The social network: How people infer relationships from mutual connections

Claudia G. Sehl, Ori Friedman, & Stephanie Denison

University of Waterloo

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Abstract

People infer that individuals are socially related if they have overlapping preferences, beliefs, and choices. Here we examined whether people also infer relationships by attending to social network information. In five preregistered experiments, participants were shown the social networks of two target people and their friends or acquaintances within a group, and judged if the targets were socially related to one another. In the first three experiments, adults (total N = 528) were more likely to judge that individuals were friends when a high rather than low proportion of their friendships were mutual. Adults also considered other factors when inferring friendships, such as the number of friends each individual had. In the final two experiments, 5-7-year-olds (total N = 135) were also sensitive to the proportion of mutual relationships. Together, our work suggests that people use proportional information and statistical inferences when assessing whether individuals are socially related.

Keywords: social inferences, inferring relationship, proportional information, social cognition, cognitive development

The social network: How people infer relationships from mutual connections

It is not always obvious whether people are socially related or are unacquainted. For example, suppose you join a new volunteer organization and want to know whether two fellow volunteers, Alice and Bob, are friends with one another. This might be easy to discern if you see them interact with one another, or if you hear other volunteers talk about them. But are there any ways to infer whether they are friends even without such information?

One way to infer whether Alice and Bob are friends is by considering if they are similar. People prefer being friends with those who have the same preferences (Vélez et al., 2019) and beliefs (Heiphetz et al., 2014), and make similar choices (Kandel, 1978; McPherson et al., 2001), and so they infer that individuals with these things in common are friends (Afshordi, 2019; Roberts et al., 2017) or are members of the same group (e.g., Gershman et al., 2017; Gershman & Cikara, 2020; Lau et al., 2018; 2020). Even children infer friendships using these cues (e.g., Liberman & Shaw, 2017; Martin et al., 1999; Roberts et al., 2017; Shutts et al., 2013). For instance, both children and adults in one study were more likely to infer that individuals were friends if they were related in meaningful ways (e.g., excelling at singing) rather than arbitrary ways (e.g., passing by each other on the street; Afshordi, 2019; see also Neal et al., 2014).

Another way to infer whether Alice and Bob are friends is to consider their other friends in the volunteer group. A body of research investigated people's ability to learn relations in social networks in paired-associate learning paradigms (e.g., DeSoto & Bosley, 1962; Flynn et al., 2006; Janicik & Larrick, 2005; Zitek & Tiedens, 2012; for a review, see Brands, 2013). In these experiments, participants learned about pairs of relationships, like *Jim likes Ray* and *Ray likes Stan*, and their memory for the relationships was subsequently tested. Although participants were never told whether Jim liked Stan, they later misremembered having learned this, thus completing the triad (Freeman, 1992; see also DeSoto, 1960). These responses were errors because participants were attempting to faithfully remember social relations. Nonetheless, these errors show that people infer that individuals are friends when they have a friend in common (for related findings with children, see Markovits & Dumas, 1999).

Here we examine whether people also infer social relationships by considering information about *multiple* mutual connections. For example, friendship between Alice and Bob might seem more likely if it turns out they have seven friends in common rather than just one. Inferences of social relationships may depend on numerical information about the number or proportion of connections that are mutual. If so, this would suggest people infer relationships not only from domain-specific cues (e.g., shared preferences), but also using domain-general numerical knowledge and statistical inferences. This possibility is broadly consistent with recent work showing that attention to proportional and statistical information underlies many social judgments, including inferences about preferences (e.g., Kushnir et al., 2010; Heck et al., 2021), group membership (e.g., Gershman et al., 2017; Gershman & Cikara, 2020), and emotions (e.g., Doan et al., 2020; Asaba et al., 2019).

But, how do people determine whether the number of mutual friends is sufficiently high to imply that two individuals are friends with each other? One possibility is that people begin by estimating the number of mutual friends the individuals would be expected to have by chance alone. If the individuals have more mutual friends than expected by chance, then people might infer they are likely to be friends. Conversely if they have fewer mutual friends than would be expected by chance, people might infer the individuals are unlikely to be friends. Mathematically, this expected value based on chance can be calculated by (Blitzstein & Hwang, 2015):

$$E[mutual\ friends] = \frac{(number\ of\ friends\ Alice\ has)(number\ of\ friends\ Bob\ has)}{total\ number\ of\ people}$$

To illustrate, imagine that the volunteer group has 24 members. Alice and Bob each have 6 friends in the group. Applying the formula, we should expect Alice and Bob have 1.5 mutual friends *by chance*. So, if we learned they actually have 5 mutual friends, we might reject this assumption of chance and conclude that more could be going on. For example, we might feel this number of mutual friends is a suspicious coincidence (Griffiths & Tenenbaum, 2007): There are many more mutual friends than expected by chance, so perhaps relationships in this network are not random. Instead, the network could include cliques, and Alice and Bob might be part of the same clique. Alternatively, if we learned that they have 1 or 2 mutual friends, we would have little reason to assume they are part of a structured network, or at least little reason to think they are related in such a network.

Of course, most people are unlikely to know the formula for determining the number of mutual friends we should expect by chance. So even if people do infer friendships by considering the number of mutual friends expected by chance, they might do so in ways that diverge from the formula. For example, people might be insensitive to the impact that the total number of people in the group should have on estimations—they might not realize that as the total number of people increases, fewer mutual friendships should be expected by chance. Likewise, they could be insensitive to the number of individual friendships that each person has, not realizing that as this increases, the number of mutual friendships expected by chance increases. Such departures from normative calculations should be expected given that people often neglect relevant numerical information in complex problems. For example, similar departures from normative reasoning characterize base-rate neglect (Bar-Hillel, 1980; Tversky & Kahneman, 1974), as when people make judgments by considering numerical information about the accuracy of medical test, while ignoring the prevalence of the disease in the larger population (e.g., Eddy, 1982; Hammerton, 1973).

We examined how children and adults use social network information to infer relationships. Our first experiments examined adults. Participants saw diagrams of two target people and who they were friends with in a group (for a sample see Figure 1). Participants then judged whether the targets were friends with each other. Across experiments, we manipulated factors corresponding with elements of the formula.

The final two experiments examined children. We expected they might use social network information to infer relationships because children are sensitive to many other cues indicating relationships (e.g., Liberman & Shaw, 2019; for a review, see Afshordi & Liberman, 2021) and because young children are sensitive to proportional and statistical information (e.g., Diesendruck et al., 2015; Heck et al., 2021; Kushnir et al., 2010; Vélez & Gweon, 2020)[1]. Rather than asking about friendships, though, children were told which people in the group knew each target, and were then asked whether the targets knew one another. We avoided asking about friendships because we worried that children would show a "yes" bias when asked yes/no questions about friendships as many schools encourage referring to all classmates as friends.

[1] We did not test children younger than age 5 because we thought they would struggle to understand the diagrams used to convey social relations. However, younger children might infer relations from mutual connections if these were presented in a different way, since infants and toddlers make statistical social inferences (Kushnir et al., 2010; Ma & Xu, 2011; Vélez & Gweon, 2020; Diesendruck et al., 2015; Wu & Gweon, 2021).

Our first experiment examined if adults are more likely to expect targets to be friends if they have more mutual friendships rather than fewer. This experiment also tests whether adults are sensitive to the total number of people in the group. According to the formula, as group size increases, fewer mutual friends are expected by chance. Hence, if group size is large rather than small, participants may be more surprised to see many mutual friends, and they may therefore infer the targets are friends with one another.

Experiment 1

Data and materials for all experiments are available online on the Open Science Framework: https://osf.io/25p6a/. All experiments were preregistered. The preregistration for Experiment 1 is available at https://aspredicted.org/DQ4_M72.

Method

Participants. We tested 176 participants (M_{age} = 37.50, range = 19-71, 75 female, 99 male, 2 other/unspecified). Data were excluded from an additional 17 participants who failed at least one of the three post-test comprehension checks or neglected to answer on one or more trials. An additional 7 participants were excluded for failing at least one of the pre-test comprehension checks[2]. Participants in all experiments were recruited from Cloud Research (Litman et al., 2017). They were located throughout the United States and had a HIT rate above 95%.

Materials and Procedure. Participants saw diagrams of two people and their friendships with others in a group (see Figure 1a; faces were generated from "Avatar maker", n.d.). Participants first saw instructions explaining the diagrams. Then, they completed two comprehension questions about the number of friendships each target had in a sample diagram. If they did not pass both pre-test comprehension trials, they repeated the instructions and pre-test trials again, for a maximum of two repeats.

Participants then completed six test trials (order randomized across participants) which each represented one cell in a 3x2 design manipulating: 1) whether the targets had one, three, or five mutual friends (out of a total of 6 friendships per target); 2) whether the overall number of non-targets was low (12) or high (24). In each trial, participants judged how likely it is that the two targets were friends, on a 7-point Likert scale from extremely unlikely to extremely likely.

After completing the six trials, participants completed three more comprehension questions. The first was a four-option multiple choice question about what judgments were made in the task (i.e., likelihood of friendships, enemies, same family, similar looking). The other two emulated the pre-test trials, where participants indicated the number of friends that targets had in a sample diagram. Finally, participants were asked about their age and gender.

Results

In all experiments on adults, responses were coded from -3 (extremely unlikely) to 3 (extremely likely), with 0 (neither likely nor unlikely) as the mid-point. Data were analyzed using a linear generalized estimating equation (GEE) model, with within-subjects factors (number of people overall and number of mutual friends) as predictors.

There was a main effect of mutual friends, Wald χ^2 (2) = 1101.63, $p < .001$, as participants rated the likelihood of friendship higher when there were more mutual friends displayed. (Figure 1b) There was also a main effect of overall number of people, Wald χ^2 (1) = 6.97, $p = .008$, as participants rated the likelihood of friendship higher in trials with few people

[2] We accidentally overlooked this exclusion criterion when pre-registering this experiment. The pattern of results does not change if these seven participants are included.

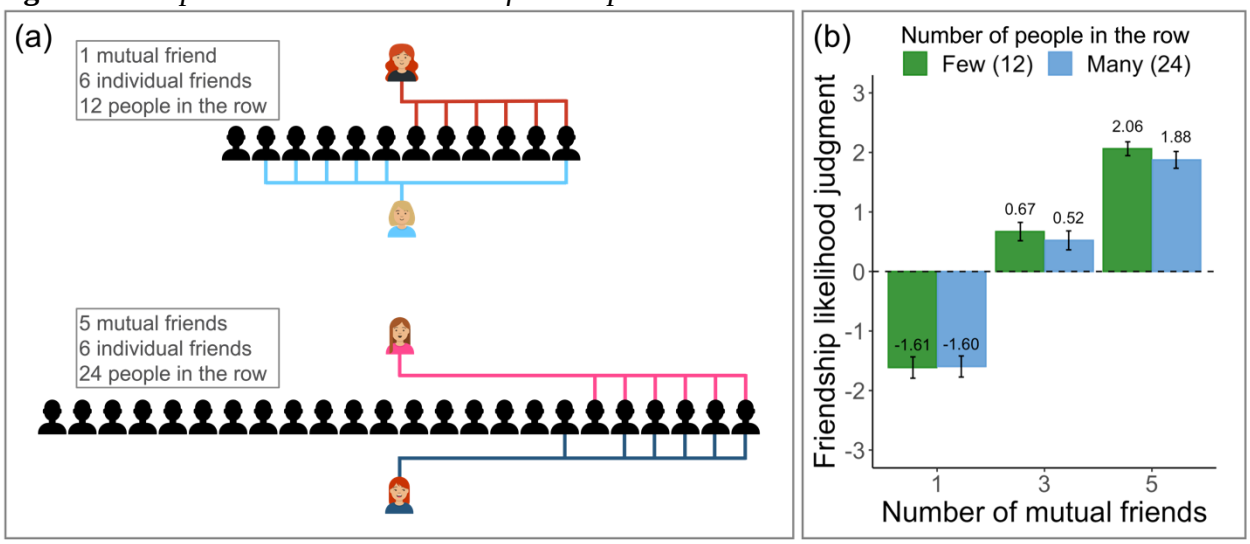
than trials with many people. There was no significant interaction between these factors, Wald χ^2 (2) = 4.87, p = .088. Pairwise comparisons of mutual friends using a Bonferroni correction revealed that friendship ratings were greater when the targets had 5 mutual friends than 3 or 1 mutual friends, ps < .001, and also greater when they had 3 mutual friends than just 1, p < .001.

Discussion

Participants judged that targets were more likely to be friends when they had more mutual friends. They also thought targets were more likely to be friends when there were fewer people in the group, but this effect was negligibly small. These findings could also be explained by participants' domain-specific knowledge about friendships and populations. In the General Discussion, we consider the extent to which judgments in our experiments were based on domain-general versus domain-specific reasoning.

However, besides considering these factors, participants may have also considered the total number of friendships each individual had. In this experiment, each target had a total of 6 friends. But perhaps their judgments would change if this number differed. For example, having 5 friends in common might seem like a suspicious coincidence when individuals have 6 friends each. But it is less noteworthy if they have 10 friends each, and so it is perhaps a weaker sign that the individuals are friends with one another. In the next experiment, we examined whether the number of friends influenced participants' friendship judgments. Specifically, we had participants again consider target individuals with varying numbers of mutual friends (1, 3, or 5). We also manipulated the overall number of friends each target had (6 or 10). However, this time the number of people in the row was held constant at 24 people.

Figure 1. *Sample materials and results from Experiment 1.*



Note. [a] Sample network diagrams, where lines between people indicate they are friends. In all experiments, people with two lines connected to them (i.e., friends with both targets, a mutual friend) were always displayed on the rightmost side of the row. People that had one line connected to them (i.e., friends with one target but not the other) were displayed in the middle. People with no lines connected to them (i.e., were not friends with either target) were always displayed on the leftmost side of the row. [b] Results from Experiments 1. In all graphs, error bars show ±1 standard error. Values represent average results per condition.

Experiment 2

The preregistration is available at https://aspredicted.org/HSS_81P.

Method

Participants. We tested 172 people (M_{age} = 36.89, range = 22-65, 71 female, 100 male, 1 other). Data were excluded from an additional 27 participants who failed to answer on one or more trials, or failed at least one of the post-test comprehension checks. Participants were also excluded if they did not pass both pre-test comprehension trials on at least one of their three attempts[3].

Materials and Procedure. Participants saw identical instructions and pre-test comprehension trials from Experiment 1. Participants completed six randomized test trials which each represented one cell in a 3x2 design manipulating: 1) whether the targets had one, three, or five mutual friends; 2) whether the total number of friends each target had was low (6) or high (10). The number of overall people in the group was held constant at 24 people for all trials (Figure 2a). Participants made their judgments on the same scale as in Experiment 1, and completed the same three comprehension questions.

Results

There was a main effect of mutual friends, Wald χ^2 (2) = 811.15, $p < .001$, as participants rated the likelihood of friendship higher when there were more mutual friends displayed (see Figure 2b). There was also a main effect of number of friends per target, Wald χ^2 (1) = 8.30, p = .004, as participants rated the likelihood of friendship higher in trials with few (6) friends per target than many (10) friends per target. There was a significant interaction effect between these factors, Wald χ^2 (2) = 167.62, $p < .001$. When targets had 5 mutual friends, participants judged the targets were more likely to be friends when they had 6 friends each rather than 10 ($p < .001$). However they showed the opposite pattern when targets had 3 mutual friends ($p < .001$). When targets had only 1 mutual friend, judgments did not differ based on whether targets had few (6) or many (10) friends ($p = .233$).

Discussion

Consistent with findings from the previous experiment, participants inferred that individuals were more likely to be friends when they had more mutual friends. Participants also considered how many friends each individual had, but this factor interacted with the number of mutual friends. This interaction provides mixed support for the idea that people use total number of friends to detect suspicious coincidences. This account was supported by findings when there were five mutual friends—people thought it more likely that targets were friends if 5 of 6 of their friendships were mutual (a suspicious coincidence) than if 5 of 10 of their friendships were mutual (not so suspicious). However, the account was not supported with 3 mutual friends and 1 mutual friend. With 3 mutual friends, for instance, ratings were actually higher when the individuals each had 10 friendships rather than 6.

This interaction might result from participants using a combination of strategies. For example, they might conclude that individuals are likely to be friends if a high *proportion* of their total friendships are mutual—for example, 5 mutual friendships out of 6 might be deemed a suspicious coincidence. And they might likewise conclude that individuals are unlikely to be friends if a low proportion of their total friends are mutual (1 mutual friendship out of 6 or 10).

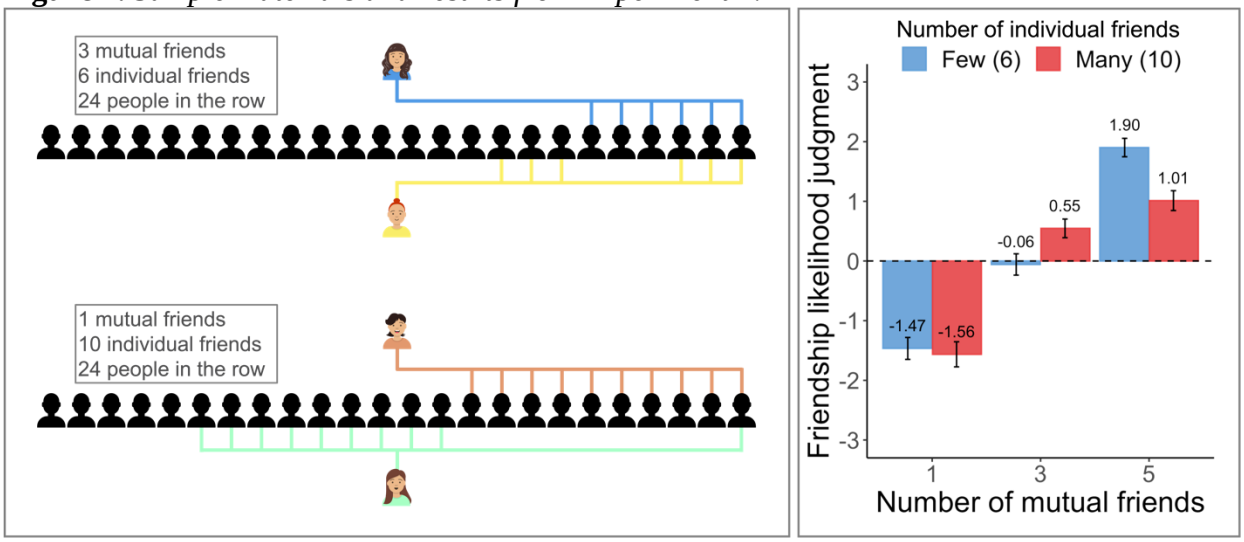
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[3] A technical error occurred, where some participants were prompted to complete the pre-test comprehension checks a third time, despite having correctly responded on their second attempt. These ten participants were retained in our final sample, as they provided at least one correct response on pre-test comprehension checks and met all the other exclusion criteria.

But in the absence of decisive proportional information, participants might assume that individuals are more likely to be friends with one another if they each have many friends rather than fewer.

In the next experiment, we tested the basic claims of this explanation. Specifically, we examined if people are more likely to infer that individuals are friends if (A) a high proportion of their friendships are mutual, and (B) they each have more friends than fewer. To investigate this, we showed participants scenarios about target individuals who had few (6) or many (12) friends. This time, the proportion of mutual friends was manipulated across three conditions with varying ratios of mutual friends to the total number of friends per target: low (1:6), half (1:2), and high proportion (5:6). For example, at the half level, target individuals either had 6 friends each with 3 friends in common, or they had 12 friends each with 6 friends in common.

Figure 2. *Sample materials and results from Experiment 2.*



Experiment 3

The preregistration is available at https://aspredicted.org/LGF_B6D.

Method

Participants. We tested 180 people (M_{age} = 39.66, range = 20-79, 68 female, 112 male). Data were excluded from an additional 22 participants who failed to answer on one or more trials, or failed at least one of the pre-test or post-test comprehension checks.

Materials and Procedure. Participants saw identical instructions and pre-test comprehension trials from Experiment 1. Participants completed six randomized test trials which each represented one cell in a 3x2 design manipulating: 1) proportion of mutual friends, 1:6, 1:2, or 5:6; 2) the total number of friends each target had, 6 or 12 [4]. The number of overall people was held constant at 24 people for all trials (Figure 3a). Participants made their judgments on the same scale as in the previous experiments, and completed the same three comprehension questions.

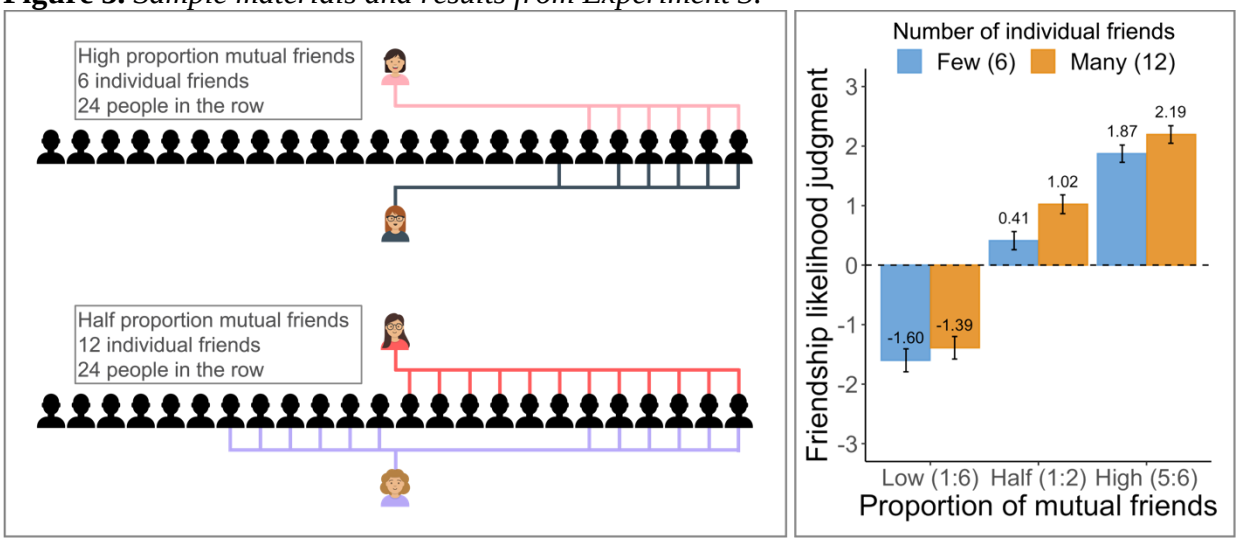
Results

[4] There is a typo in the preregistration. It misdescribed the number of mutual friends in the condition where targets had 12 friends each.

There was a main effect of proportion of mutual friends, Wald χ^2 (2) = 1219.26, $p < .001$, as participants rated the likelihood of friendship higher when there were more mutual friends displayed (Figure 3b). There was also a main effect of number of friends per target, Wald χ^2 (1) = 56.11, $p < .001$, as participants rated the likelihood of friendship higher in trials with many (12) friends per target than few (6) friends per target. There was a significant interaction between these factors, Wald χ^2 (2) = 14.72, $p < .001$. At each level of proportion, participants judged friendships as more likely when targets had 12 friends each rather than 6 (low, $M_{difference} = 0.21$, $SE = 0.09$, $p = .024$; half, $M_{difference} = 0.61$, $SE = 0.08$, $p < .001$; high, $M_{difference} = 0.32$, $SE = 0.06$, $p < .001$). However, the effect of number of friends per target was larger in half proportion trials than in both low ($p < .001$) and high proportion trials ($p = .002$), but there was no difference between low and high proportion trials ($p = .312$).[5]

As specified in our pre-registration, we conducted pairwise comparisons using a Bonferroni correction to directly test whether the number of mutual friends or the proportion of mutual friends is used in these friendship judgments. We directly compared two trials: 5 mutual friends out of 6 and 6 mutual friends out of 12. This comparison is informative because 6 mutual friends is more than 5 mutual friends, but 5:6 is a greater proportion of mutual friends than 6:12. Results revealed that participants rated friendship as more likely in the 5:6 trial than 6:12 trial, $p < .001$.

Figure 3. *Sample materials and results from Experiment 3.*



Discussion

Participants again rated friendship as more likely when individuals had a greater number of mutual friends. They also considered the proportion of mutual friends (relative to each individual's total number of friendships). Participants rated friendships as more likely when 5 of 6 friendships were mutual (i.e., higher proportion, lower number) than when 6 of 12 friendships were mutual (lower proportion, higher number). Friendships were also rated as more likely when the targets had more friends rather than fewer. These results could also speak to findings in Experiment 2. As in that experiment, the findings suggest that when strong proportional information is lacking, people make greater use of information about the total number of friends

[5] We analyzed data in all experiments using SPSS, but we used R to further analyze this interaction.

they have. Specifically, they are more likely to conclude that individuals are friends with one another if they have many friends rather than fewer.

In the next two experiments, we examined if children make similar inferences. Specifically, we asked if children use network information to infer whether people know one another. As a first step, we looked at whether children judge that targets know one another if they know many people in common rather than few (i.e., similar to what adults did in the experiments so far).

Experiment 4

The preregistration is available at https://aspredicted.org/VG1_B1D.

Methods

Participants. We tested 60 five- to seven-year-olds (M_{age} = 6;6 [years;months], range = 5;1-7;11, 31 female, 29 male); twenty children per age (in years). One additional five-year-old was excluded for failing a comprehension trial. In both child experiments, children were tested individually online in a live video call, in the presence of their parent or guardian. Parents were instructed to look down or to turn away from the screen while testing took place.

Materials and Procedure. Children saw diagrams similar to those from the previous experiments (see Figure 4a). To familiarize them with the diagrams, they first completed two comprehension trials. These used diagrams where one target had more friends than the other, and children were asked who knew more people (see OSF for the stimuli and scripts). If they answered incorrectly, the experimenter counted the number of people each target knew, and asked again. Answering incorrectly a second time resulted in data exclusion.

Children then completed six test trials in a within-subjects design, where targets either had one, three, or five mutual acquaintances. There were two trials at each of these levels, and trial order was randomized across participants. In all trials, targets knew six people each out of a group of 12. In each trial, one target's acquaintances were shown first, then the other target's acquaintances appeared. Children judged whether the two targets knew each other (yes/no). As an exploratory measure, children were asked a follow-up question assessing their confidence after each test question ("Maybe [yes/no] or for sure [yes/no]?"). If children failed to answer, or said "I don't know", the question was repeated. If they neglected to respond again, the experimenter moved to the next trial.

Results

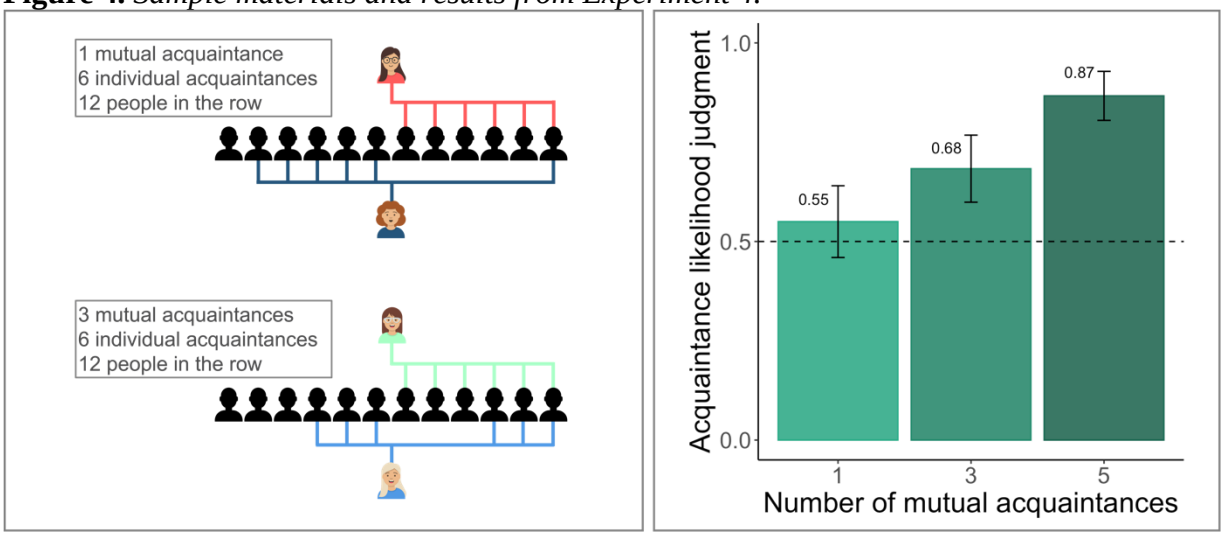
Children's yes/no responses were entered into a binary logistic GEE model (independent correlation matrices), with age in months (mean-centered) as a covariate, and number of mutual acquaintances as a within-subjects factor (Figure 4b). There was a significant main effect of condition, Wald χ^2 (2) = 23.86, $p < .001$, as children were more likely to judge that targets knew one another when they had more mutual acquaintances. There was no main effect of age, Wald χ^2 (1) = 0.88, $p = .347$, and no significant interaction between condition and age, Wald χ^2 (2) = 5.34, $p = .069$. Bonferroni-corrected pairwise comparisons revealed that children were more likely to judge the targets knew one another when they five mutual acquaintances than when they had three ($p = .003$) or one ($p < .001$). But there were no significant differences between judgments for three mutual acquaintances and just one ($p = .105$). The same pattern of results was observed in an exploratory analysis incorporating children's responses to the follow-up confidence questions (see the Supplemental Material).

Discussion

At all ages, children inferred that target individuals were more likely to know each other when they knew more people in common. Given that we found that adults consider the

proportion of friends that are mutual, we investigated if children are similarly sensitive to proportion. Hence, in the final experiment children were shown low proportion trials (3 of 9 acquaintances in common, and 4 of 10) and high proportion trials (3 of 4 and 4 of 5). If children use proportion of acquaintances, their judgments should be greater for high than low proportion trials.

Figure 4. *Sample materials and results from Experiment 4.*



Experiment 5

The preregistration is available at https://aspredicted.org/CVP_VKZ.

Methods

Participants. We tested 75 five- to seven-year-olds (M_{age} = 6;4, range = 5;0 -7;11, 37 female; 38 male); approximately equal number of children per age (in years)[6]. Two additional five-year-olds were excluded for failing a comprehension trial.

Materials and Procedure. Children completed the same comprehension trials as in the previous experiment. Children then completed four test trials in a within-subject design, where targets either had a low or high proportion of mutual acquaintances. There were two trials at each of these levels: low proportions, 3:9; 4:10; high proportions, 3:4, 4:5 (Figure 5a). Trial order was randomized across participants, and there were 16 people in the group for all trials. Children made the same judgments as in Experiment 4, including the confidence questions.

Results

Children's yes/no responses were entered into a binary logistic GEE model (independent correlation matrices), with age in months (mean-centered) as a covariate, and proportion of mutual acquaintances as a within-subjects factor (Figure 5b). There was a significant main effect of proportion, Wald χ^2 (2) = 6.59, p = .010, as children were more likely to judge that targets knew one another when they had a greater proportion of mutual acquaintances. There was no

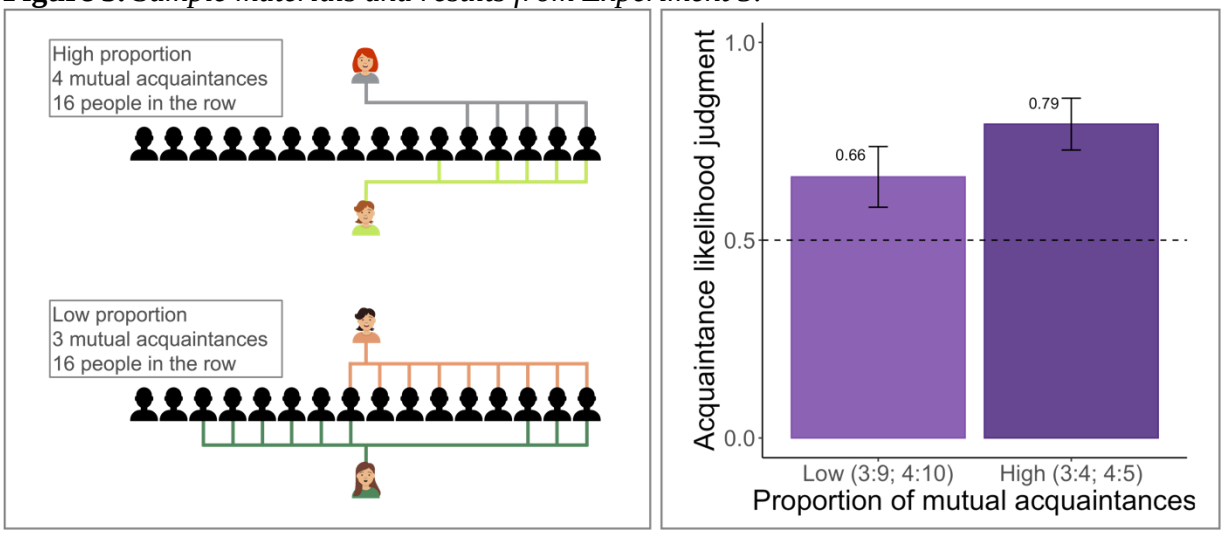
[6] In the first child experiment, we tested 20 children per age in years (N = 60). Due to slow data collection, in the next children's experiment we preregistered a smaller sample size (16 children per age; N =50). Results showed no statistically significant effect of proportion, age, or condition-by-age interaction, despite responses hinting towards greater judgments in high than low proportion trials. We investigated if the lack of a proportion effect was due to reduced sample size by reanalyzing the data with 50% more participants. This simulated data was created by randomly duplicating 25 existing responses and coding them as additional participants. Results showed a significant effect of proportion, suggesting that the lack of effect might be due to reduced power. Hence, we collected an additional 25 children, for a total of 75 participants.

main effect of age, Wald χ^2 (1) = 0.11, p = .743, and no significant interaction between condition and age, Wald χ^2 (1) = 1.38, p = .239. The same pattern of results was observed in an exploratory analysis incorporating children's responses to the follow-up confidence questions (see the Supplemental Material).

Discussion

At all ages, children inferred that target individuals were more likely to know each other when they had a greater proportion of acquaintances in common.

Figure 5. *Sample materials and results from Experiment 5.*



General Discussion

Across five experiments, we examined how people use social network information to infer relationships. In our experiments, participants were introduced to pairs of target individuals, and their friends or acquaintances. In three experiments on adults, we found they were more likely to judge that the target individuals were friends with one another when a high rather than low proportion of their friendships were mutual. Adults also considered other factors when inferring friendships. For example, they showed some sensitivity to the number of friends each target had. Then in two experiments on children, we found that they are also sensitive to proportion when inferring relationships.

This work contributes to knowledge of how people infer relationships. Some prior work shows that people infer friendships between individuals based on their similarities with one another. For example, people are more likely to judge that two individuals are friends if they have preferences in common, make similar choices, or are members of the same group (e.g., Afshordi, 2019; Gershman et al., 2017). However, this earlier work did not examine how people make inferences based on social network information. Other work did provide participants with information about relationships in a social network (e.g., Jim likes Ray) in paired associate learning tasks (e.g., Picek et al., 1975; Simpson et al. 2011; Tompson et al., 2019; Zitek & Tiedens, 2012). These studies focused on people's ability to learn new information, and not on their ability to make inferences that extend beyond the information given. The present experiments bring these two approaches together and are the first (to our knowledge) to examine how people use incomplete information about a social network to infer additional relations.

We found that both adults and children were sensitive to proportional information. Beyond thinking that relationships were more likely when individuals had many mutual connections rather than few, participants also considered the *proportion* of targets' relationships that were mutual. Adults rated friendships as more likely when individuals had a higher proportion of mutual friends, even when their absolute number of mutual friendships was comparatively low. For instance, adults rated that friendship between targets was more likely when 5 of 6 friends (83%) were mutual than when 6 of 12 friends (50%) were mutual.[7] Likewise, five- to seven-year-olds rated individuals as more likely to know each other when they had a higher proportion of mutual acquaintances, even though the number of acquaintances was constant (Experiment 5). For example, judgments were greater when 4 of 5 acquaintances were mutual (80%) than when 4 of 10 acquaintances were mutual (40%). However, the observation that adults and children responded similarly is only tentative because we did not directly compare their responses, and because we used different methods in adult and child experiments. Whereas adults were told and asked about friendships, children were told and asked about individuals knowing each other.

Our findings also suggest that adults are more likely to view targets as friends when they have more rather than fewer friendships overall. For instance, in the final experiment with adults, judgments were higher when individuals had 12 friends rather than 6. Another instance is in the second experiment, where individuals with 3 mutual friends of 6 were judged as less likely to be friends than individuals with 3 mutual friends of 10. Although there were exceptions to this pattern, it could reflect "more is more" reasoning (e.g., Stavy et al., 2002): This is the tendency to think that one increase begets another. In this case, more friends leads people to assume greater chances of the targets being friends with one another. However, there is no clear evidence that children used more-is-more reasoning. In the final experiment, children's judgments were lower when targets had 9 or 10 acquaintances than when they had 4 or 5. Instead, judgments were higher when there were fewer acquaintances, since there was a greater proportion of mutual acquaintances for these trials (low proportion: 33-40% mutual; high proportion: 75-80% mutual).

But how did adults and children reason about mutual relationships? One possibility is that these judgments depended on domain-general reasoning. In the Introduction, we suggested that people might make these judgments by detecting suspicious coincidences. On this view, when target individuals had more friends in common than would be expected by chance, participants concluded that the targets were likely to be socially related. Other domain-general accounts are possible, though. For example, participants might have a sense of how many mutual connections are expected by chance for different kinds of networks (e.g., Kemp & Tenenbaum, 2008).[8] They might have one set of expectations for truly random networks and a different set for networks that have different kinds of properties—for example, clusters of interconnected nodes between subsets of the total population (e.g., cliquey network). On this view, rather than rejecting

[7] Findings from the first two experiments are also consistent with adults considering proportion. Friendship judgments were greater when targets had fewer friends each, and also when there were fewer people in the group. However, these findings may be less conclusive as we did not control for number of mutual friends.

[8] Another domain-general account is that participants relied on the basic heuristic that things sharing many features are likely to go together and to be related. However, this account might not specifically predict that participants should focus on the *proportion* of mutual relations relative to overall number of relations. A further problem for this account is that people do not infer social relations from some kinds of similarity. For example, they do not infer affiliation from arbitrary similarities like targets happening to be at the same place at the same time, or targets both having it snow on their birthdays (Afshordi, 2019).

suspicious coincidences, what participants are doing is matching expectations based on the kind of network they think they have evidence for.[9]

However, participants could also have drawn on domain-specific knowledge about social relationships. For instance, they might have concluded that targets with many friends in common would have many opportunities to get to know one another. And they also could have believed that targets with many friends are more sociable overall (compared to targets with few friends) and therefore more likely to be socially connected with one another. Participants might also believe that targets with many mutual relationships are likely to have similar personalities and this conclusion might again favor the view that they are likely to be socially related.

One way to examine these potential influences on people's judgments would be to see which findings replicate with other kinds of networks, including non-social ones. For example, imagine that networks represented flights between cities (i.e., rather than relationships between people), and participants judged whether two target cities are likely to have a direct flight between them. If people think that cities with many mutual connections are likely to have direct flights (i.e., parallel to the present findings), this would suggest our tasks tapped into domain-general reasoning. However, if people made different inferences with flights, this might be indicative of domain-specific influences. For example, people might infer that having a direct flight between target cities is unlikely, because it would be redundant—why connect two cities if they already have many indirect connections?

Another way to examine these potential influences would be to see if people's judgments about social networks vary across different social contexts. People's understanding of vague quantifiers like "a few" and "many" sometimes depend on social context—while having 100 friends on Facebook only seems like a few, having 100 friends in real life seems like many (Moll et al., 2021; see also Pogue et al., 2012). This domain-specific knowledge could matter for the present work. For example, if two people at a vacation resort with 100 guests have 3 mutual friends, this might feel like good evidence that they are friends with one another. However, 3 mutual friends might only be weak evidence for friendship if two people instead work together at a company with 100 employees. This difference likely depends on background knowledge, such as how long it typically takes people to make friends. A related future direction would be to see if judgments vary across different social relationships. For example, judgments about friendships might differ from those about mere acquaintances. Again, although we examined both kinds of relations, this was split by age and so our findings do not indicate whether relationship-type affects judgments.

Another question is whether our findings depend on the diagrams we showed participants, and whether children and adults would respond similarly if social network information was presented in other ways. An alternative approach might be to show pairs of individuals at a time, similar to the method used in research on people's ability to memorize social networks (Brands, 2013). This way of depicting social relationship might be more ecologically valid than our approach—relationships are never displayed as lines between faces in real life. But participants would probably have difficulty tracking and remembering the interactions of numerous unfamiliar targets with others. Our diagrams were intended to reduce these memory demands.

[9] Our experiments do not address issues because we did not probe beliefs about the structures of networks. For example, participants did not judge whether networks were cliquey or random.

Beyond contributing to knowledge about how adults and children use network information to infer social relations, the present work joins other recent studies in showing that attention to proportional and statistical information underlies many social judgments. For instance, people consider the rarity of their shared preferences with others as an indicator of how meaningful the overlap is. In one study, adults preferred to interact with those who shared a rare preference with them rather than a common one, such as liking the same unpopular book (Vélez et al., 2019). People also infer that individuals' shared choices are suggestive of belonging to the same latent social group (Gershman et al., 2017; Gershman & Cikara, 2020; see also Vélez & Gweon, 2020). Similar inferences are seen in young children. For example, preschoolers use statistical information to infer preferences (Kushnir et al., 2010; Heck et al., 2021; see also Vélez & Gweon, 2020; Diesendruck et al., 2015; Ma & Xu, 2011) and emotions (Doan et al., 2020; Asaba et al., 2019; see also Doan et al., 2018; Wu & Gweon, 2021 for inferences about surprise). Together this growing body of findings suggests that unexpected outcomes gives rise to myriad social inferences across the lifespan.

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