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Gender homophily in online dyadic and triadic relationships

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Abstract

Gender homophily, or the preference for interaction with individuals of the same gender, has been observed in many contexts, especially during childhood and adolescence. In this study we investigate such phenomenon by analyzing the interactions of the ∼10 million users of Tuenti, a Spanish social networking service popular among teenagers. In dyadic relationships we find evidence of higher gender homophily for women. We also observe a preference of users with more friends to connect to the opposite gender. A particularly marked gender difference emerges in signing up for the social networking service and adding the first friends, and in the interactions by means of wall messages. In these contexts we find evidence of a strong homophily for women, and little or no homophily for men. By examining the gender composition of triangle motifs, we observe a marked tendency of users to group into gender homogeneous clusters, with a particularly high number of male-only triangles. We show that age plays an important role in this context, with a tendency to higher homophily for young teenagers in both dyadic and triadic relationships. Our findings have implications for addressing gender gap issues, understanding adolescent online behavior and technology adoption, and modeling social networks.

Keywords: gender homophily; social networks; triangle motifs; local clustering coefficient; age patterns

1 Background

Homophily is the tendency of individuals to interact preferentially with similar others. Homophilous behavior in general can be found for many different characteristics and attributes, such as race, age, religion, education, occupation, and gender [1]. The extent of its influence on human behavior is following roughly the aforementioned order according to McPherson et al. [2]. As "a basic organizing principle", it has been widely studied both for human and animal groups [3]. Gender is one of the most important human attributes which plays an important role during the entire life span [4], and gender homophily has been largely documented in literature, especially for childhood and adolescence [5].

The emergence of social networking sites (SNSs) allows to observe the extent of homophily from a computational social science perspective, bypassing possible biases induced by surveys or small and limited samples while getting evidence from digital traces of millions of users. On the one hand, this can lead to complement findings from traditional survey-based studies with evidence from a large portion of the population. On the other

hand, it can help to unveil behavioral patterns which are induced by online platforms. As we spend more and more time on social networking services, and they are becoming fundamental pathways for information flow in our society [6], understanding the impact of homophily in this context is particularly important for comprehending phenomena such as the dynamics of technology adoption, social contagion and segregation [7–9].

As we will see in the following review, most of the existing literature on this issue relies on surveys or observations of limited samples of individuals, while large scale studies based on data from social networking services still leave many aspects unexplored. With this study we aim to fill this gap, extending the work presented in [10] to offer a detailed picture of gender homophily in Tuenti, a Spanish social networking site especially popular among teenagers.

1.1 Gender differences in social network sites

It is a common believe that men are more frequently early adopters of new technologies. However, in the case of many social media websites and services women are in the vanguard. Thus, women outnumbered men by a considerable amount for most social networking sites [11, 12], with Pinterest having the largest gender inequality [13] and LinkedIn being one of the few exceptions.[a] With technology entering the mass market, women lean in and overtake males not only in spending time on social networking platforms, but also in owning gadgets or playing casual social games [14]. Madden et al. [15] showed that girls between 14 and 17 are more active on SNSs: they are more likely to use SNSs than boys. This gender difference continues and stays valid for the overall SNS users [11]. Asking teenagers about how they actually use SNSs, Espinoza and Juvonen [16] found that girls not only spend more time on SNSs than boys, but also that this usage is "more central" to their social lives and that social network sites interfere more in their lives. Hargittai and Hsieh [17] showed gender differences in the level of engagement with social practices on SNSs. While, according to their survey, women engage in more strong-tie activities than men, e.g. interacting with existing friends, women pursue fewer weak-tie activities than men, e.g. developing new relationships. As shown by boyd [18], "Older boys are twice as likely to use the sites to flirt and slightly more likely to use the sites to meet new people than girls of their age. Older girls are far more likely to use these sites to communicate with friends they see in person than younger people or boys of their age."

Among the first works focused on gender differences in online friendship preferences based on data collected from social networking sites were Lewis et al. [19] for Facebook and Thelwall [20] for MySpace. Another study [21] analyzed online social interactions in the setting of a massive multi-player online game. The authors found that males reciprocate friendship requests from females faster and that females have more communication partners. The linguistic style of messages has also been shown to be influenced by gender in Twitter [22], Facebook [23] and Wikipedia [24].

As most of the studies rely on analysis of US-based users [25], often mixing the gender-dimension with racial aspects, some of these findings can be less relevant in non-US contexts. Gender influence on access to information and communication technologies often varies according to local and cultural practices [26–28].

In this work we use a complete dump of a large Spanish social networking service to present an extensive analysis of gender preferences emerging online. Spain is among the most "social media addicted" countries in the European Union [29] with almost 75% of the

Spaniards using Internet as an instrument for communication and interaction with others. Focusing on gender differences in Spanish adolescent lifestyles, Hernando et al. [30] found that Spanish females are more and longer connected (via cell phone and the Internet) than males and that females hang out more than males with friends online. Despite the above mentioned findings, there is still a lack of understanding of gender roles in online social communications, for the US and even more for non-US contexts. Furthermore, to the best of our knowledge no extensive study based on evidence from large scale data has inspected the impact of gender preferences on joining a social networking site.

1.2 Gender homophily in the offline world and on social network sites

In early studies of face-to-face interactions Shrum et al. [31] analyzed gender and racial homophily in a sample of friends from an American school (junior, middle and high school). Their findings indicate that racial homophily increases and gender homophily decreases with school grade. In the Netherlands, Baerveldt et al. [32] looked at gender and ethnic homophily for a sample of adolescents between 16 and 18 years from 20 urban high schools. They found a high tendency to gender homophily (more pronounced for girls) and ethnic homophily in all studied ethnic groups. To explain this slightly higher female homophily, Aukett et al. [33] showed that the degree of emotionality and intimacy in same-gender friendship is higher for women than men. Women do also tend to place a higher value on these friendships than men do. Maccoby [5] argued that the decrease of gender homophily with age lies in the interest in the opposite gender. According to Rose and Rudolph's review [34], girls seem to have a greater preference for extended dyadic interactions and pro-social behavior, while boys interact more in peer groups with a high network density and clear dominance hierarchy.

We refer to [35, 36] for reviews of gender homophily studies. Hereby, Stehlé et al. [35] present a detailed picture, as they show an increasing gender homophily with age for strong ties, defined as pairs of children who interact more than a defined threshold, while for weak ties, they find for gender homophily a negative correlation for girls and age and a positive correlation for boys and age.

As already seen in research on gender homophily presented in the previous paragraphs, some studies find few gender differences [37–43], while others [36, 44–49] show important differences in the quantity and quality of male and female friendship patterns both in the offline and online world. One reason for these contradicting results might be the different components of friendship, as well as differences in age and culture [3]. Most of the studies are based on surveys or self-reported data with rather small samples, which might reflect patterns of specific milieus. Studies with large data sets allow to discover general patterns, extending the case study perspective towards a global overview of gender homophily. In this direction, a remarkable effect of gender homophily was found for interactions in online games [21] and in Wikipedia [50], a community with a strong gender gap. Large scale analyses of social networking sites instead reported no homophily for messages posted on one another's profile in MySpace [51], and only a neglectable effect of homophily on the Facebook friendship graph [52]. However, these studies only consider gender, age and degree separately, so they leave the question open of whether different results for gender homophily would be found for users of different age groups or with different number of connections.

1.3 Gender homophily in triadic relationships

The study of dyads and triads is crucial to understand social structure, already reflected in guiding thoughts of classic sociology such as Simmel's question "What is society?" [53]. A dyad represents the smallest possible social group, a pair of individuals, being the core of any "intersubjective relationship". A triad is a group of three people, forming the building block of social order and society [54]. Hence, the detailed analysis of the dyadic and triadic structure of a SNS allows to draw a picture of (gendered) group structure and cohesion.

While the concept of homophily in previous literature is mostly focused on preferences in dyadic relationships, few studies have inspected the effects of gender homophily on triadic relationships and on larger groups. Among these, Goodreau et al. [28], in a study based on self-reported friendship relationships in several U.S. schools, found a higher probability of triadic closure in children friendship when at least one girl was involved, and a similar pattern was reported for teenagers [55]. Kossinets and Watts [56] found no influence of gender on triadic closure in a university's email exchanges, while Huang et al. [57] analyzing the factors which influence triadic closure in microblogging, observed little influence of gender, with a slightly higher probability of closing a triangle when the third user is a woman. Similarly, Szell and Thurner [21] found a higher clustering coefficient for female users in trade networks in online games. Kovanen et al. [58] investigated temporal triangle motifs in mobile phone calls and their composition according to age and gender reporting a prevalence of all-females motifs. David-Barrett et al. [3], by analyzing profile pictures in which more than one person appear, found that women favor dyadic relations, while men favor larger, all-male cliques. If we exclude studies on microblogging, representing a special scenario given its usage for news consuming and its asymmetric connections which are less likely to represent real friendship ties [59], no extensive study has focused on gender homophily in triads in social networking services. Furthermore, age has been mostly neglected by the literature in this context so far. The only exception are a few studies that have analyzed the interplay between gender homophily and user age in triads in the field of mobile communications [58, 60].

1.4 Research questions

The preceding discussion has reviewed the phenomenon of gender homophily in the offline and online world, evidencing how this varies with age, and is especially relevant during childhood and adolescence. It has also shown that most of the existing literature on this matter is based on surveys or observations of reduced samples of individuals, while large scale studies on social network sites data still leave many relevant aspects, such as age patterns, mostly unexplored. In this study we aim to deepen our understanding of gender homophily and its impact on crucial aspects including the way in which users join a social networking service, the establishment of preferential relationships and grouping patterns.

Therefore, based on the review presented above, we formulate the following research questions:

RQ1: How does gender homophily affect joining a new social environment?

RQ2: How does gender homophily affect the establishment of connections and the interactions?

RQ3: How does gender homophily affect the strongest interactions of a user?

RQ4: How does gender homophily affect the creation of groups?

In the rest of the paper, we will tackle these questions by presenting a detailed analysis of data from the Spanish social networking platform Tuenti, with a special focus on young users and how homophily varies according to user age.

2 Dataset and methods

2.1 The social network site Tuenti

This study is based on a complete anonymized snapshot of the Spanish social networking service Tuenti,[b] extracted on December 11, 2010. At the time of data collection, Tuenti (the name comes from "tu [id]enti[dad]", Spanish for "your identity") was one of the largest Spanish social networking platforms and was sometimes referred to as the "Spanish Facebook". It provided many features common to other popular social networking platforms: it allowed users to set up a profile, connect with friends, share web links and media items and write on each other's walls. In particular, the terms of agreement specified by Tuenti did not allow kids younger than 14 to join the service and obliged users to specify a place of residence located in Spain. From 2006, the founding year, until November 2011, one year after our data was collected, Tuenti was an *invitation-only* social networking service.

2.2 Demographic composition

The Tuenti dataset contains self-reported demographic data, including gender and age of each user. Figure 1 depicts the demographic composition of the SNS, by age and gender, showing that at the time of data collection Tuenti was extremely popular among young people, and especially among teenagers. There are 4,376,472 (45% of the total) participants aged 14 to 20 with a Tuenti profile, which is in line with user surveys reporting that nearly 70% of Spanish people between 14 and 19 had a Tuenti account in 2011 [61]. We can observe small differences between the numbers of male and female participants (see Figure 1 and Table 1 for the exact numbers) similar to the ones reported in surveys [62]. While in this study we do not take into account user location, geographical patterns of friendship connections and interaction for this dataset are analyzed in detail in [63] and [64].

2.3 Friendship and interaction networks

The Tuenti dataset contains a complete lists of all online friendship connections and for every user also the order by which the user was adding her/his friends. Since Tuenti was an invitation-only social network service by the time the dataset was collected, we assume that the first friend of a user is the one who successfully invited her/him to join the service. Although this assumption is not necessarily 100% correct (e.g., a user might have
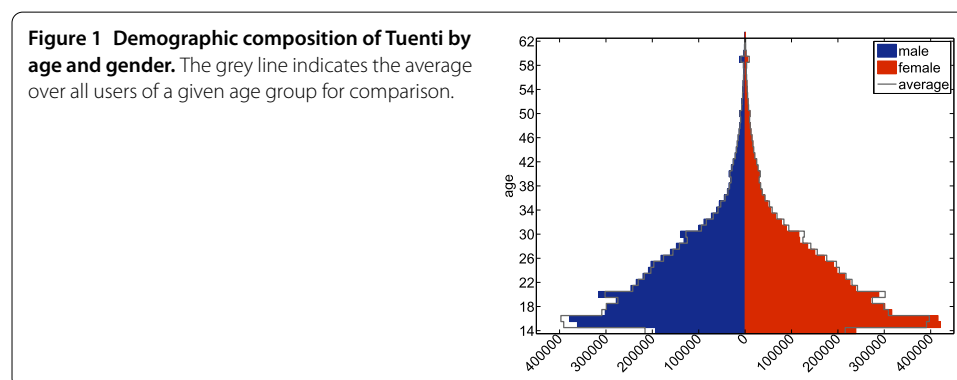

Figure 1 Demographic composition of Tuenti by age and gender. The grey line indicates the average over all users of a given age group for comparison.

Table 1 Number of users in the Tuenti dataset broken down by gender

# Users	Total	≥10 friends	≥1 reciprocal interactions
Male	4,899,659	3,269,611	2,247,992
Female	4,784,975	3,350,189	2,521,200
Total	9,684,634	6,619,800	4,769,192

The second column shows these numbers for users with at least 10 friends, and the third column users who had at least one reciprocal interaction during the three-months observation period (i.e. users included in the interaction network).

Table 2 Number of connections in the friendship network and in the network of reciprocal interactions, broken down by gender

Connection type	Male-male	Female-female	Mixed
# Friendship	135,064,946 (25.2%)	143,740,462 (26.8%)	256,894,050 (48.0%)
(Null model)	(23.9%)	(26.1%)	(50.1%)
# Interactions	12,236,165 (19.6%)	22,698,114 (36.4%)	27,346,769 (43.9%)
(Null model)	(17.2%)	(34.3%)	(48.5%)

Results reported for the null model are average values over ten shuffled networks (standard deviation $<10^{-5}$).

removed the first friend, or the first friend might have quit the service before the data were collected), we believe that such exceptions happen only in a very reduced number of cases and do not affect our results.

Furthermore, the dataset contains all interactions in the form of the number of messages posted by a user on another user's page (wall) during a period of three months between September 11 and December 11 2010.

Using all the above information we construct two networks:

- The **friendship network** is based on all friendship connections between users. This network is undirected since friendship connections in Tuenti are reciprocal.
- The **interaction network** is a sub-network of the friendship network in which we only keep links between two users if they have sent to each other at least one wall message during the three months period of observation. We note that the interaction network is as well undirected, as we only take into account reciprocal interactions.

Tables 1 and 2 report the total number of users and connections for these networks broken down by gender. We immediately observe the higher numbers for female users in the interaction network indicating their higher activity, in comparison to male users, in sending (and receiving) wall messages on this social platform.

Hereinafter, when analyzing gender homophily by age we focus especially on younger users, i.e. until their twenties. We only show results for users younger than 50 and omit older users for whom data, in general, is very sparse and not very representative.

When showing results averaged by user, we furthermore omit users having few connections to avoid the possible biases (towards very large or very small fractions) these users could introduce in the results. For the friendship network, we omit users having less than 10 friends, while for the interaction network we omit users who had reciprocal interactions with less than two friends during our three-months observation period.

2.4 Null model for assessing gender homophily

The numbers of men and women in the networks are not exactly equal, and more importantly, their degree distributions are not equal. Women have more connections, especially in the interaction network, and this leads to a higher number of dyadic and triadic re-

lationships involving women. As the networks are unbalanced it is difficult to assess the impact of homophily just by observing in absolute terms the results obtained.

To compensate for this inequality, we assess how the results we observe differ from the results one should expect given the user composition of the networks. To do so, first we produce randomized equivalents of our networks by re-shuffling users' attributes, i.e. age and gender. To maintain the same gender and age proportions, and the same degree distribution for each gender and age, we randomly re-shuffle the attributes of all users having the same degree (keeping the attributes of the same user together). Therefore, the resulting networks have the same identical link structure as the original network, and have the same number of connections involving men and women, as well as the same number of connections for users of each age. The demographic composition of the network, i.e. the proportion of men and women for each age, is also respected. In the following we will refer to such networks as *shuffled networks*. It should be noted that our method is based on shuffling user attributes, and not reshuffling connections as frequently done in the analysis of complex networks [28, 65]. Comparing the results observed in the real networks with the average of the results obtained in 10 of these shuffled networks allows us to assess to what extent gender preferences are affecting user behavior.

3 Results and discussion

In this section we answer the research questions defined above by analyzing the friendship and interaction networks in the case of Tuenti. In all the figures, we use red and blue (or pink and cyan) to depict women and men, respectively. We use continuous lines to show the results observed in the networks, and dashed lines to show the results expected according to the null model.

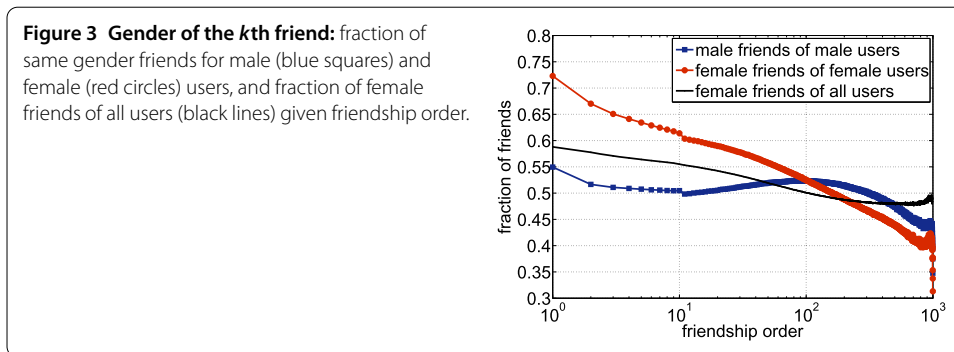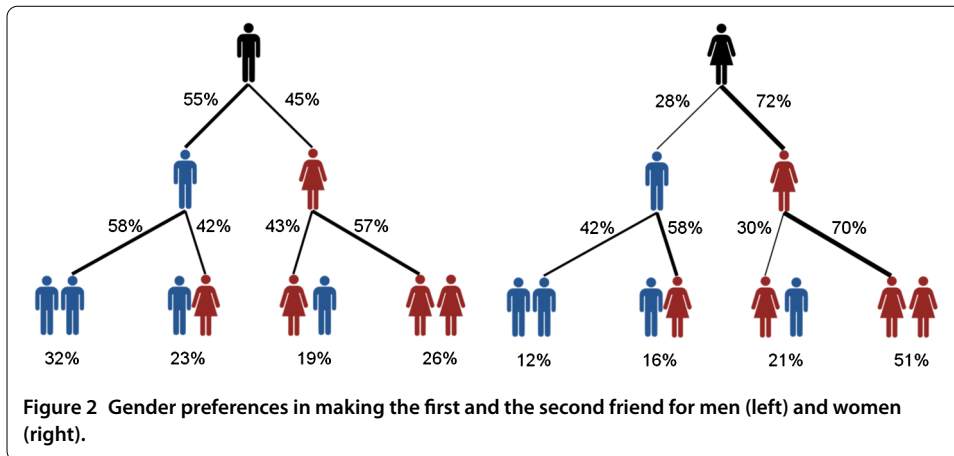### 3.1 RQ1: gender homophily in building the online social environment

Gender has been observed to play a crucial role in defining people's decisions about adopting and using new technologies. Thus, men are reported to be more driven by instrumental factors (i.e. perceived usefulness) while women to be more motivated by process and social factors [66].

In this section we study the influence of gender homophily on building users' online social environment, by examining differences in how men and women start their online social experience and how they organize their personal social network. We compare the order in which they are making friends of the same or opposite gender and inspect how age influences their gender preferences.

3.1.1 The first friend

The first friend of a user has a special importance in an invitation-only social networking service, as in general it represents the user who has successfully invited her/him to join the service. In Figure 2 we look at the gender of the first and of the second friend of a user. We observe that male users sign up through the invitation sent by another man in 55% of the cases and only in 45% of the cases after the invitation by a woman. The gender bias however is much more remarkable for female users: in 72% of the cases women accept an invitation to join the online platform from another woman, and just in 28% of the cases from a man.

We observe a similar trend for the second friend of a female user in the case that the first friend was already a woman. However if, on the contrary, the first friend of a woman
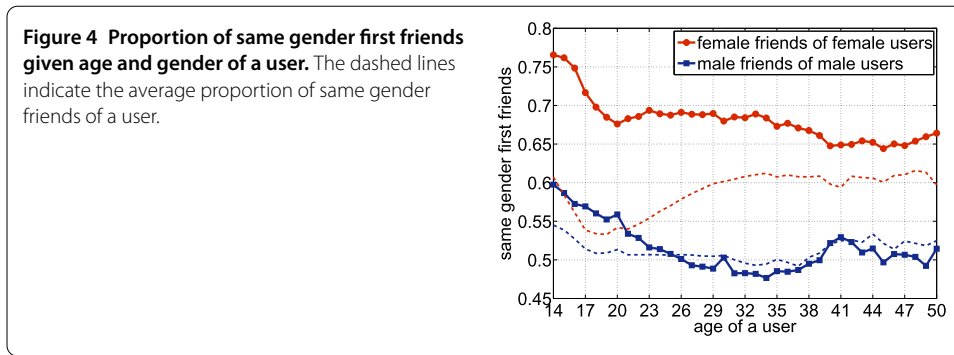
Figure 2 Gender preferences in making the first and the second friend for men (left) and women (right).

Figure 3 Gender of the *k*th friend: fraction of same gender friends for male (blue squares) and female (red circles) users, and fraction of female friends of all users (black lines) given friendship order.

was a man, the probability of being the second friend as well a man rises to 42%. For male users the dependency on the gender(s) of the first two friends is even stronger: the second friend has in almost 6 of 10 cases the same gender as the first friend.

3.1.2 Friendship order

We go beyond the first two friends and look at how the probability of adding same gender friends varies as the number of connections of a user grows. In Figure 3 we plot the average fraction of same gender friends for the *k*th friend of male and female users for *k* = 1 to 1,000 (the Tuenti friendship limit). In the same plot we also show the average fraction of female friends for all users. We find that most women, as they join the new social platform, connect primarily to their female friends, creating female dominated ego networks. Women prefer to add other female users until their degrees grow larger than 150. When they have over 150 friends they tend to connect more with male users. In the next section (RQ2), we confirm that women with many friends have a smaller fraction of same gender friends. For men we do not observe pronounced preferences. The only observation is that at the very beginning of their online social experience, and also when they have between 50 and 200 friends approximately, men have a slight tendency to connect preferentially with other men.

3.1.3 Age patterns

To inspect how age influences homophily in joining the social network site, we plot the fraction of same gender first friends as a function of user age in Figure 4. We find that ho-

Figure 4 Proportion of same gender first friends given age and gender of a user. The dashed lines indicate the average proportion of same gender friends of a user.

mophily tends to be higher for younger users starting with a preference of 76% for 14 years old female users and 60% for 14 years old male users. Homophily decreases with user age showing almost no preference (around 50%) for men in their late twenties and still a considerable same-gender preference (between 65% and 70%) for women. The comparison with dashed lines, indicating homophily in the overall friendship network, shows that the preference observed for first friend of women and young men is remarkably higher than for an average friend.

Although we consider the current age of a user with respect to an action (signing up) that might have happened in the past, the age difference with respect to the moment in which users registered can not exceed 4 years (the dataset was collected in 2010, and Tuenti was created in 2006) and is mainly between 1 and 2 years (Tuenti's popularity "boom" started in 2008). Therefore, we believe this issue does only slightly affect the results.
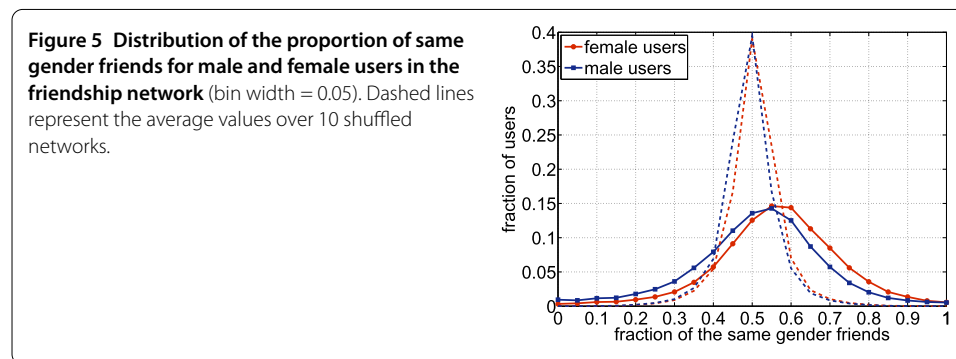
3.1.4 Discussion

The results show that women organize their online social environment differently from men especially in the initial steps, as they are more likely to add other women as their initial friends and to try a new service and enter a new social environment following an invitation by another woman. In particular, among women between 14 and 16, three out of four joined the SNS accepting an invitation from a female friend. The lower homophily observed for male users may reflect the difference in purposes to sign up for social networking services as it was reported in previous literature. Contrarily to women who use SNSs mainly for relationship maintenance [67], men have been reported to use them to a higher extent for meeting new people and finding potential dates [4, 18]. The dataset does not contain information about rejected invitations, so we do not know to which extent such strong preferences are due to women being more active in inviting other women, or more prone to accept invitations received from other women than from men. In any case, the results show evidence that gender matters at the moment of joining a new SNS. In particular, our analysis suggests that for women, and especially teenagers, the perceived presence of other women is very important in the first stages into a new virtual environment. This finding is particularly relevant for fostering technology adoption among women, and can help understand and address the gender gap issues suffered by some online communities, such as for example Wikipedia [68].

Table 3 Basic friendship statistics by gender, together with 25% and 75% quantiles

	Friends	avg # male	avg # female	avg % same gender
Friendship network	male	82 [20, 116]	78 [19, 106]	51.48%
	female	76 [15, 104]	85 [23, 122]	56.46%
(Null model)	male	79 [21, 111]	81 [21, 114]	49.36%
	female	79 [20, 113]	82 [20, 116]	50.64%
Interaction network	male	13 [2, 16]	14 [2, 18]	47.47%
	female	12 [2, 16]	20 [4, 27]	67.31%
(Null model)	male	11 [2, 16]	16 [3, 20]	42.13%
	female	14 [2, 18]	19 [3, 25]	57.97%

The average values over the 10 shuffled networks have standard deviations always <0.005.

Figure 5 Distribution of the proportion of same gender friends for male and female users in the friendship network (bin width = 0.05). Dashed lines represent the average values over 10 shuffled networks.

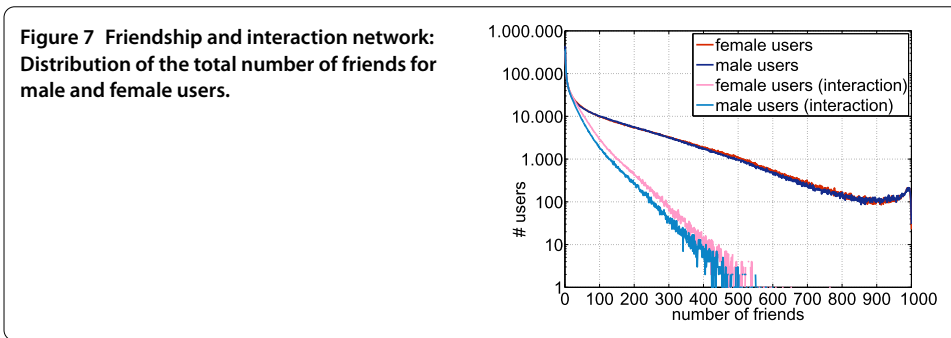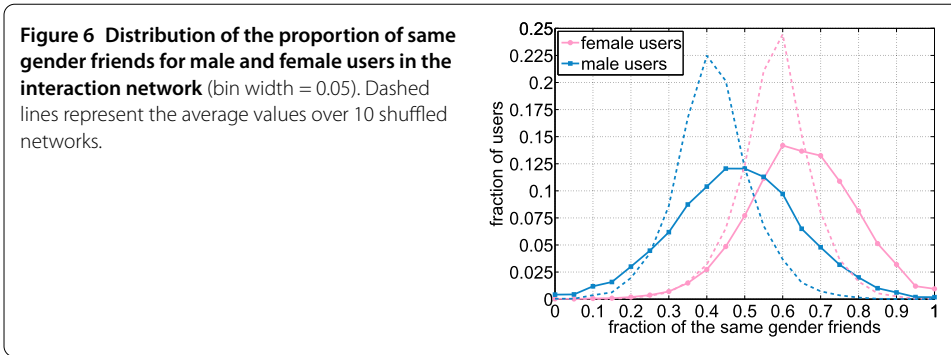## 3.2 RQ2: gender homophily in establishing connections and interacting with friends

While in the previous section we have focused on the first steps of a user in joining the social networking platform and adding the first friends, we now take a wider view on gender preferences in adding friends and interacting with them in the social networking service. We present some general statistics about homophilous behavior and also look in more detail at how this behavior varies according to the degree and the age of the users.

3.2.1 General statistics

We find a small preference for users to have friends of the same gender (see Table 3): on average men have 82 male and 78 female friends (versus the expected values of 79 and 81, respectively), while the average for women is 85 female and 76 male friends (versus the expected values of 81 and 79). This tendency towards homophily is stronger when analyzing the average proportion of same gender friends per user: 51.5% for men and of 56.5% for women, versus expected values of 49.4% and 50.6%. This is caused by a higher homophily of users with a lower number of friends (degree), as we will see in the next section.

For female users, reciprocal interactions with other women are prevalent: they talk on average to 20 other women and 12 men. For men we find that they contact women just a little more often than men. However, this is due to the higher activity of female users, as shown by the stronger preference for interacting with women observed in the shuffled networks.

To offer a more detailed picture we plot the distribution of the proportion of same gender friends for female and male users, in the friendship network (Figure 5) and in the interaction network (Figure 6). In both figures, the variables are approximately normally

Figure 6 Distribution of the proportion of same gender friends for male and female users in the interaction network (bin width = 0.05). Dashed lines represent the average values over 10 shuffled networks.

Figure 7 Friendship and interaction network: Distribution of the total number of friends for male and female users.

Figure 8 Friendship network: Proportion of female users among users with a given degree (bin width of grey dots is 1, red line represents the results of a median filter applied on the grey dots with a sliding window of length 10).

distributed, around the values shown in the third column of Table 3. The observed values are much more spread than the ones expected from the null model, and they are shifted to the right indicating a tendency to homophily in all cases.

3.2.2 Gender homophily by degree

Previous work on Facebook [19] reported that men and women are almost indistinguishable with respect to their network size. In our case we also do not find any major differences between the degree distributions in the friendship network of male and female users (Figure 7). However, by analyzing the gender ratios of users with a given degree (Figure 8) we find that users with a low (<100) or high (>300) number of friends are slightly more often women.

When focusing on friends with whom users had reciprocal interactions we observe a more noticeable difference according to gender, with women having in general more interactions, as shown by the pink line being more shifted to the right than the cyan line in Figure 7. Figure 9 offers a more precise view, and shows that the proportion of women is

Figure 9 Interaction network: Proportion of female users among users with a given degree (bin width of grey dots is 1, red line represents the results of a median filter applied on the grey dots with a sliding window of length 2).
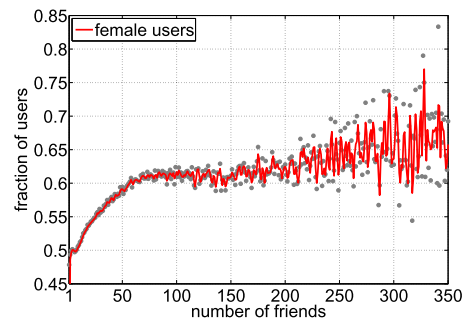

Figure 10 Friendship network: Proportion of same gender friends of a user given her/his degree (bin width of grey dots is 1, red and blue lines represent the results of a median filter applied on the grey dots with a sliding window of length 10). Dashed red and blue lines represent the values expected according to the shuffled null model. The standard deviation of the average over the 10 reshuffled networks is always <0.005, and <0.001 for degrees lower than 500.
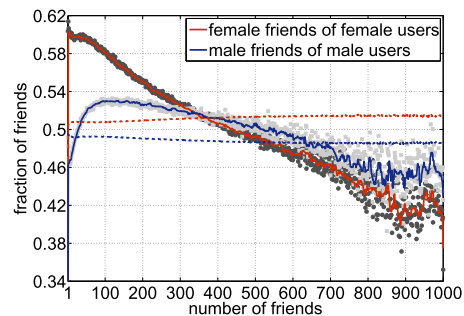
increasing with degree in the interaction network. Users that have reciprocal interactions with more than 60 friends are women in more than 60% of the cases.

To understand the dependency between gender homophily and the size of a user's circle of friends (degree), we now consider the fraction of same gender friends, given the degree, for male and female users separately. Figure 10 shows such fraction in the friendship network, with dashed lines indicating the values expected according to the null model. Women with few friends exhibit a marked preference for connection with other female users: around 60% for women having less than 50 friends. This preference tends to decrease with increasing degree, until women with more than 400 friends, who tend to have more male friends. For male users we observe a more balanced pattern, while we still find that users with many friends prefer to befriend opposite gender users. Interestingly, men with a low number of friends also have a higher proportion of female friends. This finding is in contrast with the slight tendency of men to add other men as their initial friends, observed in Figure 3, suggesting that a preference for the opposite gender applies only to male users having a small circle of friends (less than 25) in the SNS.

In the interaction network (Figure 11) we observe a similar trend, although in this case, due to the higher presence of women in the interactions, both lines are shifted towards a higher proportion of female friends. The dashed lines representing the results in the shuffled networks quantify this effect, showing that for both genders we should expect about 58% of interactions with female users. As for the friendship network, male users exhibit a more stable pattern, while homophily is specially high for female users having low degrees, and on the contrary we observe, with respect to the null model, a tendency to heterophily for women interacting with over 150 friends.

Figure 11 Interaction network: Proportion of same gender friends of a user given her/his degree (bin width of grey dots is 1, red and blue lines represent the results of a median filter applied on the grey dots with a sliding window of length 2). Dashed red and blue lines represent the values expected according to the shuffled null model; the standard deviation of the average over the 10 reshuffled networks is always <0.05, and <0.005 for degrees lower than 300.
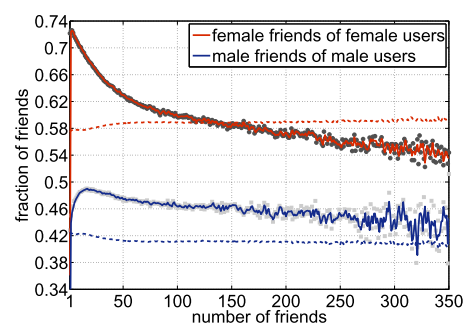
Figure 12 Average degree given age and gender of a user, in the friendship and in the interaction network.
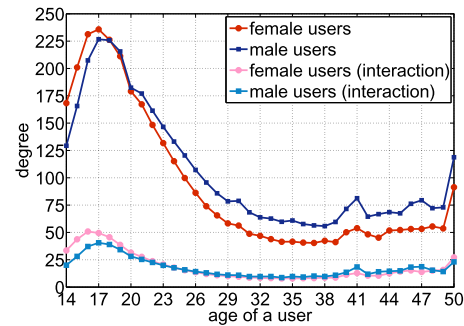
Figure 13 Average fraction of same gender friends in the friendship and interaction networks, given the age of a user. Dashed lines represent the values expected according to the null model. The standard deviation of the average over the 10 shuffled networks is always <0.005, and <0.0005 for age lower than 28.
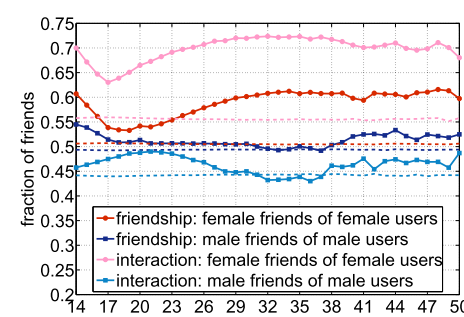
3.2.3 Age patterns

We now look at the interplay between age and gender homophily. First we examine how the degree of male and female users in the two networks varies according to the age of the users (Figure 12). As one could expect given the higher penetration of the social network service among young people shown in Figure 1, users between 14 and 25 are also the ones with the highest degrees, with a peak at the age of 16-17 for women, and of 17-18 for men. Women have on average a higher degree than men in the group of users younger than 18 while the opposite is the case for users older than 20. The curve gets stable around the age of 30, suggesting that after this age we have a different usage of the social network site (accordingly to its low penetration among this age group), mostly oriented to inter-generational connections with younger users, as reported for Facebook in [52].

After getting a more clear picture of age patterns in the social networking service, we are now ready to analyze the relationship between homophily and user age. In Figure 13 we can observe that homophily has a different dependence on age for men and women. The youngest female users in the network, 14 years old, have a strong homophily which

rapidly decreases with age until around 17, and then increases again for older users. For male users we observe different patterns in the two networks: in the friendship network the youngest users have high homophily, that decreases with age until an almost neutral preference after 18. In the interaction network instead the pattern for men is somehow specular to the one observed for women, with the highest homophily between 17 and 24.

3.2.4 Discussion

Our finding of a generally higher homophily for women is consistent with offline studies where men were reported to have 65% and women 70% of same gender friends [69]. Interestingly, the percentages of same gender friends we found in the friendship network are lower than the ones reported for offline studies. This attenuation of the evidence of homophilous behavior might be due to the ease of adding a "friend" in a social networking service compared to considering someone as a friend in real life, and therefore to a presence of casual relationships in which gender is less relevant. The higher homophily of users having smaller circle of friends, and therefore being possibly more selective in adding friends in the SNS, may be interpreted as an element to support this hypothesis. A similar effect of degree, with gender homophily being prevalent especially for users having few friends, and an opposite tendency to heterophily for users having many friends, was also reported for Facebook based on surveys [12]. An exception to this rule are in our results male users with very small circles of friends, who on the contrary exhibit a slight preference to connect and interact with women.
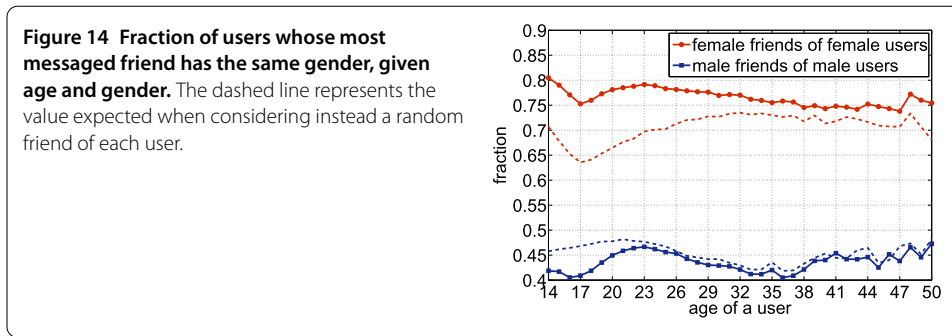
In line with previous literature [5, 18] the results show evidence of higher homophily among young teenagers, decreasing with age. The inverse pattern observed for male users in the interaction network, with homophily increasing until 22, seems to indicate a different behavior for the two genders, with an increase of the interest for the opposite gender having the strongest effect for female users around the age of 17-18.

Gender homophily observed in the Tuenti friendship network is in contrast with the neglectable homophily reported for the Facebook social graph [52]. This might be due to several reasons, including the higher average degree in Facebook (which according to our findings is associated with lower homophily as discussed above) and the different average age, with Tuenti having an over-representation of teenagers.

3.3 RQ3: gender homophily in strongest online interactions

Following [70–72], where authors introduced simple proxies such as communication reciprocity [70, 73] or interaction frequency [72] to quantify different dimensions of tie strengths [74], we examine whether strong interaction ties are likely to exhibit greater homophily.

For each user we say the **most messaged friend** to be the one to whom that user has sent the highest number of wall messages, and from whom she/he has received at least one message. In this way, we select the friend to which each user has devoted most of her/his attention, among the ones who have reciprocated such attention at least once. Therefore, although the interaction network is undirected, this relationship is directed and not necessarily reciprocal. To insure that each user has only one *most messaged friend* we introduce the following procedure for ties resolution: first we look at the number of messages received by the user from the candidate friends, and choose the friend with the largest number. In cases when there are still more than one candidate, i.e. interaction values are tied

Figure 14 Fraction of users whose most messaged friend has the same gender, given age and gender. The dashed line represents the value expected when considering instead a random friend of each user.

again, we pick randomly one of the friends having the maximum values of both messages received from and sent to the user.
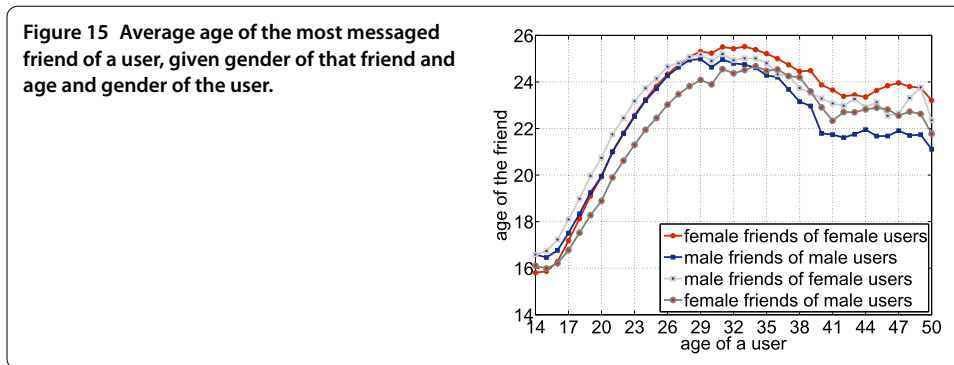
The presented approach has the advantage of focusing on a user's actions to quantify her/his preference, without influence of the higher or lower activity levels of her/his friends. In this way we avoid the effects of the possible tendency of some friends to post more or less wall messages. However, as a drawback, this measure is based on an asymmetric definition of tie strength. To check the impact of this asymmetry, we introduce for comparison an alternative symmetric measure, consisting in the minimum of the numbers of messages exchanged between two users in the two possible directions (and then, in case of tied values, the maximum value of the two as secondary criterion). We found that in 93.4% of the cases this balanced metric leads to select the same friend as in the asymmetric case, and the results obtained do not differ noticeably from the ones shown in what follows.

The most messaged friend has the same gender in the 44.2% of the cases for male users and in the 77.1% of the cases for female users. For women the percentage is higher than the one observed in the interaction network (67.3%), while for men it is lower (47.5%). In the next subsection we inspect how the age of a user influences such preferences.

3.3.1 Age patterns

Figure 14 shows the fraction of times in which the most messaged friend of a user is of the same gender. As a comparison in this case we plotted with dashed lines the probability of getting a friend of the same gender when picking a random friend among the ones a user has reciprocal interactions with (which corresponds to homophily in the interaction network, shown in Figure 13). We can see that the preference of all users for having the strongest interaction with a female user is especially marked for teenagers, and then tends to disappear for men over 22.

In Figure 15 we plot the average age of the most messaged friend broken down by gender. In this case we do not show the comparison with results for the case of picking a random friend, as there are no noticeable differences, indicating that the friend with whom a user interacts most tends to have on average the same age as an average friend. We see that users between 14 and 25 have the most messaged friend around the same age, and that for mixed-gender relationship the female friend tends to be one-two years younger. Over 30 there is a clear shift and users interact most with younger friends, which can be an online reflection of parent-child or other kinds of inter-generational relationships. A similar tendency was also reported for Facebook connections [52].

Figure 15 Average age of the most messaged friend of a user, given gender of that friend and age and gender of the user.

3.3.2 Discussion

Overall, users of both genders are more likely to have their strongest interaction with a woman (in 67% of the cases). Therefore, in this context we observe strong gender homophily for women, but not for men. This result is partly different from what was observed in studies of offline behavior [4] and for mobile phone networks [75], where the strongest social ties correspond to different-gender romantic relationships. This pattern, which characterizes especially teenagers, can be interpreted in light of the higher importance of stronger-tie activities for girls, as reported in [16, 17] and [18].

3.4 RQ4: gender homophily in triadic relationships

In the literature gender homophily has been mostly investigated at the level of dyadic, i.e. one-to-one, relationships. In other words the primer interest was to study how people make and communicate with their friends regardless the social group they are in. In this section we deepen the analysis of gender homophily and go beyond dyadic relationships by inspecting how gender affects group creation and community structure. To this end we focus on triadic relationships, the building blocks of any cohesive group structure.

A **triadic relationship** (or *transitive relationship*, or simply *triangle*) is a group of three users all connected to each other. A high presence of triangles (or a high *clustering coefficient*) is one of the key elements that distinguish social networks from other kinds of networks, such as biological or technological ones [76]. Therefore, it is particularly relevant to assess how gender affects the formation of transitive relationships.

In the following we study the gender compositions of triangle motifs in the friendship and interaction networks at the global level, and then check the impact of gender on the formation of transitive relationships in the ego network of each user.

3.4.1 Global count of triangle motifs

There are four possibilities for the gender composition of the triangles: 3 women, 3 men, 1 man and 2 women, or 2 men and 1 woman. In case of a perfectly gender balanced network, one could expect, using the binomial distribution, to have exactly 12.5% man-only triangles, 12.5% woman-only triangles, and 37.5% of the triangles in each of the two mixed triangle possibilities. However, as already observed the networks are not gender-balanced, and a remarkable difference in the number of connections involving men and women exists. This is true especially in the interactions network where female users are much more active, which leads to a higher overall number of triangles involving women.

Therefore, to assess how gender influences the formation of transitive relationships we observe to what extent the results deviate from the ones expected according to our null

Table 4 Proportion of triangle motifs with different gender composition in the friendship and interaction networks

Type of triangle	Friendship		Interaction	
	Observed	Shuffled	Observed	Shuffled
Males only	16.0%	11.6%	9.9%	6.2%
1 female, 2 males	32.5%	36.6%	24.4%	28.4%
2 females, 1 male	34.5%	38.4%	37.3%	43.3%
Females only	17.0%	13.4%	28.4%	22.1%
Total	3.64×10^{10}		1.24×10^{8}	

The differences between observed and expected proportions (shuffled, calculated via reshuffling the gender of users having the same degree) are highly significant (standard deviation of reshuffling <0.0005).

model, by comparing the proportion of triangles observed in the real networks with the average proportion obtained over 10 of the networks in which we have reshuffled user attributes. The results, reported in the following, are all highly significant: the standard deviation of the values observed for the reshuffled networks is smaller than 0.0005.

In total we find more than 3.64×10^{10} triangles in the friendship network. The second and third column of Table 4 list the proportion of triangles of different composition together with the expected values based on the networks with randomly reshuffled genders. We clearly observe a much larger proportion of single gender friendship triangles than expected. In particular, although the number of female only triangles is higher, if we compare the results with the ones obtained in the reshuffled networks we find a stronger deviation for male only triangles (+38%, versus +27% for female only triangles).

When analyzing the interaction network, i.e. the connections which mutually exchanged messages, we find a striking difference between men and women, as can be observed in the two rightmost columns in Table 4. The number of female only triangles is about 3 times larger than the number of male only triangles. This difference seems high, however reshuffling shows that again we would actually have to expect an even larger disproportionality between male only triangles and female only triangles, given that women are much more active in sending (and receiving) messages. In this case the proportion of male only triangles exceeds by 60% the expected value, while the proportion of female only triangles is only 28.5% higher than expected. This indicates that male users are in general less active in the SNS, but when they interact they tend to create more gender homogeneous groups.

While the results presented so far are based on the total number of triangles of different composition in the network, and might be affected by users having higher degrees, in the following we focus on individual users, inspecting the presence of triadic relationships in their ego-network, and looking at how this varies according to age and gender.

3.4.2 Clustering coefficient by user age
We now check how the tendency to create tightly knit groups, and specifically gender heterogeneous or gender homogeneous ones, changes with user age. To do this we rely on the notion of **local clustering coefficient**, which is defined as the proportion between the number of triangles in which a node is involved, and the total number of triangles in which it could be involved given its degree [77].

Beyond looking at the local clustering coefficient of a user in the overall network (i.e., based on triangles of any gender composition, normalized by all the connections of a user) we also define a **gender-restricted clustering coefficient**, when we do the same considering only friends that have the same gender as the selected user. This is the local clustering
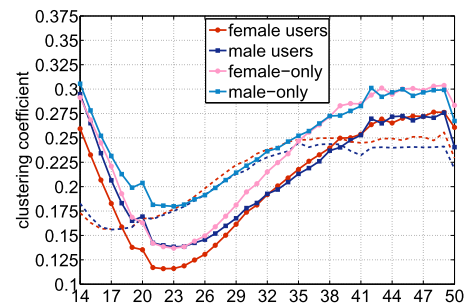
Figure 16 Friendship network: Local clustering coefficient given user age. Red and blue lines represent local clustering coefficient of female and male users in the whole network, while pink and cyan lines represent local clustering coefficients in the gender-restricted networks. The red and blue dashed lines represent the values expected according to the null model for women and men in the whole network; expected values for the female-only and male-only networks are omitted as they are almost indistinguishable from the ones obtained respectively for women and men in the whole network. Standard deviation of reshuffling is always <0.02, and <0.003 for age lower than 30.

Figure 17 Interaction network: Local clustering coefficient given user age. Red and blue lines represent local clustering coefficient of female and male users in the whole network, while pink and cyan lines represent local clustering coefficients in the gender-restricted networks. Dashed lines represent the corresponding values expected according to the null model. Standard deviation of reshuffling is always <0.02, and <0.003 for age lower than 30.
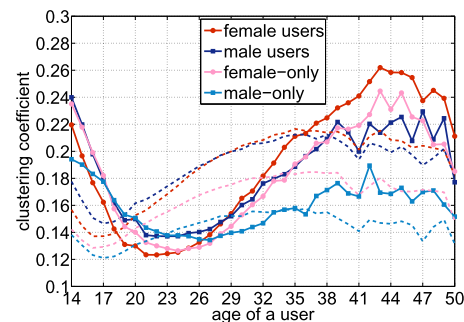
coefficient of the users in the two gender-homogeneous networks obtained by removing respectively all male and all female users. As a result, we count gender-homogeneous triangles involving the user, normalized by the number of connections with users of the same gender. So, while the local clustering coefficient of a user in the overall network indicates the tendency of a user to form transitive relationships in general, the gender-restricted one measures the tendency to form gender homogeneous groups.

Figure 16 shows how the clustering coefficient of a user in the friendship network varies according to user age. The same results for the interaction network are shown in Figure 17. The dashed lines, representing the values obtained in the shuffled networks (null model), approximately trace the inverse of the degree distribution by age (shown in Figure 12); this is in line with previous literature, that reported a negative correlation between degree and local clustering coefficient [78].

We observe that in both networks clustering decreases with age for young users, then it starts to increase again. This general trend is not aligned with the one expected according to the null model indicating a marked age pattern in the data. The strongest deviations are found for young teenagers, whose tendency to form dense groups is much larger than expected, and for users over 20, who on the contrary exhibit sparse relationships.

In comparison with values in the overall network and in the null model, gender-restricted clustering coefficient is especially high in both networks for teenagers. For female users it is very high below an age of 16 and then decreases rapidly with age, while for male users it decreases more slowly, remaining higher than expected until about an age of 23. Furthermore, for female users older than 20 we observe in both networks an

opposite tendency to less gender-homogeneous groups, which we find for male users only to a minor extent over the age of 23 in the interaction network.

3.4.3 Discussion

The above results show that users do not only tend to connect preferentially with others of the same gender, but they also tend to group more by gender, and to create gender-homogeneous groups of friends. As demonstrated in [4], gender segregation is a widespread characteristic of offline social behavior. Our findings show that, in this sense, online social behavior tends to reproduce this offline phenomenon, and that this happens more markedly for male users. In fact, although we find a higher number of triangles involving female users, in apparent agreement with the prevalence of all-female triangle motifs reported for phone calls by Kovanen et al. [58], when comparing with the null model we observe a higher deviation from the expected values for male users. The decrease in users' clustering with age indicates that young teenagers tend to have more cohesive groups of friends, and that they diversify their connections as they grow up. The fact that this trend stops at the age of 21-22 seems to tell that around this age users have already diversified their friends, and created connections out of their main groups of friends. The inversion of the tendency for older users might be attributed to the lower presence of older users in our data, as has been showed in Figure 1. While we may assume that for users 14 to 25 years old, most of their friends have a Tuenti account, for older users only a part of their friends are in the SNS. Therefore, the higher clustering for older users can be interpreted as only specific groups among their real-life friends are present online and many diversified connections are missing in our data. The higher tendency of young teenagers to form gender-homogeneous groups, more prolonged in time for male users, confirms findings reported for offline behavior [34, 79, 80].

4 Conclusions

Recent studies on digital inequalities treat gender in very different ways. Some only concentrate on the influence of gender on human behavior [26], others such as Zillien [81] consider gender only as one of many variables in the emergence of digital inequalities, and yet others like boyd [82] completely ignore the gender dimension. This lack of consistence in considering gender and its influence on digital inequalities indicates that there are still many open questions that need to be addressed. In this study we have presented an extensive analysis of a large social network site to shed light on the phenomenon of gender homophily and to explore how it varies with respect to different kinds of online activities and interactions according to age.

Our analysis of the Tuenti social networking service offers a detailed picture of online behavior for a large portion of the Spanish population: the dataset includes about the 70% of Spanish teenagers. The results are therefore robust for this age group while for adult users, due to the sparsity of the data and a prevalence of inter-generational relationships, some conclusions need further confirmations from qualitative studies or from more representative datasets.

Overall, our results show evidence of gender homophily in dyadic relationships for both genders, being higher for women, and decreasing with age for young teenagers. This was mostly expected according to previous literature on offline and online behavior [3, 31–33, 35]. However, the extent of homophilous behavior is surprisingly high in some settings,

such as women's strong preference for signing up for the social network site on invitation of another woman, adding other women as their initial friends and having the strongest interactions with a woman. The high feminine homophily observed in this context suggests a crucial importance of gender for women in the starting phase of their experience in a new virtual environment. These findings may be particularly relevant for understanding dynamics of technology adoption and contagion in social media, and for facing the gender gap issues that are persistently hard to overcome in some online communities [68]. Our combined analysis of age and gender patterns in particular suggests that the role of active women in involving their female fellows may be a fundamental condition for creating a "network effect" especially among female teenagers. As we only have access to information about all accepted friendship requests and accepted invitations to join the service, we cannot answer the question to which extent female users are in the first steps reluctant to accept invitations from men.

Our results contrast with the neglectable overall effect of homophily reported for the Facebook social graph [52]. Beyond the possible effect of cultural specificities of the Spanish context, the stronger effect of gender homophily in Tuenti might be explained in light of the younger age of its users, or by their lower average degree. In fact, in agreement with survey-based studies focused on Facebook users [12] we have observed a stronger tendency to homophily for users having lower degrees, and on the opposite a tendency to heterophily, i.e. a preference for the other gender, for users having many connections. Therefore, in absence of more detailed results about Facebook or other similar social networking sites, it is difficult to assess to which extent our different results are due to cultural differences. Further studies on large samples of users from other countries would help to shed light on this aspect.

Contrary to findings reported for mobile phone calls [58] and microblogging [57] we did not observe a higher tendency of female users to form gender homogeneous triangles, while we observed a stronger deviation from the expected values in a randomized model for the number of male-only triangles. This result, in apparent contradiction with the higher homophily observed for women in dyadic relationships, is consistent with studies of offline behavior [34] and of online behavior with respect to profile pictures in SNSs [3] reporting a higher tendency of males to form gender homogeneous groups. Also in line with offline studies [34], the tendency to form knit groups of same gender users is specially high for young teenagers, and decreases with age, with a sharper pattern for female users. Our findings show evidence that the interplay of age and gender with local clustering is an important element to understand grouping phenomena and the growth of social networks. While in this study we have highlighted triads as the basic building blocks of larger groups, and studied a snapshot of the social network, analysis of the gender composition of larger cliques and cohesive clusters of users, as well as studies of temporal patterns in tie formation and triadic closure might shed further light on the importance of gender homophily with respect to grouping behavior and network evolution dynamics.

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Endnotes
ᵃ report by *Rapleaf*: http://readwrite.com/2008/07/29/social_networks_women_outnumber_men
ᵇ http://www.tuenti.com

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