share was about 33 % for the lockdown cohort and 27 % for the hybrid cohort (Table A2 in Appendix A).

[12] The findings remain robust when using a variable for either shared tutorial instead of the individual tutorial variables (Table A5 in Appendix D).

[13] We only counted forward directed triangles of acquaintances and friendships and used a decay parameter of 1.38, which led to the best fit. The higher the decay parameter the higher weight is put on additional triads closed in case an added tie closes more than one triad. For reasons of model stability and to ensure comparability across cohorts, we used a decay parameter of .69 in the imputation model.

[14] They also remained stable when a *t*-test was conducted.

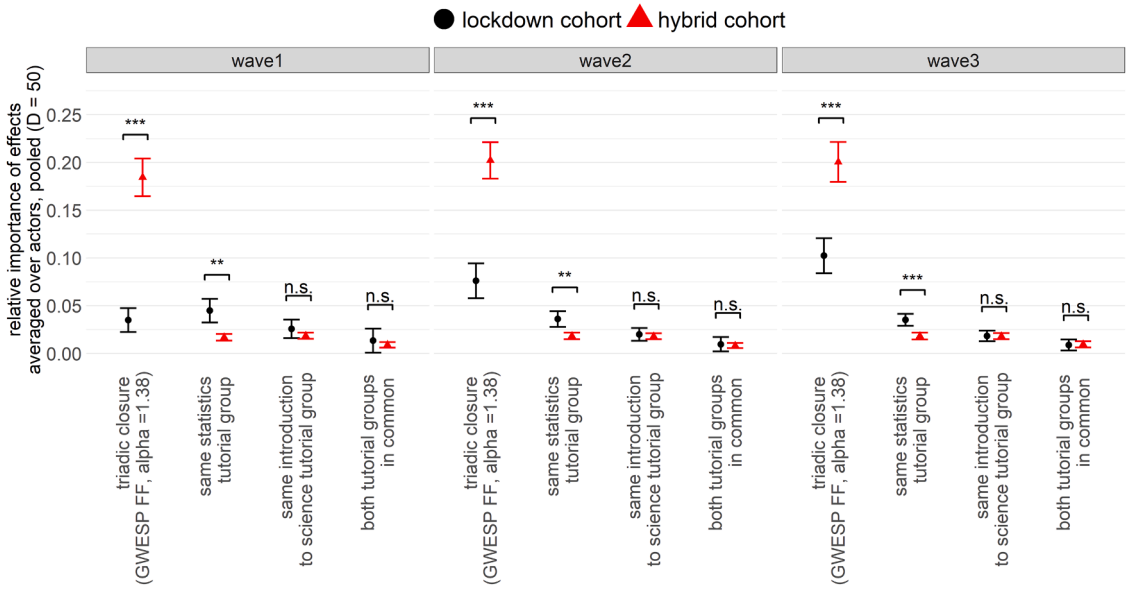

Fig. 2. Relative importance (RI) of effects averaged over all imputations and all actors. SE are also calculated over all actors and all imputations and pooled by Rubin's Rule. Note: The confidence levels reported for the cohort comparison were obtained by a z-test and are indicated by stars: * indicates $p < .05$; ** indicates $p < .01$; *** indicates $p < .001$ and n.s. indicates none significant differences. The error bars attached to the point estimates are 1.385 std. errors which correspond to an 83.4 % confidence interval as it is recommended by Goldstein and Healy (1995) and Payton et al. (2003) for the visual comparison of group means. The 83.4 % confidence interval is only used for the visualisation and has no impact on the significance levels of the statistical test.

RI of the GWESP effect for the lockdown cohort varies between 3.5 % (wave 1) and 10.2 % (wave 3), the RI for the hybrid cohort varies between 18.4 % (wave 1) and 20.2 % (wave 2). This finding supports hypothesis 3 that becoming acquainted with acquaintances of acquaintances seems much easier when in-person meetings are possible. The RI for all effects can be found in Table A4 and Figure A3a and for all actors in Figures A3b and A3c in Appendix C.

According to hypothesis 4, sharing the same classroom was expected to boost acquaintanceship. In line with this reasoning, Table 1 shows that participating in the same statistics tutorial significantly increased the tendency of actors to get acquainted or befriended in both cohorts. The effect of sharing the same group of "introduction to science" was statistically significant only in the hybrid cohort. However, sharing both tutorials had no additional significant effects in either cohort. Both tutorials were very interactive, but the "introduction to science" was rather informal and not graded, whereas the statistics tutorial accompanied a graded lecture, and students had to work together in teams to prepare for the statistics exam. It is plausible that the hybrid cohort with more in-person opportunities for interaction also connected via the more informal tutorial, while the lockdown cohort did not. Interestingly, in the lockdown cohort, sharing the more constraining statistics tutorial enforced tie formation while sharing the less constraining "introduction to science" tutorial did not.

In addition, we posited two conflicting hypotheses about the strength of the impact of sharing classes on tie formation under lockdown and hybrid conditions: During lockdown, opportunities for contact were exclusively restricted to (digital) class attendance. Therefore, the effect of participating in the same class should be stronger for the lockdown than for the hybrid cohort (hypothesis 5). However, the remaining opportunities for contact in digital classrooms might be less efficient in producing mutually rewarding interactions compared to classrooms in physical co-presence. Therefore, the effect of participating in the same class could also be lower for the lockdown than for the hybrid cohort (hypothesis 6). The findings in Fig. 2 (and table A4 in the appendix) show that the RI of sharing the same statistics tutorial for tie formation was significantly higher in the lockdown than in the hybrid cohort in all 3 waves. While the RI of the statistic's tutorial effect was about 1.8 % in all waves, the impact of the effect in the lockdown cohort was up to 4.5 % (wave 1) and minimum 3.5 %. This implies that, for the statistic tutorial, the structural mechanism underlying hypothesis 5 might be more important than the mechanism of restricted interaction suggested by hypothesis 6. For sharing the introduction to science tutorial group, we only found a significant effect on tie formation for the hybrid cohort. However, the relative importances for both cohorts were not significantly different.

The models included additional effect parameters for density, reciprocity of relationships (positive significant for both cohorts), indegree popularity (significant for both cohorts, but different directions), indegree activity (negative significant only for the hybrid cohort) and outdegree activity (positive significant only for the hybrid cohort). Further, we controlled for out-isolates to adjust for students who did not nominate any friends or acquaintances (positive significant for both cohorts). And we added effects regarding gender: A gender homophily effect (n.s.), a sender gender effect (n.s.), and a receiver gender effect ($p < .001$ for the hybrid cohort only). Males had a higher probability to receive ties in the hybrid cohort. Significant differences between the RI for the cohorts were observed between cohorts for indegree popularity, outdegree activity and receiver gender (see table A4 in Appendix C).

6. Discussion

This paper compared the evolution of acquaintance networks among two cohorts of freshmen students. The first cohort began their studies during the Covid-19 lockdown (the lockdown cohort) while the second cohort that started studying after lockdown when classes were given in a mixture of online and offline modes (the hybrid cohort). We viewed this setting as a natural experiment that shows how networks may develop if communication were (almost) exclusively digital. We asked (1) whether the density was lower and the rate of evolution of the student network was slower for students belonging to the lockdown cohort than for those who belonged to the hybrid cohort, (2) whether the social mechanism of transitivity was particularly mitigated in the pandemic because the tendency for triadic closure is supposed to be most effective when the triad is embedded in a physical context, and (3) whether shared classes as formal meeting places do impact friendship formation and if so, whether they were less or even more important for the lockdown than for the hybrid cohort.

We used Stochastic Actor-Oriented Models (SAOM) with the same model specification for both cohorts. To compare the cohort-specific results, we drew on the concept of relative importance of effects (Indlekofer and Brandes, 2013).

An intuitive descriptive approach and comparisons of the density using different treatments for missing data provide evidence that the density of the freshmen network of acquaintances in the lockdown cohort reached a lower level at the end of the term than in the hybrid cohort. The same holds for the average outdegree: Students in the hybrid cohort nominate significantly more friends and acquaintances than students in the lockdown cohort throughout the entire first term. The network of acquaintances in the lockdown cohort developed significantly slower throughout the students' entire first semester. The communication channels among the students in the lockdown cohort were very restricted, thus thwarting the process of evaluation of fellow students. Another explanation might be that many students did not move from their hometowns and, hence, maintained their old peer network. This embeddedness might have lowered the saturation level for new acquaintances among fellow students during the lockdown.

However, our main argument is that making new acquaintances in a lockdown scenario was more effort, because meeting new people and interacting with them was complicated, particularly because large gatherings like parties were not allowed. Under normal conditions, such occasions provide opportunities to be introduced to the acquaintances of acquaintances and allow the mechanism of triadic closure to unfold. For this reason, students might be saturated with a smaller number of friends and acquaintances than in the hybrid scenario. Indeed, the tendency towards triadic closure was significantly lower in the lockdown than in the hybrid cohort. Hence, becoming acquainted with acquaintances of acquaintances seems to be much easier when in-person meetings are possible and if triads are embedded in some physical (not: virtual) context, because in co-presence, introducing acquaintances to each other is not a matter of intention but something that simply happens by occasion.

We further posited the hypothesis that sharing classes increases the probability of tie formation and two competing hypotheses about the relative importance of this effect in the lockdown and the hybrid cohort: When opportunities for contact are restricted to (digital) class attendance, the effect of participating in the same class should be stronger for the lockdown than for the hybrid cohort. However, digital classrooms might be less efficient in producing mutually rewarding interactions, and the effect of participating in the same class could also be lower for the lockdown than for the hybrid cohort. Our findings show that sharing classes increases the general tendency towards tie formation in both cohorts. The results further imply that for the statistics tutorial, the relative importance of participating in the same group was higher for the lockdown than for the hybrid cohort. Hence, the first, structural mechanism might outweigh the second mechanism of restricted interaction for this type of class with rather high constraints. In contrast, for the more informal "introduction to science" tutorial, we found a significant effect on tie formation only for the hybrid cohort and the cohort-specific effects did not differ significantly. Hence, only when students are forced to work together in a virtual classroom setting and prepare for graded exams – as in the statistics tutorial –, they are more driven to relate to their fellow students and establish ties.

Our findings are subject to some limitations: Complete data is a crucial aspect for network analysis as information is lost not only about non-participants but also about participants' relations. However, by imputing missing ties, we mitigated this source of potential bias. Nevertheless, we could only impute ties to and from students who had granted permission to use their photos in the study. For those who did not grant us this permission, we could not display any personal identifiers and therefore they could not be selected by other participants. However, we could show that the tendency to participate was not too divergent between both cohorts. For a few individuals, the information about their tutorial groups was missing. We could not impute this information meaningfully. We suppose that this limitation potentially lowers effect sizes in our models and hence contributes to a more conservative test of hypothesis 4. Moreover, our analysis is based on the comparison of two networks that obviously are similar in many respects but systematically vary: The members of the first cohort started their studies under strict lockdown, the second under a hybrid teaching regime. However, the second cohort experienced lockdown at an earlier stage in their life-course – in many cases in their last year of schooling. Hence, the hybrid cohort might have been more familiar with online teaching and online communication when starting their studies. After all, the comparison of two networks is a case study. Hence, caution is necessary when inferring to student networks of other subjects, at other universities or in other countries.

What can we learn from this natural experiment about network evolution under the condition of extreme digitalisation of communication? Of course, the pandemic situation posited an extreme setting, because individuals did not deliberately choose to avoid offline meeting occasions but were forced to by negative sanctions and inference is limited due to the reasons stated above. Therefore, our findings can only inspire an empirically informed speculation: Even after some months, networks will evolve at a slower pace and remain less dense: Individuals will have only a few friends and acquaintances because relationships are not embedded in foci of social activities in physical co-presence. Even though exchange with *existing* acquaintances and friends might be quite effective using digital communication (Elmer et al., 2020), it might become quite hard to make *new* acquaintances and friends. The reason is that, without physical co-presence in rewarding situations, all those casual occasions to meet others and to be introduced to them by shared acquaintances are missing. The tendency towards triadic closure is much stronger when three people are embedded in the same physical focus of activity. When communication takes place only in digital ways, triadic closure depends on the intentional choice and the effort of the linking actors to introduce two of their acquaintances and friends to each other. In classical offline settings, however, the choice is more driven by occasions in particular situations. The pre-structuring power of social activities being organised around (virtual) social activities will be enforced because there tend to exist fewer informal meeting occasions. At the same time, the virtual context will restrict the possibilities of non-verbal

communication. However, technological progress might help to overcome these restrictions. In a more realistic vision of a digitalised future, social activities will take place both virtually and in physical co-presence. Consequently, we can expect that all these possible impacts of digitalised communication might depend on how dominant it is in organising the various foci of social activities in the future. With respect to the use of virtual classrooms in teaching, the results imply that online classes might be more successful when they include formalized team work and when students receive grades or other relevant incentives.

Further research is needed to investigate the long-term implications of contact restrictions on students' networks, success, well-being, and how to encourage connectivity in settings with limited contact opportunities. This is meaningful not only for the student cohorts all over the world that have been impacted by the Covid-19 pandemic but also concerning the increase of online teaching in universities and a growing number of long-distance study programs (both significantly boosted by the pandemic). Moreover, further research is needed to find out whether acquaintances and friendships established in an online setting are as persistent and supportive for well-being and success as relations established in offline settings.

CRediT authorship contribution statement

Judith Gilsbach: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Johannes Stauder:** Writing – review & editing, Writing – original draft, Visualization, Project administration, Investigation, Conceptualization.

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Appendix

A. Null- and self-cancelling decisions

To check our model fit and confirm that the rates were not increased by bad model fit in either cohort we reran our analysis with 5 imputations and saved the chains to calculate the share of all decisions in the Markov Chains that were null- or self-cancelling decisions. The extend is similar for both cohorts (see table A2).

Table A2
Percentage of all decisions in the Markov Chains that were either null-decisions or self-cancelling decisions; the analysis was repeated for this metric with 5 imputations due to limited computational capacities

of all decisions in mini-steps	lockdown cohort	hybrid cohort	lockdown cohort	hybrid cohort
	period 1		period 2	
% null decisions	20.6	10.7	19.5	8.0
% self-cancelling decisions	18.7	22.2	11.2	18.5
% cumulated	39.3	33.0	30.6	26.5

B. Documentation of the multiple imputation-procedure

Table A3 compares the results of SAOM imputation for both freshmen cohorts with two scenarios: The null-imputation of ties missing due to non-response and the deletion of missing actors.[15] Missing actors cause not only missing information about themselves but also about their relations to others. The 42 students in the lockdown cohort could create up to (42 *(42−1) =) 1722 possible relations. In the second wave, due to the nonresponse of three students (3 *(42−1) =) 123 of the possible relations could not be observed (Table A3). In waves 1 and 3, however, more students did not respond resulting in 369 missing relations in the third wave when 7 students of the lockdown cohort did not respond. However, the number of missing relations does not only depend on non-response but also on network size. Therefore, in the third wave of the hybrid cohort, 1495 potential relations could not be observed, because 23 out of 66 students were missing. For both cohorts, non-response peaked in the third wave. Table A3 shows that if missing actors were removed from the network, the density would constantly be overestimated (see line "Density (deletion of missing actors)" compared to "Average density SAOM imputation"). If the missing ties were assumed not to exist, density would be underestimated (see line "Density (null-imputation)", except for the respective first waves).

[15] Null imputation assumes that all non-observed ties do not exist; deletion of missing actors removes all actors who did not fill in all three surveys from all waves including their in- and outgoing ties.

Table A3
Basic tie related measures by cohort and wave

	lockdown cohort			hybrid cohort		
	wave 1	wave 2	wave 3	wave 1	wave 2	wave 3
Number of …						
… possible relations	1722	1722	1722	4290	4290	4290
… observed relations	93	190	218	637	758	600
… absent relations	1465	1409	1135	3133	2752	2195
… missing relations	164	123	369	520	780	1495
Density (null imputation)[a]	.054	.110	.127	.148	.177	.140
Density (deletion of missing actors)[b]	.064	.134	.162	.199	.265	.260
Average density SAOM imputation[c]	.054	.117	.146	.148	.198	.184
N students observed	38	39	33	58	54	43

[a] Null imputation assumes that all non-observed ties do not exist.
[b] Deletion of missing actors removes all actors who did not fill in all three surveys from all waves including their in- and outgoing ties.
[c] Average density SAOM imputation reports the average density over 50 imputations for each network at each point in time.

C. Additional tables to document the relative importance of effects (RI)

Table A4
Relative importance (RI) of effects, pooled estimates and standard errors for 50 imputations in each cohort

	wave 1			wave 2			wave 3		
	lockdown cohort	hybrid cohort	cohort comparison	lockdown cohort	hybrid cohort	cohort comparison	lockdown cohort	hybrid cohort	cohort comparison
effect	RI (SE)	RI (SE)	p-value	RI (SE)	RI (SE)	p-value	RI (SE)	RI (SE)	p-value
outdegree (density)	.074 (.044)	.044 (.025)	.283	.063 (.038)	.042 (.024)	.322	.059 (.034)	.044 (.025)	.360
reciprocity	.087 (.014)	.117 (.010)	.038*	.107 (.013)	.130 (.009)	.077	.125 (.013)	.126 (.009)	.477
triadic closure (GWESP FF, alpha =1.38)	.035 (.009)	.184 (.014)	< .001***	.076 (.013)	.202 (.014)	< .001***	.102 (.013)	.200 (.015)	< .001***
indegree - popularity (sqrt)	.092 (.018)	.170 (.009)	< .001***	.107 (.018)	.166 (.008)	.001**	.119 (.019)	.162 (.008)	.020*
indegree -activity (sqrt)	.170 (.022)	.210 (.014)	.066	.209 (.029)	.191 (.010)	.286	.174 (.025)	.176 (.009)	.474
outdegree - activity (sqrt)	.172 (.026)	.095 (.012)	.004**	.183 (.022)	.103 (.013)	.001**	.206 (.022)	.102 (.013)	< .001***
out-isolate	.159 (.038)	.038 (.013)	.001**	.075 (.022)	.027 (.011)	.026*	.045 (.017)	.047 (.015)	.460
same statistics tutorial group	.045 (.009)	.017 (.002)	.001**	.036 (.006)	.018 (.002)	.003**	.035 (.004)	.018 (.003)	< .001***
same introduction to science tutorial group	.026 (.007)	.019 (.002)	.164	.020 (.005)	.018 (.002)	.358	.018 (.004)	.018 (.002)	.475
both tutorial groups in common	.013 (.009)	.009 (.002)	.316	.010 (.005)	.008 (.002)	.402	.009 (.004)	.010 (.002)	.443
female receiver	.060 (.014)	.055 (.006)	.376	.054 (.013)	.054 (.006)	.478	.049 (.012)	.056 (.006)	.317
female sender	.061 (.015)	.029 (.006)	.024*	.055 (.015)	.028 (.006)	.051	.052 (.014)	.027 (.006)	.049*
same gender	.007 (.005)	.013 (.005)	.183	.006 (.004)	.013 (.005)	.144	.005 (.004)	.013 (.005)	.108

Note: *** significant at .001 level, ** significant at .01 level, * significant at .05 level.

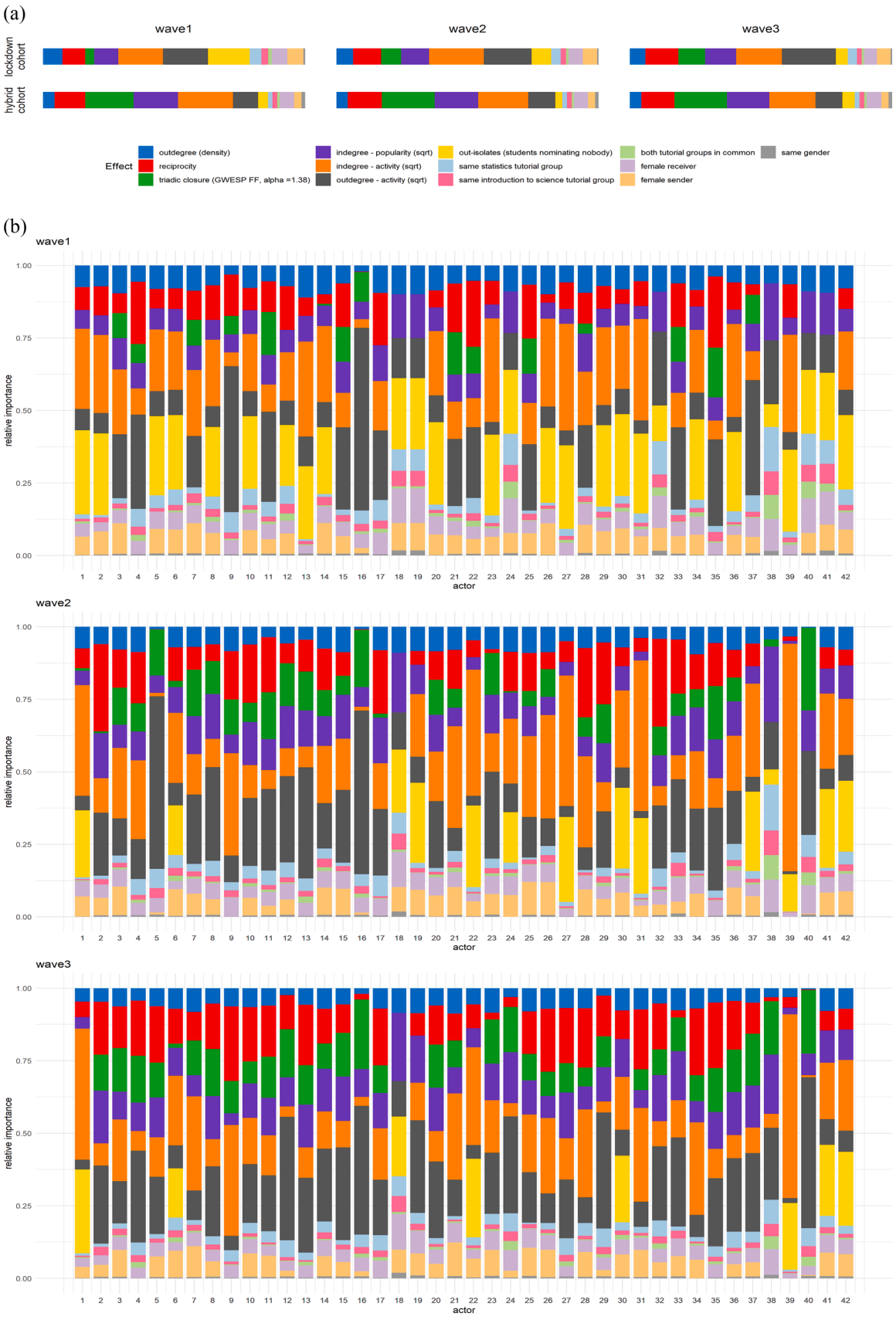

Fig. A3. Panel (a) presents the relative importance of Effects (RI) averaged over all actors by wave and cohort., panel (b) for the lockdown cohort by actors and wave and panel (c) for the hybrid cohort by actors and wave.

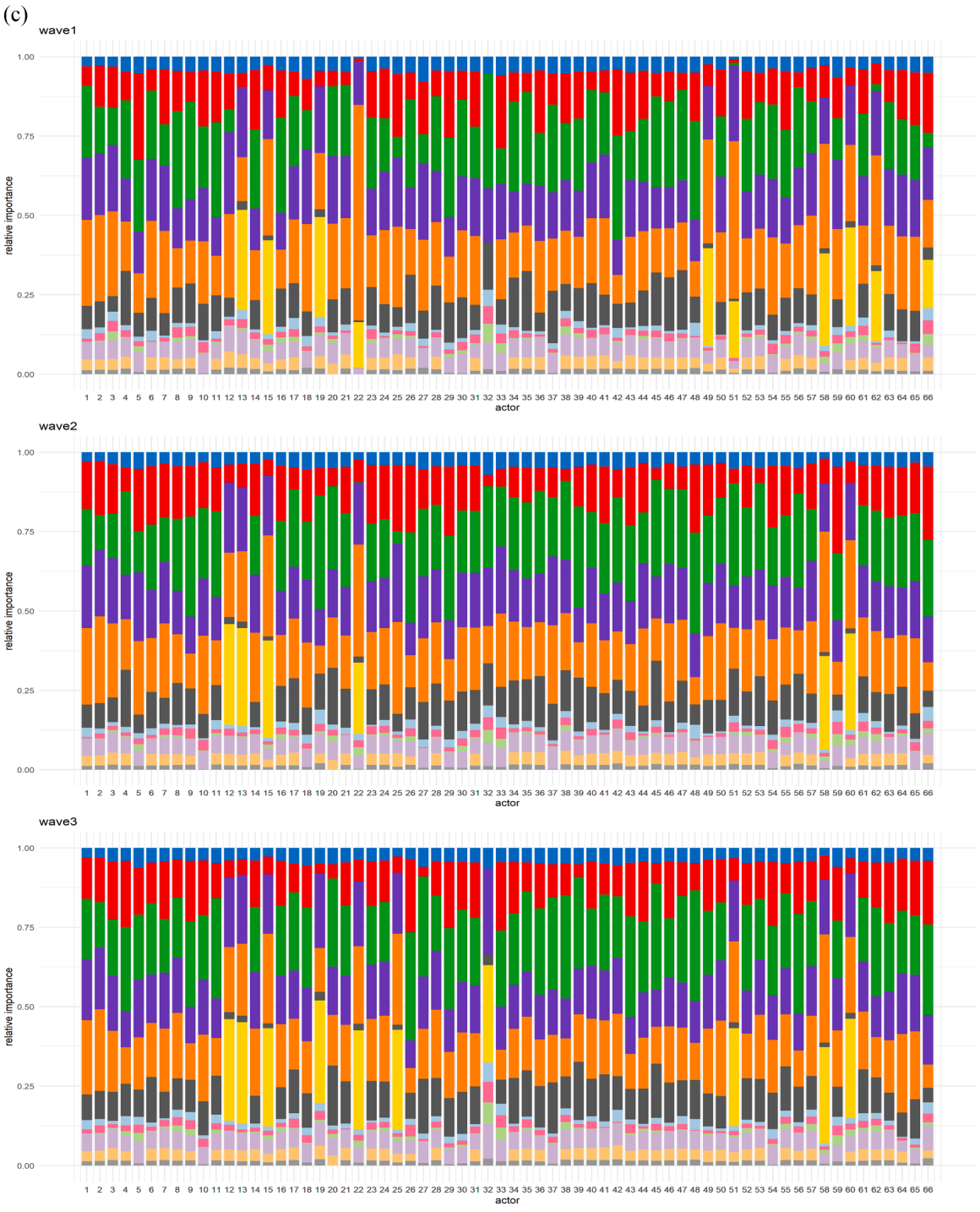

Fig. A3. (*continued*).

D. Robustness test

Table A5
SAOM analysis results, robustness check with either tutorial in common instead of separate tutorial variables, pooled estimates and standard errors for 50 imputations in each cohort

	lockdown cohort	hybrid cohort
Effect	Estimate (SE)	Estimate (SE)
rate constant (period 1)	7.546 (1.655)	12.021 (1.030)
rate constant (period 2)	6.329 (0.792)	10.445 (0.768)
outdegree (density)	0.297 (1.413)	0.316 (0.339)
reciprocity	2.732 (0.561)***	1.842 (0.118)***
triadic closure (GWESP FF, alpha =1.38)	0.649 (0.184)***	0.901 (0.068)***
indegree - popularity (sqrt)	0.243 (0.150)*	−0.369 (0.063)***
indegree -activity (sqrt)	−1.847 (1.007)	−0.708 (0.120)***
outdegree - activity (sqrt)	0.616 (0.357)	0.126 (0.058)*
out-isolate	2.329 (0.928)*	2.263 (0.657)***
either tutorial group in common	0.553 (0.181)**	0.308 (0.082)***
female receiver	−0.503 (0.224)*	−0.372 (0.109)***
female sender	−0.715 (0.614)	−0.217 (0.115)
same gender	−0.020 (0.172)	0.113 (0.101)

Note: *** significant at .001 level, * * significant at .01 level, * significant at .05 level.

We reran the analysis with an effect to measure the impact of either shared tutorial instead of separate variables for the tutorials on “Statistics” and “Introduction to science”.

E. Goodness of fit

Goodness of fit was tested using the sienaGOF function for the imputation and the analytical models with the last imputation respectively. All p-values were above.05. We conclude that the models fit the data.

F. Reproducibility

Please find the analysis scripts under https://github.com/JGilsbach/Digital-communication-and-tie-formation-amongst-freshmen-students-during-and-after-the-pandemic. The full data cannot be disclosed due to the risk of deanonymisation of individual students.

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