How Does Facebook Retain Segregated Friendship? An Agent-Based Model Approach

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Abstract
Facebook, the largest social networking site in the world, has overcome the structural barriers that historically constrain individuals to reach out to different others. Through the platform, people from all walks of life and virtually any location can develop diverse friendships online. However, friendships on Facebook have been as segregated as friendships in real life. This research sought to understand why the leading social networking site intended to “bring the world closer together” retains segregated friendship. In doing so, I employed a series of agent-based simulations based on the Framework for Intergroup Relations and Multiple Affiliations Networks (FIRMAN). As demonstrated, Facebook has primarily enhanced users’ capacity to maintain a larger number of friendships (tie capacity), but it has done little to empower users’ ability to accept diversity and befriend different others (tie outreachability). Facebook must focus on the latter should they truly wish to contribute to the development of a more inclusive society. While in this study I focus on ethnically segregated friendship on Facebook, I argue that the same explanation might also hold for racially and ideologically segregated friendships on other bidirectional social networking sites.

Keywords
Facebook, friendship, segregation, agent-based model, ethnicity

Introduction
Diverse friendships have been shown to have a variety of benefits for individuals, including enhanced creativity (Lee et al., 2012), improved health outcomes (Pachucki & Leal, 2020), increased tolerance (Ikeda & Richey, 2009), and advanced career paths (Aten et al., 2017; Seebuck & Savage, 2014). However, most friendships tend to be homogeneous and segregated, as demonstrated by prominent examples in gender (Laniado et al., 2016), race (Campigotto et al., 2021), and ethnicity (Smith et al., 2014; van Tubergen, 2015). And

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historically, this phenomenon was driven by structural factors such as dispersed living locations (Mouw & Entwisle, 2006), unbalanced demographic composition (Joyner & Kao, 2000), divided foci (Feld, 1981), and language barriers (Li & Zizzi, 2018; Titzmann et al., 2012), which constrain individuals’ ability to reach out to different others. Of course, psychological factors such as preference (Ilmarinen et al., 2016; Yu & Xie, 2017) and intergroup attitudes (Bahns et al., 2015; Fischer, 2011) also play roles.

Today, the invention of social networking sites such as Facebook has overcome the structural barriers in unprecedented ways. Through Facebook, people from all walks of life and virtually any location can connect and form friendships online (Bouchillon, 2021). For instance, a Pacific Islander in Hawaii can become Facebook friends with a European American in Maine; an African American in Mississippi can befriend an Asian American in California on Facebook. Thus, it makes sense to assert that diverse friendship should be more prevalent or at least have increasing rates in the online environment. It turns out, however, friendships on Facebook have been as segregated as friendships in real life (Hofstra et al., 2017; Wimmer & Lewis, 2010). Even more so, they have involved less salient dimensions such as personality traits (Lönnqvist & Itkonen, 2016), moral values (Dehghani et al., 2016), and political ideology (Huber & Malhotra, 2017).

Developing a New Friendship on Facebook

Founded in February 2004, Facebook has been the largest social networking site in the world (Tankovska, 2021). As of 2021, Facebook allows users to send friend requests virtually to anyone available in any part of the world and maintain up to 5,000 friendship connections. The users who receive the friendship invitations can accept, delete, or ignore the requests. The sender will only get notified if their friend requests are accepted. They will never know if the recipients delete or ignore the friend request. Once connected as friends, Facebook users can do various things including but not limited to seeing shared personal information, sharing photos and videos, commenting on each other’s posts, and sending direct messages. Indeed, the sharing features will vary depending on the user’s privacy settings.

Past surveys have reported that 31% of American teenagers had Facebook friends who they had never met in-person (Lenhart & Madden, 2007). Another research experiment has revealed that 35% of Facebook users did accept friend requests from strangers even if they were bots (Boshmaf et al., 2011). From the receiver’s perspective, users decided to develop a new friendship with someone on Facebook if they knew that person in real life, shared similar interests, or had mutual friends (Rashtian et al., 2014). Moreover, compared to female users, male users tend to send more friend requests to other users on Facebook (Muscanell & Guadagno, 2012). From the sender’s perspective, friend requests sent by more attractive or
opposite sex users tend to get accepted (Patil, 2012). Ironically, this making-new-friends phenomenon does not lead to a more diverse social network as previously mentioned. Rather, it amplifies and extends segregated friendship, from offline to online (Hofstra et al., 2017; Wimmer & Lewis, 2010).

**Current Study**

This research sought to understand why Facebook, a leading social networking platform that has been initially designed to “bring the world closer together” (Facebook, 2019), retains segregated friendship particularly along ethnic lines. In doing so, this study employed agent-based modeling derived from the Framework for Intergroup Relations and Multiple Affiliations Networks (FIRMAN) introduced by Firmansyah and Pratama (2021). I chose FIRMAN since it simplifies the otherwise very complex process of friendship development in a formal language. Moreover, its premise that friendship must be reciprocated in order to develop aligns with the friending mechanism on Facebook. In this regard, two users will not become friends on Facebook unless one accepts the other’s friendship invitation. This agent-based simulation approach also allowed me to further investigate which part of this extended friendship segregation has been nurtured by the platform, and which part comes naturally from the individuals. By recognizing these factors, such interventions to catalyze diverse friendship development on Facebook and other social networking sites in general can be further developed.

In the following section, I briefly explain FIRMAN and its components (i.e., social identity space, social identity distance, length of ties, tie outreachability, and tie capacity). Then, I introduce my hypotheses and test them using agent-based simulation (Macal, 2016). This approach is particularly useful to make sense of macro-level social phenomena through micro-level behavioral detail (Squazzoni et al., 2014) and infer causal relationships between the independent and dependent variables that are otherwise difficult to be manipulated and captured in real settings due to ethical, economical, and practical reasons (Bonabeau, 2002; Jackson et al., 2017).

**Methods**

**Theoretical Framework: Framework for Intergroup Relations and Multiple Affiliations Networks (FIRMAN)**

FIRMAN (Firmansyah & Pratama, 2021) is a formal theoretical framework in which individuals or agents are represented as nodes (with specified coordinates) and their relationships as ties (with specified lengths) in social identity spaces. A social identity space is an abstract space constituted by \(n\) numbers of social identities derived from the groups to which the individuals belong (e.g., gender, ethnicity, and sports clubs). FIRMAN has been useful to explain why homogeneous friendships persist even in a diverse place in which the probability of developing heterogeneous friendships is actually greater than chance alone.

**Social Identity Distance and Length of Ties.** Consider six individuals \(i \in \{A, ..., F\}\) of two different ethnic groups in a hypothetical population. Let color depict their social identity (SI) with orange for the ethnic majority group and purple for the ethnic minority group. The majority group is arbitrarily assigned to 0, while the ethnic minority group is assigned to 1. The one-dimensional social identity space for this population is depicted in Figure 1.

With the individuals located in the social identity space, we can easily calculate their social identity distance \((w_{\text{dist}})\) representing similarity/dissimilarity between any pair of nodes using equation (1), which is derived from Manhattan distance (Black, 2019). Social identity distance
differs from Borgadus’ social distance that is used to assess individuals’ subjective acceptance of outgroup members as alters (Firmansyah & Pratama, 2021).

**Equation 1**

**Social Identity Distance.**

\[w_{\text{dist}_{xy}} = w \cdot \sum_j |SI_x - SI_y|\]

*Note.* \(w_{\text{dist}_{xy}}\) denotes social identity distance between individuals \(x\) and \(y\); \(w\) denotes weight for social identity; \(SI\) denotes social identities; \(j\) denotes \(j\)-th social identity (for a population with multiple social identities).

In this example, \(w_{\text{dist}_{xy}} = 0\) means that nodes \(x\) and \(y\) are of the same group (e.g., A and C; E and F), while \(w_{\text{dist}_{xy}} = 1\) means otherwise (e.g., B and E; C and F). It is worth noting that the operation \(\Sigma\) and constant \(w\) are particularly useful should the numbers of social identities measured in the study be more than two (Firmansyah & Pratama, 2021). As such, they represent that, just as in real life, not all social identities are created equal. For instance, in the United States, people of different political affiliations are more prejudiced and thus more distant from one another than people of different races, all other social identities remaining constant (Iyengar & Westwood, 2015).

Such social identity distance will determine the length of ties (LT) needed to establish relationships between pairs of nodes in the social identity space. As shown in Figure 2, reciprocated friendships (undirected ties) between nodes of the same ethnicity (e.g., A and C; E and F) requires zero length of ties (\(w_{\text{dist}_{AC}} = LT_{AC} = 0\); \(w_{\text{dist}_{EF}} = LT_{EF} = 0\)), whereas friendships between nodes of different ethnicities (i.e., B and E) requires one length of ties (\(w_{\text{dist}_{BE}} = LT_{BE} = 1\)). It is worth noting that the zero length of ties (\(LT = 0\)) between two nodes are depicted by short tie rather than no tie (between a pair of stacked nodes) for practical and aesthetic reasons.

**Tie Outreachability and Tie Capacity.** FIRMAN (Firmansyah & Pratama, 2021) further postulates that nodes have different latent abilities concerning the maximum lengths and numbers of ties that they can generate in social identity space called *tie outreachability* (TO) and *tie capacity* (TC), respectively. Tie outreachability arguably represents the extent to which one can tolerate and accept group differences in real life, whereas tie capacity arguably represents the number of friends one can keep at a time. Individuals cannot generate ties longer than their tie outreachability and more than their tie capacity. Thus, in social identity space, a reciprocated friendship between a pair of
nodes will develop, if and only if, both can generate ties equal to their social identity distance, and both still have a capacity to do so. Mathematically, these conditions can be expressed as follows.

**Equation 2**

Reciprocated Friendship Formation.

\[
\text{friends}_{xy} \leftrightarrow \text{w}_{\text{dist}_{xy}} \leq \min\left(\text{TO}_x, \text{TO}_y\right) \land \text{num}_{f_x} < \text{TC}_x \land \text{num}_{f_y} < \text{TC}_y
\]

*Note.* \(\text{friends}_{xy}\) denotes reciprocated friendship between individuals \(x\) and \(y\); \(\text{w}_{\text{dist}_{xy}}\) denotes weighted social identity distance between \(x\) and \(y\); \(\text{num}_{f}\) denotes the number of friends each node currently has.

To put equation (2) into context, let Table 1 define tie outreachability and tie capacity for individuals \(\{A, \ldots, F\}\). All dyadic relationships in the social identity space presented in Figure 2 meet the conditions as stated in equation (2). For instance, B and E are friends since their ties can reach out to each other positions (\(\text{w}_{\text{dist}_{BE}} = 1; \text{TO}_B = 1; \text{TO}_E = 1\)) and their current numbers of friend are not more than their tie capacity (\(\text{num}_{f_B} = 2, \text{TC}_B = 2; \text{num}_{f_E} = 2, \text{TC}_E = 2\)).

It is worth highlighting that the social network in Figure 2 has reached equilibrium such that no more friendships can be developed. For instance, \(F\) could have been friends with \(A\) since their current numbers of friends are fewer than their tie capacity (\(\text{num}_{f_F} = 1, \text{TC}_F = 3; \text{num}_{f_A} = 2, \text{TC}_A = 3\)). However, they could not do so since \(A\) cannot generate ties equal to the social identity distance between them (\(\text{TO}_A = 0; \text{TO}_F = 1; \text{w}_{\text{dist}_{AF}} = 1\)). In another case, \(F\) could have been friends with \(D\) since their ties can reach out to each other’s position (\(\text{TO}_F = 1; \text{TO}_D = 1; \text{w}_{\text{dist}_{FD}} = 1\)). However, since \(D\) has already reached their maximum tie capacity, they cannot generate another tie to develop a new relationship including with \(F\) (\(\text{TC}_D = 3, \text{num}_{f_D} = 3; \text{TC}_F = 3, \text{num}_{f_F} = 1\)). Indeed, the observed length and number of ties in a social identity space are not always proportional to the nodes’ tie outreachability and tie capacity.

**Hypothesis**

In light of FIRMAN, I argue that Facebook as a technology platform has enhanced individuals’ tie capacity but not their tie outreachability. If in real life individuals can maintain only a few friendships, on Facebook they can keep in touch with more friends and even up to five thousand connections (Hofstra et al., 2021; Manago et al., 2012). Simultaneously, the platform has
dramatically increased the pool of potential friends: from limited people nearby to limitless users worldwide. However, Facebook has little to no bearing on tie outreachability. In this respect, those who are intolerant offline remain intolerant online and still cannot accept group differences (Chaudhry & Gruzd, 2020; Matamoros-Fernández, 2017). These conditions arguably make Facebook retain ethnically segregated friendships. In other words, Facebook friendship patterns closely resemble those of offline friendships.

H1: Friendships on Facebook are as segregated as friendships offline.

H2: Facebook retains segregated friendship by increasing users’ tie capacity but not their tie outreachability.

The results will be validated using empirical findings of a study examining Facebook users’ offline and online personal networks in the Netherlands (Hofstra et al., 2017). I had a particular interest in the referenced study since it simultaneously compared users’ friendships in both offline and Facebook contexts. Meanwhile, other studies focus on either offline friendship only (e.g., Campigotto et al., 2021; Joyner & Kao, 2000; Smith et al., 2014) or Facebook friendship only (e.g., Barnett & Benefield, 2017; Korkmaz et al., 2020; Noë et al., 2018).

**Simulation Design**

I considered probability distributions proposed by Firmansyah and Pratama (2021) to generate agent populations in my simulation study. In this regard, I used the Bernoulli distribution to generate agents’ social identity (SI) with \( p = .22 \). This parameter value is my effort to match the proportion of the majority-minority population in the referenced study (Hofstra et al., 2017) used to validate the results, that is, 78.40% for the majority group and 21.60% for all minority groups combined. Based on my simulations, parameter values higher than \( p = .22 \) resulted in over-estimating the minority group proportion, whereas values lower than \( p = .22 \) resulted in underestimating the proportion. It should be noted, for parsimony purposes, I only incorporate one minority group, unlike the referenced study (Hofstra et al., 2017), which has five minority groups. I used social identity weight \( w = 1 \) since I only incorporated one social identity in this study.

Furthermore, I also used the Bernoulli distribution to generate tie outreachability (TO) with parameters \( q \in \{2, .5, .8\} \), representing populations with few, moderate, and many tolerant agents who can generate up to one length of ties. In the original manuscript, Firmansyah and Pratama (2021) proposed the binomial distribution to generate tie outreachability with parameters \( m \) (numbers of trial) and \( q \) (probability to succeed). Since this study only incorporates one social identity, I chose to employ the Bernoulli distribution, which is the special case of binomial distribution with one variable. I intentionally choose different notation \( q \) to distinguish it with SI’s parameter \( p \) albeit derived from the same distribution.

| Individual (ego) | Tie Outreachability | Tie Capacity | Friends (Alters) |
|------------------|---------------------|--------------|------------------|
| A                | 0                   | 3            | C, D             |
| B                | 1                   | 2            | D, E             |
| C                | 0                   | 2            | A, D             |
| D                | 1                   | 3            | A, B, C          |
| E                | 1                   | 2            | B, F             |
| F                | 1                   | 3            | E                |

Note. Friendship networks of these individuals are visualized in Figure 2.
To generate the tie capacity (TC), I used the normal distribution with \( \mu \in \{3, 30\} \) and the same \( \sigma^2 = .25 \). I then employed specific codes so that the normal distribution only generates discrete numbers (see the source codes for review). These two parameters represent individuals’ tie capacity in offline and Facebook environments. I decided to use these semi arbitrary values for efficiency reasons (e.g., less computing cost and less running time). Moreover, past research revealed that the average number of Facebook connections whom users consider friends was 155.2, while the average number of offline friends were 13.6 (Dunbar, 2016). The difference between the two types of friendships is 11.25 times. However, I decide to use 10 times difference for parsimony purpose.

Furthermore, I generated agents with \( n = 30 \) for the total number of agents in the offline settings and \( n = 300 \) for the number of agents in the Facebook settings for each simulation trial. As previously explained, Facebook increases the pool size of potential friends. The summary of the parameters used to generate agents is presented in Table 2.

I call simulations sharing the same tie outreachability (TO) parameter as a case and simulations sharing the same tie capacity (TC) parameters as a scenario. For each scenario in each case, I performed 100 trials constituting 600 simulations in total. All simulations were conducted in R 4.1.0 with the help of RStudio 1.4.1103. The source codes and data sets are available as the supplementary materials.

**Simulation Procedure**

In all simulations, agents, for various reasons, need friends, and thus aim to develop friendships. They can only befriend other agents from their own population. The order of who gets to initiate and to whom is determined through a stochastic process. Agents who receive a friendship invitation cannot decline unless constrained by their tie outreachability or tie capacity. In this respect, they cannot befriend others whose social identity distance (w_dist) is greater than their tie outreachability and cannot develop any more friendship should their numbers of friends (num_f) have reached their tie capacity. This process will continue until no friendship can be further developed among agents in the population. In other words, the system has reached its equilibrium. Figure 3 illustrates the algorithms employed in this study.

**Analytic Strategy**

As for the analysis, first, I investigated if the developed friendships are ethnically segregated at both group and individual levels. At the group level, I examined the total numbers of homogeneous and heterogeneous friendship dyads in the population. At the individual level, I measured

| Case | Scenario | SL | N  | TO  | TC          | Simulation Trials |
|------|----------|----|----|-----|-------------|-------------------|
| 1    | Offline  | p = .22 | n = 30 | q = .2 | \( \mu = 3, \sigma^2 = .25 \) | 100               |
|      | Facebook | p = .22 | n = 300 | q = .2 | \( \mu = 30, \sigma^2 = .25 \) | 100               |
| 2    | Offline  | p = .22 | n = 30 | q = .5 | \( \mu = 3, \sigma^2 = .25 \) | 100               |
|      | Facebook | p = .22 | n = 300 | q = .5 | \( \mu = 30, \sigma^2 = .25 \) | 100               |
| 3    | Offline  | p = .22 | n = 30 | q = .8 | \( \mu = 3, \sigma^2 = .25 \) | 100               |
|      | Facebook | p = .22 | n = 300 | q = .8 | \( \mu = 30, \sigma^2 = .25 \) | 100               |

*Note. SL = social identity; N = number of agents; TO = tie outreachability; TC = tie capacity. Each case represents the comparison between offline and Facebook friendships under different conditions of TO parameters.*
the percentage of ethnically similar alters (friends) for each ego (agent). Second, I compared offline scenarios with \( n = 30 \) and Facebook scenarios with \( n = 300 \) for each case and investigated if they share the same segregated patterns confirming my hypothesis. As previously mentioned, the results would be compared to the results of the referenced study (Hofstra et al., 2017). Finally, I also measured agent satisfaction by examining the agent’s number of friends and comparing them with a threshold following Firmansyah and Pratama (2021). This hypothetical satisfaction is analogous to the fact that most, if not all, people require friends to meet their social needs (Hojjat & Moyer, 2017). In this study, agents would be satisfied should they have friends at least half (satisfaction threshold = .50) of their tie capacity and be not satisfied, otherwise. As a comparison, I also used other thresholds (i.e., .25 and .75) to evaluate agents’ satisfaction. While providing additional feedback to the system, these figures might help explain ways in which Facebook has intervened in users’ friendships.

**Results**

**Generated Agent Populations**

The proportions of ethnic majority and minority groups in all agent populations are depicted in Figure 4. On average, the ethnic majority group made up 78.02% of the population. This number is close to the ethnic majority percentage in the referenced study, which was 78.40%. As previously stated, I incorporated only one ethnic minority group for parsimony reasons. It is worth noting that the difference between the majority–minority group patterns in the offline (Figure 4-left) and Facebook (Figure 4-right) environments was due to the randomization process and different \( N \) values (i.e., \( n = 30 \) for offline and \( n = 300 \) for Facebook), despite the fact that both were derived from the same distribution (i.e., Bernoulli) and shared a common parameter (i.e., \( p = .22 \)). I will discuss how this could potentially bias the results and how I address this possibility.

Figure 5 illustrates the agents’ tie outreachability and tie capacity generated throughout the simulations. As can be seen, their variability is similar across scenarios and cases in which their parameters were held constant. For instance, the proportions of agents with \( TO = 1 \) are relatively the
Figure 4. Generated agents’ social identity in all simulations. Note. The proportions of the ethnic majority (78.02%) and minority (21.98%) are relatively the same in all simulation scenarios.

Figure 5. Generated agents’ latent variables in all simulations. Note. The proportion of agents with tie outreachability (TO) ∈ {0, 1} are relatively equal across scenarios in the same case (horizontal comparison). The proportion of agents with tie capacity (TC) ∈ {3, 30} are relatively the same across cases with the same scenario (vertical comparison).
same across scenarios in the same case (horizontal comparisons), whereas the proportion of agents with $TC \in \{3, 30\}$ are relatively the same across cases with the same scenario (vertical comparisons).

**Developed Friendships**

Figure 6 visualizes a randomly chosen developed friendship network for each scenario and case. It should be noted that these networks are visualized using the Fruchterman–Reingold algorithm with the help of the igraph package (Csardi & Nepusz, 2006), not in FIRMAN’s social identity space. Hence, the nodes’ position and the length of ties connecting them in the network do not represent FIRMAN’s social identity distance nor length of ties. At first glance, the developed social networks do appear to exhibit segregated friendship along ethnic lines, with the strongest group segregation occurring in Facebook scenarios where $TO, q = .2$.

Furthermore, the number of developed dyadic friendships in all simulations is depicted in Figure 7. As illustrated, the majority of friendships are formed between nodes of the same ethnicity. In contrast, heterogeneous dyads accounted for a relatively small proportion of total friendships, with the proportion increasing as the tie outreachability (TO) parameter values increased (vertical comparison). Marginal means of heterogeneous friendship dyads for $TO, q \in \{.2, .5, .8\}$ are 2.03%, 10.75%, 23.47% of the total dyads, respectively. Meanwhile, the proportions of homogeneous friendships remain relatively constant across tie capacity (TC) parameters, despite the fact that the average number of total dyads increases dramatically from marginal means = 44 dyads for $TC, \mu = 3$ (offline scenario) to marginal means = 4,479 dyads for $TC, \mu = 30$ (Facebook scenario).

Figure 8 presents the percentage of alters (friends) who share the same ethnicity with the egos. As can be seen, both majority and minority members tend to befriend other agents of the same ethnicity across scenarios.
Figure 7. The number of developed dyadic friendships in all simulations. Note. Increasing the tie capacity (TC) parameter and population size (n), while holding the tie outreachability (TO) parameter constant does not lead to more heterogeneous friendship formations.

Figure 8. The percentage of ego-alter similarity in all simulations. Note. The percentage of ego-alter similarity in Facebook scenarios (right column) seem to mirror in offline friendship scenarios (left column).
group. These numbers even exceeded the expected percentage of ego-alter similarities caused solely by random chance given the proportions of the majority and minority in the population, which are 78.02% for the majority and 21.98% for the minority. Moreover, it is interesting to note that simulations in the offline scenario have more variability compared to the simulation in the Facebook scenario. This difference is due in part to the fact that the majority–minority group compositions in the offline scenario are not always constant throughout the simulation. Thus, in addition to the TO parameters, such results are contingent on the presence of individuals from the same or different groups. To account for this bias, I compared the mean values of all trials rather than the values from individual trials for each scenario.

As mentioned earlier, I compared and contrasted the results with the findings of the referenced study investigating the same phenomenon. I only did this for the overall groups combined since in this study I only have one minority, whereas in the referenced study, there were five groups of minorities. In the referenced study (Hofstra et al., 2017), on average individuals had 76.218% ethnically similar alters for offline scenario (friends in general in their term) and 75.974% ethnically similar alters for Facebook scenario (Facebook friends without kinship in their term). As can be seen in Table 3, the third case has the most similar results with the referenced study.

To determine whether Facebook friendships replicate offline friendships, I divide the percentage of ego-alter similarities in the Facebook scenario by the percentage of ego-alter similarities in the offline scenario. I also did the same for the findings in the reference study. Table 4 presents the results.

As can be seen, the ratios are almost identical in all cases. Only when the TO, \( q = .2 \), the ratios show different directions. In this respect, the proportions of ego-alter similarities are higher in the Facebook scenario than they are in the offline scenario.

### Agent Satisfaction

In Figure 9, the percentage of satisfied agents with a satisfaction threshold of .50 across all simulations is depicted. As can be seen, only in the offline friendship scenarios did the simulations make some agents

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**Table 3.** Mean Percentage of Developed Offline and Facebook friendships in all Simulations.

| Case | Scenario | Parameters | Mean (SD) Percent |
|------|----------|------------|-------------------|
| 1    | Offline  | \( q = .2 \) \( \mu = 3, \sigma^2 = .25 \) | 97.784 (7.073) |
|      | Facebook | \( q = .2 \) \( \mu = 30, \sigma^2 = .25 \) | 98.185 (.959) |
| 2    | Offline  | \( q = .5 \) \( \mu = 3, \sigma^2 = .25 \) | 89.628 (7.853) |
|      | Facebook | \( q = .5 \) \( \mu = 30, \sigma^2 = .25 \) | 89.044 (1.020) |
| 3    | Offline  | \( q = .8 \) \( \mu = 3, \sigma^2 = .25 \) | 77.799 (5.575) |
|      | Facebook | \( q = .8 \) \( \mu = 30, \sigma^2 = .25 \) | 75.981 (.651) |

**Table 4.** The Ratio of Facebook and Offline Friendships.

| Case | Parameter | Facebook-Offline Friendships Ratio |
|------|-----------|-----------------------------------|
|      | TO        | Simulation | Hofstra et al., 2017 | \( \Delta \) |
| 1    | \( q = .2 \) | 1.004      | .997                 | -.007          |
| 2    | \( q = .5 \) | .993       | .997                 | .004           |
| 3    | \( q = .8 \) | .977       | .997                 | .020           |

*Note.* \( \Delta = \) Facebook-offline friendship ratio in the referenced study - Facebook-offline friendship ratio in the simulation.
dissatisfied. In contrast, in the Facebook friendship scenarios, the simulations made all agents have friends at least half of their tie capacity (TC) and thus satisfied. As previously stated, I also compared agent satisfaction to other thresholds (i.e., .25 and .75). The noticeable differences appear in the offline scenario, as shown in Figures 10 and 11 in the Supplementary Materials. In this regard, the higher the threshold, the greater the number of agents who are dissatisfied. On the contrary, the differences between thresholds are less visible in the Facebook scenario, where almost all agents are satisfied.

**Discussion**

The results have confirmed my hypothesis that the patterns of Facebook friendship mirror the patterns of offline friendship, which are segregated along the ethnic lines. These findings corroborate previous empirical field study on the same subject (Hofstra et al., 2017; Wimmer & Lewis, 2010). While past research highlighting various antecedents including preference (Ilmarinen et al., 2016; Yu & Xie, 2017), living location (Mouw & Entwisle, 2006), demographic composition (Joyner & Kao, 2000), and foci structures (Feld, 1981), my study brings a different perspective explaining it through a basic individual level mechanism built on a formal framework, FIRMAN (Firmansyah & Pratama, 2021). In this respect, Facebook has increased users’ tie capacity (TC) but has done little with users’ tie outreachability (TO). Hence, the users, regardless of their level of tie outreachability, can keep in touch with a greater number of friends online. However, as mentioned earlier, those who are intolerant and racist offline remain intolerant and racist on Facebook (Chaudhry & Gruzd, 2020; Matamoros-Fernández, 2017), and thus cannot reach out to different others albeit they are on the very same platform.

Furthermore, my simulations demonstrate that even when the proportion of agents who are tolerant and thus capable of generating ties up to one length (LT = 1) is greater than 70% as depicted in Case 3, the percentages of homogeneous friendships remain higher than the percentages of heterogeneous friendships. In other words, both ethnic majority and minority members continue to
gravitate toward similar others despite the fact that they neither despise nor prefer to affiliate with different others (actually I do not model individual preference in this simulation). This finding is consistent with Firmansyah and Pratama’s argument (2021) that homogeneous networks are an inescapable social fact, even in a highly diverse and tolerant environment. This is because intolerant agents (TO = 0) can only befriend others of the same group. Even though few in number, intolerant agents can prevent tolerant agents (TO = 1) of the same group from developing heterogeneous friendships by reducing their tie capacity (TC). As a result, tolerant agents who befriend intolerant agents of the same group, are less capable of reciprocating, let alone initiating new friendships with individuals of different groups. While I did not incorporate TO greater than one nor did I use continuous values, the findings of Firmansyah and Pratama (2021) may provide additional insight. In this regard, the results may follow similar patterns, with a large percentage of friendships developing between agents who are similar, regardless of their level of tolerance. To substantiate this assertion, additional simulations using arguably more complicated models are required.

Indeed, it is attempting then to point finger at the users, who cannot generate a longer tie to connect with ethnically different others on Facebook in the first place. However, if Facebook can empower users’ tie capacity, why does it not, at least, try to enhance user tie outreachability as well? To my knowledge, Facebook has a history of rectifying unintended consequences of its products following the occurrence of terrible incidents that garner public attention (Fink, 2018; Vukčević, 2021). Should Facebook take the proactive step of empowering users’ tie outreachability, the number of heterogeneous friendships will increase as shown in my simulations (comparison across cases). Even if heterogeneous friendships do not outnumber homogenous friendships, the percentage of users exposed to diverse perspectives by connecting with different others on the platform will still increase.

Additionally, Facebook appears to be more concerned with pleasing their users. As the findings show, almost all agents in the Facebook simulation scenario (TC = 30, n = 300) have been satisfied with their numbers of friends. Meanwhile, in the offline scenario (TC = 3, n = 30), some agents, even though they only made up less than 20% of the total population, have not been satisfied. In this regard, Facebook has helped users to deal with the constraints caused by the systems (e.g., limited tie capacity and dispersed geographical location) such as making agents of the same groups available as potential friends (either by empowering their tie capacity or increasing potential friend pool size). This argument can also explain why many users seem content with the status quo. They will be satisfied and happy as long as they can befriend other users and keep in touch with them on the platform. The fact that segregated friendships can alienate the benefits of diversity (Lee et al., 2012; Pachucki & Leal, 2020) and exacerbate the disadvantages of homogeneity (Karimi et al., 2018; Pariser, 2011) does not appear to bother the majority of them.

Finally, the simulations suggest what needs to be done to remedy the unintended consequence of the platform design, which retains friendship segregation instead of bringing diverse people closer together. As previously mentioned, Facebook must increase users’ tie outreachability in the same way it increases users’ tie capacity by improving their tolerance and acceptance of differences. Encouraging users to do fact checking (Miškolci et al., 2018) and banning users who perpetuate conflicts (Vukčević, 2021) are not the only way to do so. In fact, Facebook with its resources, among other things, can develop friendship algorithms that favor diverse friendship formation such as suggesting tolerant users to befriend different others instead of suggesting them to befriend those of similar interests or having mutual friends (who usually happen to be of the same ethnicity). This way, I believe, will expose intolerant users who happen to befriend tolerant users, toward a more diverse perspective, just like the notion of how extended intergroup friendship reduces prejudice (Yucel & Psaltis, 2020; Žeželj et al., 2017). Of course, this intervention, albeit aiming for a greater good, needs to be run ethically, for instance by asking for users’ consent in advance.
Study Limitations and Directions for Future Research

This study has explained the extended segregated friendship phenomenon on Facebook that is otherwise complex in a parsimonious way through a series of agent-based simulations. With this strength, there are some limitations we need to consider. First, I have not yet taken into account the strength of the relationships on Facebook. I treat them as if they were similar. As past studies show (McMillan, 2022), there might be a different proportion of group homogeneity between strong ties (i.e., close friends) and weak ties (i.e., acquaintance). Second, in my simulations I have yet to include algorithms that possibly used by Facebook in intervening friendship formation such as friend suggestions based on mutual friends, similar interests, and same geographical locations. Employing this algorithm may yield even higher homogeneous friendship formations. Indeed, the algorithm may aid in the formation of heterogeneous friendship formations if the compositions of individuals with similar interests and living in similar geographical locations are diverse in the first place. Third, in this study, I only focus on one social identity (i.e., ethnicity) at a time. While the findings might be generalizable, they do not necessarily hold for friendship development involving more than one dimension at a time. In other words, friendship development on Facebook involving multiple social identities might have different patterns. Thus, I suggest that future research consider these limitations when designing future simulation studies on friendship formation on Facebook.

Conclusion

Facebook’s mission “brings the world closer together” as a social networking site platform seems to be a failure. Friendships on Facebook have been as segregated as offline friendships. My study demonstrates that this is because Facebook primarily increases users’ capacity to befriend more people, while doing little to improve users’ ability to befriend diverse others. Facebook must focus on the latter should Facebook truly wish to contribute to the development of a more inclusive society. While in this study, I focus on ethnically segregated friendships on Facebook, I argue that the same explanation might also hold for other social identities such as race and ideology. However, the friendship development patterns might not be necessarily similar should those social identities be examined together at the same time. I leave this assertion for future research.

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Supplemental Material

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