Staying Connected & Healthy: Exploring the Impact of the COVID-19 Pandemic on Friendship Networks and Well-Being of High School Students

Chi-Shiun Tsai[0009−0005−7311−3107]

Carnegie Mellon University, Pittsburgh PA 15213, USA
chishiut@andrew.cmu.edu

Abstract. This study examines the impact of school closures during the COVID-19 pandemic on the friendship networks of high school students and their well-being. This study utilizes survey data collected from 536 high school students between October 2021 to June 2022. By using mixed-effects models, the results indicate that students reported feeling less happy during the school closures. Moreover, this study introduces several new network metrics, including Differences in Closeness and Differences in Fondness. The former between the ego and alter's perspectives is positively associated with happiness and health. In addition, the clustering coefficient at the individual level shows a positive correlation with happiness. This study highlights the significance of considering the closeness aspect of relationships and the asymmetries in perceived relationships to better understand the well-being of high school students during school closures.

Keywords: COVID-19 · Friendship networks · Cognitive social structures · Asymmetric perceptions · Well-being

1 Introduction

During disruptive events, such as public health crises, people adapt their behaviors, including reaching out to others within their networks for support. Maintaining social connections during critical times is essential for mental health and well-being. During the COVID-19 pandemic, high school students are vulnerable to the negative impacts of the pandemic on their well-being due to limited in-person social interactions. This study aims to examine how changes in high school student friendship networks during the COVID-19 pandemic, specifically in terms of asymmetric relationships, are associated with their well-being.

Adolescence is a transition period for personal growth and development, and interactions with peers play an important role in shaping adolescents' behavior and mind [2, 4]. Studies suggest that academic achievement, individual traits, and educational goals are critical to the development of friendships between adolescents [6]. Besides, the structure of social networks is correlated with health

behavior, and can also predict individual well-being states [14]. When individuals encounter disruptive events, they strengthen ties while maintaining the existing size of their social network [8, 16]. By strengthening relationships with others, individuals can get a sense of support. Indicating how tightly the egos are within the network, the clustering coefficient is considered an indicator of happiness and health status [11].

According to previous studies, people with fewer close friends experienced a higher level of loneliness during the COVID-19 pandemic [12]. High school students experienced changes in their psychological health and well-being [9, 19] However, these studies are mainly based on the objective aspect of relationships between high school students. Most studies do not consider different aspects of relationships, assuming that the relationships are symmetric. It is unclear whether different high school students would perceive the same relationships as identical. Considering cognitive social structures, the behaviors and mental well-being of the ego will be influenced by the perceived network [7, 17]. Therefore, it is critical to consider the asymmetric perceptions during the pandemic, especially during school closures when in-person interactions are limited. Several studies have explored changes in asymmetric relationships but not in the context of high school students [5, 13]. The relationships between high school students resemble those between adults in closed organizations. The high school context enables us to explore how high school students perceive relationships, which can link to the organization theory by understanding the development of network cognition during adolescence. Therefore, besides the ego perspective on the relationships with each alter, this study explores the influence of asymmetries in perceived relationships on how high school students react to abrupt changes caused by the pandemic.

2 Methods

This study uses data collected from October 2021 to June 2022. The data collection process was approved by the Institutional Review Board on Humanities and Social Science Research of Academia Sinica, which involved obtaining informed consent from all participants and their parents (AS-IRB-HS07-111081).

Data include survey responses from high school students in Taiwan during the pandemic. Schools in Taiwan were closed from May to June 2022 due to a surge in COVID-19 cases, resulting in a switch to online learning for high school students. Furthermore, data collected before and after school closure enables comparisons of changes in social networks and the impact of these changes on students' well-being.

In total, 536 high school students from 20 classes in Taiwan took part in all four waves. The study was conducted in four waves, and the time for each wave is as follows: (1) October 18 to November 30, 2021; (2) January 3 to January 21, 2022; (3) March 15 to April 15, 2022; (4) June 1 to June 15, 2022. Since the survey questions have changed between the first two waves, this study focuses

on the last three waves. Participants completed the survey at different times but within the time frame assigned for each wave.

2.1 Measurements

There was a battery of questions that took between 30 and 40 minutes to complete. To ensure the reliability and validity of the survey, participants were repeatedly asked the same questions during each wave. The measured variables are displayed in Table 1. Network variables are constructed by calculating the average of each ego's responses to the relationships with the alters in the ego's class.

To assess the impact of asymmetry in relationships and the amount of social support the ego receives, the following variables were constructed based on each participant's responses to the above-mentioned network-related questions.

- **Differences in Closeness**
  - DeltaClosenessEgo: This is calculated as the average of the difference between the ego response and the alter's response to the closeness aspect from the ego.
  - DeltaClosenessAlter: It is calculated as the average of the difference between the ego response and the alter's response to the closeness aspect from the alter.
- **Differences in Fondness**
  - DeltaFondnessEgo: It is calculated as the average of the difference between the ego response and the alter's response to the fondness aspect from the ego.
  - DeltaFondnessAlter: This is calculated the average of the difference between the ego's response and the alter's response to the fondness aspect from the alter.
- **Clustering coefficient at the individual level**: Each edge of the friendship network is constructed if both the ego's response and the corresponding alter's response are equal to 1. The clustering coefficient for each ego is defined as the fraction of possible triangles through that ego that exists [10].

2.2 Models

Taking into account the hierarchical structure, with students nested within classes, of the data, mixed-effects models were built for each of the outcomes of well-being: happiness and health. All models include a random intercept for each student and a random slope for the effect of the wave within each school (class), assuming that the effect of waves on the outcome variable is different across classes, but the effect of other independent variables (such as gender, family household income, living status, etc.) is the same for all participants.

For each outcome variable, there are six models:

1. **Model I**: A baseline model without controlling for other variables.

Table 1. Measured variables

Variable	Description
Demographic characteristics	gender (male/female/other) and age
Socioeconomic status	parents' education, marital status, family household income level, and living status.
Well-being	
Happiness	Measured on a 4-point Likert scale ranging from "very unhappy" to "very happy."
Health	Measured on a 5-point Likert scale from "very unhealthy" to "very healthy."
Friendship network	
Closeness	
ClosenessEgo	"I am close to classmate 'A'.": The ego is the "sender" and the "perceiver" while the alter is the "receiver." This is measured on a 3-point Likert scale from "not at all" to "very close."
ClosenessAlter	"From my perspective, I feel that classmate 'A' is close to me.": The ego is the "receiver" and the "perceiver." The alter is the "sender." This is measured on a 3-point Likert scale from "not at all" to "very close."
Fondness	
FondnessEgo	"I like classmate 'A'.": The ego is the "sender" and the "perceiver" while the alter is the "receiver." This is measured on a 3-point Likert scale from "not at all" to "very much."
FondnessAlter	"From my perspective, I feel that classmate 'A' likes me.": The ego is the "receiver" and the "perceiver" while the alter is the "sender." This is measured on a 3-point Likert scale from "not at all" to "very much."
Friendship	Participants were asked to indicate their friends in the class by answering a yes-no question for each classmate.

2. **Model II**: Model I with demographic variables.
3. **Model III**: Model II with two aspects of the friendship network: closeness and fondness.
4. **Model IV**: Model III with clustering coefficient.
5. **Model V**: Model II with differences between the ego and alter's perspectives on closeness and fondness.
6. **Model VI**: Model V with clustering coefficient.

The models were built using the lme4 package in R version 3.6.2 [3, 18]. The summary tables were produced by the modelsummary package, and the figures were made by the sjPlot package [1, 15].

3 Results

3.1 Demographic Characteristics

As displayed in Table 2, the majority of participants were female (59.52%) and living with their parents (92.91%). Most parents were married and living together (84.14%), and over half of the participants reported that their family household income was average (58.95%).

Table 2. Demographic characteristics of 536 participants.

Characteristic	No. (%)
Gender	
Male	215 (40.11)
Female	319 (59.52)
Others	2 (0.37)
Living Status	
With parents	498 (92.91)
With cousins	6 (1.12)
Living by oneself	1 (0.19)
School dorm	30 (5.59)
Others	1 (0.19)
Family Household Income Level	
Low income	12 (2.25)
Middle class	31 (5.78)
Average	316 (58.95)
Above average	175 (32.65)
Wealthy	2 (0.37)
Parents' Marital Status	
Married (living together)	451 (84.14)
Married (not living together)	9 (1.68)
Divorced	54 (10.07)
Lost parents	18 (3.36)
Others	4 (0.75)
Total	536 (100)

3.2 Network variables

Table 3 shows the summary statistics of network variables. From the ego's perspective, the average fondness and closeness did not change much over time. However, as shown in the table, there was a slight drop in the mean for the difference in closeness during wave 2. The clustering coefficient at the individual level also did not change with time, with an average of 0.5.

Table 3. Summary statistics of network variables

Wave	1		2		3	
	Mean	St.D	Mean	St.D	Mean	St.D
FondnessEgo	0.9	0.5	1.0	0.5	0.9	0.4
FondnessAlter	0.9	0.5	0.9	0.5	0.9	0.4
ClosenessEgo	0.9	0.4	1.0	0.4	0.9	0.4
ClosenessAlter	0.9	0.4	0.9	0.4	0.9	0.4
DeltaFondnessEgo	0.1	0.4	0.1	0.4	0.0	0.4
DeltaFondnessAlter	-0.1	0.4	-0.1	0.4	-0.1	0.4
DeltaClosenessEgo	0.1	0.4	0.0	0.4	0.0	0.4
DeltaClosenessAlter	0.0	0.4	-0.1	0.4	0.0	0.4
Clustering coefficient	0.5	0.3	0.5	0.3	0.5	0.3

3.3 Models

Happiness As shown in Figure 1, the timing of the wave was negatively associated with the level of happiness for each student, which was true for all models. When considering the ego's perspective, the average closeness from the alter was associated with a 0.5 increase in happiness ($p<0.01$). However, the average fondness was not statistically significant. Furthermore, the clustering coefficient was also positively correlated with happiness ($p< 0.1$).

When taking the alter's perspective into consideration and assessing the asymmetry between the ego and alter, the average difference in closeness from the alter between the ego and the alter's perspectives was associated with a 0.39 increase in happiness ($p<0.01$). However, the average difference in closeness from the ego between the ego and the alter's perspectives decreased happiness ($p<0.05$). Additionally, the clustering coefficient was positively associated with happiness ($p<0.1$).

Health Figure 2 presents the results of models on health. The timing of the wave was not statistically significant. When considering only variables related to the perspective of the ego, the average closeness from the alter was associated with an increase of 0.43 in the level of health ($p<0.01$). However, the percentage of friends in the class was not statistically significant.

When adding variables related to the alter's perspective, the average difference in closeness from the alter between the ego and the alter's perspectives was correlated with a 0.2 increase in health, while the average difference in closeness from the ego between the ego and the alter's perspectives was not statistically significant. Furthermore, the clustering coefficient was not statistically significant.

Fig. 1. Models for Individual Happiness (*p<0.1; **p<0.05; ***p<0.01)

4 Discussion

This study explores two aspects of well-being: happiness and health. The results of the analyses indicate that first, happiness is negatively correlated with the timing of the wave, indicating that students reported feeling less happy during the school closures. Second, from the ego's perspective, when one considers that

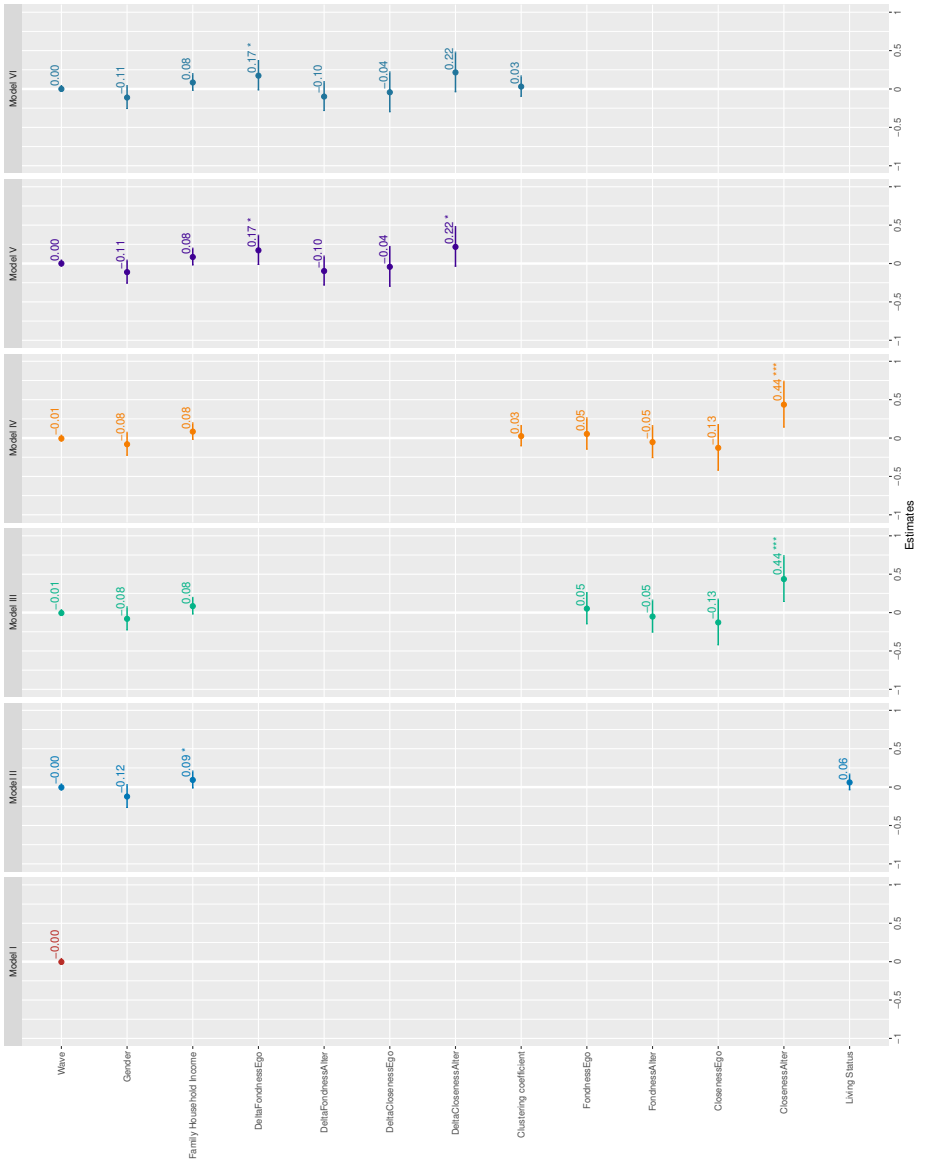

Fig. 2. Models for Individual Health (*p<0.1; **p<0.05; ***p<0.01)

the alters are close to oneself, they are more likely to be happy. This implies the importance of peer relationships and suggests that students value how others perceive them. Third, when considering the alter's perspective, a large difference in closeness between the ego and the alter's perspectives on how the alters feel about themselves is positively correlated with happiness. On the other hand, a

large difference in closeness between the ego and the alter's perspectives on how the ego feels about alters can lead to a lower level of happiness. This suggests that the alignment between the ego and the alter's perspectives on one's feelings toward others is crucial for greater happiness. Last but not least, the clustering coefficient correlates with a higher level of happiness, indicating that the sense of social support within the class is critical for individual happiness.

As for health, the results suggest that first, the wave has no significant effect on health. It is possible that during school closures, students did not experience any health changes while staying home. Second, health is correlated with how the ego perceives closeness from the alters. This implies that students care about how others perceive them, which can potentially influence one's overall health condition. Third, when considering the alter's perspective, a great difference in closeness between the ego and the alter's perspectives on the ego's alter may result in a slightly higher level of health, which suggests that the misalignment between the ego and the alter's perspectives on how others feel about oneself can be beneficial to one's health condition. The ego may feel more optimistic about the relationships than the alters, leading to a better health condition. Unlike the results for happiness, the difference in closeness between the ego and the alter's perspectives on the alter is not statistically significant. It is possible that the perspectives on the alter do not influence the ego much when face-to-face interactions are limited. Last but not least, the clustering coefficient does not necessarily correlate with health.

This study has several limitations. First, participants were recruited through school, and the survey was administered in classes. These participants were not representative of all high school students in Taiwan. Second, most measurements in this study were self-reported, and this study does not capture the transitional phase when students return from home to school. More objective measurements with the transitional phase can provide a more complete picture of students' status. Third, this study lacks information on actual interactions among classmates during school closures. It would be ideal if future research can address these limitations.

5 Conclusion

This paper sheds light on how the well-being of high school students was impacted by changes in friendship networks due to school closures during the COVID-19 pandemic. Moreover, it incorporates different aspects of relationships: closeness and fondness. It shows that peer perspective is crucial for high school students to maintain a certain level of happiness, and the alignment between the ego and the alter's perspective can lead to greater happiness. Moreover, with a higher clustering coefficient, one can experience a higher level of happiness. In terms of health, the alignment between the ego and the alter's perspective on closeness influences individual health, indicating that social relationships are indispensable for one's health. Interestingly, compared to fondness, closeness is a more crucial aspect of high school students' relationships.

References

1. Arel-Bundock, V.: modelsummary: Data and Model Summaries in R. Journal of Statistical Software **103**, 1–23 (2022)
2. Avedissian, T., Alayan, N.: Adolescent well-being: A concept analysis. International Journal of Mental Health Nursing **30**(2), 357–367 (2021)
3. Bates, D., Mächler, M., Bolker, B., Walker, S.: Fitting linear mixed-effects models using lme4. Journal of Statistical Software **67**(1), 1–48 (2015). https://doi.org/10.18637/jss.v067.i01
4. Biddle, B.J., Bank, B.J., Marlin, M.M.: Parental and peer influence on adolescents. Social Forces **58**(4), 1057–1079 (1980)
5. Brandes, U., Nick, B.: Asymmetric relations in longitudinal social networks. IEEE Transactions on Visualization and Computer Graphics **17**(12), 2283–2290 (2011)
6. Burgess, S.M., Sanderson, E., Umana-Aponte, M., et al.: School ties: An analysis of homophily in an adolescent friendship network. Centre for Market and Public Organisation (2011)
7. Cacioppo, J.T., Cacioppo, S.: Social relationships and health: The toxic effects of perceived social isolation. Social and Personality Psychology Compass **8**(2), 58–72 (2014)
8. Calo-Blanco, A., Kovářík, J., Mengel, F., Romero, J.G.: Natural disasters and indicators of social cohesion. PloS one **12**(6), e0176885 (2017)
9. Ellis, W.E., Dumas, T.M., Forbes, L.M.: Physically isolated but socially connected: Psychological adjustment and stress among adolescents during the initial COVID-19 crisis. Canadian Journal of Behavioural Science/Revue canadienne des sciences du comportement **52**(3), 177 (2020)
10. Hagberg, A., Swart, P., S Chult, D.: Exploring network structure, dynamics, and function using NetworkX. Tech. rep., Los Alamos National Lab.(LANL), Los Alamos, NM (United States) (2008)
11. Kim, E.J., Lim, J.Y., Kim, G.M., Kim, S.K.: Nursing students' subjective happiness: A social network analysis. International Journal of Environmental Research and Public Health **18**(21), 11612 (2021)
12. Kovacs, B., Caplan, N., Grob, S., King, M.: Social networks and loneliness during the COVID-19 pandemic. Socius **7**, 2378023120985254 (2021)
13. Labianca, G., Brass, D.J.: Exploring the social ledger: negative relationships and negative asymmetry in social networks in organizations. Academy of Management Review **31**(3), 596–614 (2006)
14. Lin, S., Faust, L., Robles-Granda, P., Kajdanowicz, T., Chawla, N.V.: Social network structure is predictive of health and wellness. PloS one **14**(6), e0217264 (2019)
15. Lüdecke, D.: sjplot: data visualization for statistics in social science. R package version 2.8. 10. R Foundation for Statistical Computing (2021)
16. Phan, T.Q., Airoldi, E.M.: A natural experiment of social network formation and dynamics. Proceedings of the National Academy of Sciences **112**(21), 6595–6600 (2015)
17. Poortinga, W.: Social relations or social capital? individual and community health effects of bonding social capital. Social Science & Medicine **63**(1), 255–270 (2006)
18. R Core Team: R: A language and environment for statistical computing (2019), https://www.R-project.org/
19. Wang, M.T., Henry, D.A., Scanlon, C.L., Del Toro, J., Voltin, S.E.: Adolescent psychosocial adjustment during COVID-19: an intensive longitudinal study. Journal of Clinical Child & Adolescent Psychology pp. 1–16 (2022)