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The role of ingroup assortative sociality in the COVID-19 pandemic: A multilevel analysis of google trends data in the United States

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ABSTRACT

This study tested how family ties and religiosity, two extended elements of ingroup assortative sociality, would predict group-level COVID-19 severity in the U.S. and how COVID-19 threat would predict ingroup assortative sociality at a weekly level. Multilevel models which analyzed the state-level archival (e.g., religious participation) and Google trends data (e.g., marriage for family ties; prayer for religiosity) on ingroup assortative sociality showed that religious search volume (from 2004 to 2019) significantly and negatively predicted COVID-19 severity (i.e., shorter time delay of first documented cases, shorter overall doubling times, higher reproductive ratio and higher case fatality ratio) across states (Study 1a) and counties (Study 1b) while search volume for family ties only significantly and negatively predicted county-level COVID-19 severity. Multilevel analyses also found that weekly COVID-19 severity weakly predicted weekly search volume of marriage and religion (Study 2a), but when COVID-19 threat was in the collective consciousness in a given week (i.e., Google search volume for coronavirus within 52 weeks), collective levels of ingroup assortative sociality increased from the previous week (Study 2b). Evidence across studies suggested that religiosity, compared with family ties, could serve a more important role for the U.S. people during the deadly pandemic.

Introduction

As infectious diseases were responsible for human morbidity and mortality historically (Van Bavel et al., 2020), pathogen threat profoundly influences human psychology and behaviors (Fincher & Thornhill, 2012; Thornhill & Fincher, 2014a). According to the behavioral immune system theory, mechanisms defending individuals against pathogens are characterized as proactive responses and reactive responses (Ackerman et al., 2018). First, proactive responses aim at managing infectious diseases in the long run. For example, Cashdan and Steele (2013) showed that children in areas with higher pathogen loads were socialized to be more obedient, suggesting that encouraging offspring to adhere to social expectations and norms could be a strategy of maximizing inclusive fitness in areas of heightened parasite-stress. Moreover, O’Shea et al. (2020) found that people living in U.S. states where pathogen prevalence was high showed strong implicit and explicit racism and racial prejudice, suggesting that prejudice may be used to proactively defend people against novel infectious diseases (O’Shea et al., 2020). Second, presence of pathogen threat triggers reactive responses (Ackerman...
et al., 2018). For example, manipulating people to perceive an increased risk of parasitic infection resulted in their greater ethnocentrism (Navarrete & Fessler, 2006), xenophobia (Faulkner et al., 2004) and conformity (Wu & Chang, 2012), which are mechanisms defending people against novel infectious diseases (Fincher & Thornhill, 2008, 2012; Thornhill & Fincher, 2014a).

According to the parasite-stress theory (Fincher & Thornhill, 2012; Fincher et al., 2008), heightened parasite-stress promotes ingroup assortative sociality, which avoids the transmission of novel infectious diseases from outgroup members. The cross-cultural observation that societies with higher historical parasite-stress valued strong ingroup assortative sociality (Fincher et al., 2008; Thornhill et al., 2010; Tybur et al., 2016) suggests that ingroup assortative sociality is an aspect of the behavioral immune system at a group level (Thornhill & Fincher, 2014b). Indeed, recent research on the relationship between collectivism and the Coronavirus Disease 2019 (COVID-19) has shown that collectivist countries had better control of this novel infectious disease (Gokmen et al., 2020; Maaravi et al., 2021; Webster et al., 2021). This group-level phenomenon is consistent with the proactive disease-avoidance response postulated by the behavioral immune system theory (Clay et al., 2012; Thornhill & Fincher, 2014a, 2014b). For instance, Maaravi et al. (2021) showed that collectivist countries had less COVID-19 cases and mortalities, suggesting that the historically higher parasite-stress (Murray & Schaller, 2010) of collectivist countries (Fincher et al., 2008; Thornhill et al., 2010) may have pressured people residing in these countries to proactively prevent themselves from getting novel infectious diseases in the long run through several disease-avoidance strategies (Fincher & Thornhill, 2012) such as supporting authoritarian governance (Murray et al., 2013) and socializing children to conform to social norms (Cashdan & Steele, 2013). The mitigating effect of ingroup assortative sociality on COVID-19 pandemic observed at a group level could be partly explained by the individual-level processes (Thornhill & Fincher, 2014b), in which individuals increase their ingroup assortative sociality tendencies as reactive responses to a heightened COVID-19 threat. For example, after reading news reports about coronavirus, individuals showed greater social conservatism as indicated by their support for presidential candidates (Karwowski et al., 2020). Moreover, individuals perceived a greater level of COVID-19 threat and showed a higher level of prejudice toward outgroup members, after searching for coronavirus related information (Sorokowski et al., 2020).

According to Fincher and Thornhill (2012), religiosity and strength of family ties are two extended elements of ingroup assortative sociality. Fincher and Thornhill (2008) showed that infectious diseases could contribute to the diversity of religion, because people living in areas with more infectious diseases tended to have higher levels of ingroup favoritism and outgroup avoidance to minimize the contagion risk, which consequently created the intergroup boundaries and resulted in more different religions. As religious participation was strongly and positively related to pathogen prevalence across different regions (Fincher & Thornhill, 2012), religiosity could be an ancestrally adaptive response to heightened parasite-stress. Because religiosity requires people to make great efforts to fully incorporate religious beliefs and practices into their lives, religiosity is a costly signal that effectively reveals one’s commitment to ingroup members. Thus, religiosity could serve as a reliable marker of ingroup assortative sociality (Fincher & Thornhill, 2012). Valuing strong family ties is another element of ingroup assortative sociality, given that intense loyalty and interdependence on family are the core features of commitment to ingroup members (Vandello & Cohen, 1999) and reflect the strength of xenophobia and ethnocentrism in areas with higher parasite-stress (Fincher & Thornhill, 2012). Thornhill et al. (2010) showed that indices of parasite richness were positively and significantly related to strength of family ties across nations.

From the perspective of parasite-stress theory, it could be predicted that religiosity and strength of family ties measured at a group level would predict group-level COVID-19 severity, as this theory has been found effective in accounting for the group-level ingroup assortative sociality phenomenon (Fincher & Thornhill, 2008, 2012; Fincher et al., 2008; Thornhill et al., 2010) and the geographic variation in COVID-19 prevalence and mortality (Gokmen et al., 2020; Maaravi et al., 2021; Webster et al., 2021). Therefore, testing this prediction would greatly increase the applicability of the theory and enhance the understanding of the relationships between the basic elements of ingroup assortative sociality and COVID-19 pandemic, since previous studies mainly examined the relationship between COVID-19 pandemic and collectivism (Germani et al., 2020; Gokmen et al., 2020; Huang et al., 2020), a more general concept of ingroup assortative sociality (Fincher & Thornhill, 2012; Talhelm & English, 2020). Because Thornhill and Fincher (2014b) have predicted that ingroup assortative sociality is an aspect of the behavioral immune system, it is important to further test how ingroup assortative sociality elements such as religiosity and strength of family ties would reactively respond to COVID-19 threat at a group level according to the behavioral immune system theory (Ackerman et al., 2018). To test this assumption, it is worthwhile to rely on web search data, which has been increasingly used to measure group level trends such as tracking individuals’ true feelings and interests (Lai et al., 2017) to capture the thoughts of millions of people (Pelham et al., 2018). For instance, recent research has utilized web search data to examine how collective concerns about life-threatening illnesses such as cancer would predict collective levels of religiosity from a terror management perspective (Alper, 2019; Pelham et al., 2018). Because web search data capture people’s information-seeking behaviors (Li et al., 2020) and that seeking for COVID-19 information induced ingroup bias as a reactive response to immediate (perceived) COVID-19 threat (Sorokowski et al., 2020), it is worthwhile to examine whether and how ingroup assortative sociality measured with time series web search data would serve as a reactive response to COVID-19 threat.

Compared with experimental studies, which have shown that COVID-19 threat would induce ingroup bias at an individual level (Karwowski et al., 2020; Sorokowski et al., 2020), web search data are useful in revealing the relationship at a group level and in a natural setting. This study employed Google Trends, a big data tool tracking people’s natural thoughts on specific topics over time (Arora et al., 2019) to capture people’s thoughts of family ties and religiosity. Since past research has shown that Google search terms served as a reliable proxy for researchers to gain insight into the thoughts of millions of people (MacInnis & Hodson, 2015; Pelham et al., 2018), this tool can provide much natural and ecological evidence for the relationship between ingroup assortative sociality and the COVID-19 pandemic.

Furthermore, previous research often used a single indicator to capture COVID-19 severity (Gokmen et al., 2020), which did not fully reflect the actual intensity of COVID-19 because other epidemiological indicators such as the doubling time of COVID-19 and case
fatality ratio of COVID-19 also reflect the severity of COVID-19 (Mazumder et al., 2020). In addition, conducting cross-national research (Gokmen et al., 2020; Maaravi et al., 2021) could produce biased statistical findings, since it is difficult to eliminate the confounding effects of sociocultural factors across large geographic regions (Wei et al., 2017). Wei et al. (2017) suggested that the use of samples within a single country of substantial geographic size would minimize the noise and allow more reliable estimation of the real effects. Therefore, this study chose a geographically large country (i.e., the United States) to capture sufficient variance in ingroup assortative sociality (Fincher & Thornhill, 2012) and COVID-19 severity (CDC COVID-19 Response Team, 2020; Karaye & Horney, 2020).

This research employed five epidemiological indicators to assess the overall severity of COVID-19 in U.S. states and used archival data in Fincher and Thornhill (2012) and Google Trends data on family ties and religiosity to examine the relationship between ingroup assortative sociality and COVID-19 severity. It was predicted that 1) states that valued strong family ties and heightened religiosity would have lower levels of COVID-19 severity at a group-level analysis, and 2) COVID-19 threat would predict ingroup assortative sociality at a weekly-level analysis.

Study 1a

Methods

States involved in the analysis

Analyses were conducted on Washington D.C. and 50 U.S. states.

Measures

COVID-19 severity. This study sourced time series COVID-19 data from the New York Times (https://github.com/nytimes/, as accessed on 31 December 2020). First, the duration between the date of the first documented COVID-19 cases of a given state and that of the first documented COVID-19 cases in the People’s Republic of China was computed to indicate the time delay of COVID-19 for that state (Jankowiak et al., 2020). The value of the time delay was multiplied by \(-1\) to indicate COVID-19 susceptibility. Second, the overall doubling time of COVID-19 measured the speed of COVID-19 propagation within the first 21 days since the first 25 cases (or over 25 cases) were documented (White & Hébert-Dufresne, 2020). This study calculated the doubling times of COVID-19 cases and deaths by using the method described in White and Hébert-Dufresne (2020) and the formula in Mazumder et al. (2020). For example, the cumulative cases in Alabama were 29 on 16 March 2020 and 2,005 after 21 days, so the overall doubling time of COVID-19 cases in Alabama was \(\frac{2^{21}}{29} = 3.44\). The value of the overall doubling time was multiplied by \(-1\) such that a greater value would indicate faster SARS-CoV-2 propagation. Third, this work sourced the reproductive ratio of the SARS-CoV-2 virus from https://rt.live/ and computed the mean score for each state between 01 January 2020 and 31 December 2020 so that a greater mean value would indicate faster transmission. Fourth, the case fatality ratio was the proportion of the total deaths among total confirmed cases (Verity et al., 2020). A mean case fatality ratio (between 01 January 2020 and 31 December 2020) was ascertained, and a greater ratio would indicate greater lethality. An exploratory factor analysis using a Direct oblimin rotation extracted one component from the Z-transformed indicators, which accounted for 52.80% of the variance in the unobserved construct. The indicators had a high Cronbach’s \(\alpha\) of .76. Thus, the Z-transformed indicators were averaged to compute the COVID-19 severity index.

Ingroup assortative sociality

Archival data in Fincher and Thornhill (2012). According to Fincher and Thornhill (2012), data on family ties were extracted from Vandello & Cohen, 1999. As for religious participation, Fincher and Thornhill (2012) obtained the data from the 2001 American Religious Identification Survey and the total religious adherents in each state from the survey conducted by the Association of Statisticians of American Religious Bodies. Fincher and Thornhill (2012) found that strength of family ties and religious participation were strongly and positively related to parasite-stress index across the U.S. states.

Google trends data. To capture ingroup assortative sociality in the U.S. states more naturally and ecologically, Google search data were used (Lai et al., 2017). Google Trends (https://trends.google.com/) records the number of a specific search term and compares this number with the total number of google searches conducted (MacInnis & Hodson, 2015), thereby generating a normalized relative-search-volume (RSV) score ranging from 0 (lowest search volume) to 100 (highest search volume) to indicate the popularity of that specific search term within different locations and different time periods (Connor et al., 2019). Thus, Google Trends provides two forms of data, which are regional data and time series data. Because the RSV scores are normalized, researchers can use the regional data to compare the statewide differences in the search volume of a specific search term. For example, MacInnis and Hodson (2015) compared the search behaviors about sexual contents on Google across the states. Moreover, time series RSV data enable researchers to investigate the longitudinal relationships between the examined variables. For instance, using the weekly RSV data on search terms related to major illnesses and religions, Pelham et al. (2018) found that higher Google search volume for major illnesses predicted increased search volume for religion in the following week. Thus, Google search data could serve as a reliable proxy for gaining insights into people’s private thoughts such as religion (Alper, 2019; Pelham et al., 2018) and concern about COVID-19 (Husain et al., 2020).
Strength of family ties estimated with google trends data. Because no publication has been found to use Google search data to measure state-level family ties, this study proposed that the search volume of keywords related to the concept of marriage could naturally capture people’s thoughts of family ties, given that marriage per se is a foundation of family ties (Umberson & Thomeer, 2020). Indeed, Grossmann and Varnum (2015) used a divorce-to-marriage ratio as an indicator of strength of family ties to investigate the effect of social change on individualism across U.S. states. The regional RSV scores of specific search terms from 2004 to 2019 were obtained from Google Trends. To measure American people’s thoughts about family ties, two keywords (i.e., marriage and married; Cronbach alpha = .81) directly related to the establishment of an intimate union were used. To interpret the constructed index as a measure of strength of family ties, it was important to show how important marriage was relative to divorce. Thus, two keywords (i.e., divorce and divorced; Cronbach alpha = .69) related to the dissolution of committed romantic relationships were also included. The average RSV score of divorce and divorced was subtracted from the average RSV score of marriage and married to create a marriage-divorce interest index so that higher scores indicated greater interests in family ties.

Although the present index only showed mild positive correlation with state-level marriage-to-divorce ratio (data from 1990 to 2019 were obtained from the National Center for Health Statistics, https://www.cdc.gov/nchs/index.htm), \( r = .12, p_{two-tailed} = .411 \), the validity of the marriage-divorce interest index was supported by its significant correlation with several ingroup assortative sociality measures such as the strength of family ties index in Fincher and Thornhill (2012), \( r = .43, p_{two-tailed} = .002 \), and the collectivism index in Vandello & Cohen, 1999, \( r = .35, p_{two-tailed} = .013 \). As parasite-stress was related to ingroup assortative sociality (Fincher & Thornhill, 2012), the current index also showed a marginally significant association with parasite-stress index in Fincher and Thornhill (2012), \( r = .27, p_{two-tailed} = .059 \). Given that socioeconomic development promoted individualism (Santos et al., 2017), the current index was significantly and negatively correlated with per capita personal income (Data from 2004 to 2019 were obtained from the U. S. Bureau of Economic Analysis, https://www.bea.gov/), \( r = -.36, p_{two-tailed} = .011 \). Therefore, the Google search volume of keywords related to marriage and divorce did partially capture American people’s thoughts of family ties.

Religiosity estimated with google trends data. To measure religiosity in different states using Google Trends data, a religion-secularism interest index was created. First, the RSV scores of Jesus, God, and prayer which were successfully used in Pelham et al. (2018) and Alper (2019) were averaged to compute a religion-interest index (Cronbach alpha = .90). Second, Dilmaghani (2020) showed that Google search volume for influential atheists (i.e., Sam Harris, Christopher Hitchens, and Richard Dawkins) captured people’s interests in secularism. Thus, this study obtained the RSV scores of the three influential atheists according to Dilmaghani (2020) to compute a secularism-interest index (Cronbach alpha = .81). To show how important religion was relative to secularism, the religion-secularism interest index was created by subtracting the secularism-index from the religion-index so that a higher score indicated a greater interest in religion.

The measurement validity of the current index was supported by the strong and positive correlation between the religion-secularism interest index and the state-level percentage of individuals who answered “Yes” to the question “Is religion an important part of your daily life” of the Gallup Religious Survey (Newport, 2009), \( r = .90, p_{two-tailed} < .001 \). Furthermore, the religion-secularism interest index was positively and significantly related to religious participation index in Fincher and Thornhill (2012), \( r = .58, p_{two-tailed} < .001 \), parasite-stress index in Fincher and Thornhill (2012), \( r = .65, p_{two-tailed} < .001 \), and collectivism index in Vandello & Cohen, 1999, \( r = .45, p_{two-tailed} = .001 \). As religiosity declined with economic growth (Barber, 2013), the present religion-secularism interest index was found to be negatively and significantly correlated with the per capita personal income, \( r = -.53, p_{two-tailed} < .001 \). Thus, the religion-secularism interest index estimated with Google search data ecologically captured American people’s thoughts of religion and secularism.

Covariates. As partisanship has been found to predict COVID-19 preventative behaviors and health outcomes (Gollwitzer et al., 2020), it was important to partial out the effect of partisanship on COVID-19 severity so that the unique role of ingroup assortative sociality in the COVID-19 pandemic could be estimated more accurately. Considering the causal time lag of the influence of the predictors on the outcomes (Wang, Chen, Chen, & Yang, 2021), partisanship was indicated by the state-level voting gap in the 2016 election (Gollwitzer et al., 2020). First, this study obtained the state-level election results from the New York Times (https://www.nytimes.com/elections/2016/results/president). Then, the percentage of individuals voting for Donald Trump (Republican) was used to minus the percentage of persons voting for Hillary Clinton (Democrat) so that a higher score indicated a higher level of conservative political ideology (Gollwitzer et al., 2020). Since social vulnerability index (SVI) was a significant predictor of COVID-19 (Karaye & Horney, 2020; Khazanchi et al., 2020), the state-level SVI (Agency for Toxic Substances and Disease Registry, 2020) was controlled. Furthermore, as population density, COVID-19 testing rate, airport traffic and higher age groups were significant predictors of COVID-19 (Roy & Ghosh, 2020), data on these variables were collected via GitHub (https://github.com/saturn/COVID-19/tree/master/US-COVID-Data) and the Johns Hopkins University Center for Systems Science and Engineering (JHU CSSE) (https://github.com/CSSEGISandData/COVID-19). Because parasite prevalence could serve as a proxy for COVID-19 outbreak (Jankowiak et al., 2020), the state-level parasite-stress index in Fincher and Thornhill (2012) was controlled. Finally, latitude and longitude (https://developers.google.com/public-data/) were controlled to partial out the influences of climatic (Adedokun et al., 2020) and geographic (CDC COVID-19 Response Team, 2020) factors on COVID-19 pandemic.

Statistical approach. When conducting group-level analyses (e.g., state-level), the values of variables will cluster at nearby locations (e.g., compared with non-neighboring states, neighboring states were more similar in personality traits; see Rentfrow et al., 2013), thus the presence of spatial autocorrelation will violate the assumption of the independence of data required by most standard statistical
procedures (Dormann et al., 2007; Gu et al., 2020; Kerkman et al., 2017; Legendre, 1993). This research employed multilevel analysis to analyze the data (Diez-Roux, 2000) as this strategy was frequently used in previous research to solve the spatial autocorrelation problem (Kandrik et al., 2015; Ma, 2021; Wei et al., 2017). Similar to Wang et al. (2021), this study grouped states into nine distinct divisions defined by the U.S. Census Bureau. Then, a multilevel regression model with the nine divisions as a random intercept was specified. Because multilevel analysis was used to address the issue of spatial autocorrelation only and the main interest and focus of this study were to examine how state-level predictors would explain the statewide differences in COVID-19 severity, a state-level model was specified. The proposed predictors were treated as fixed effects (Hox, 2010) and the effect size of each fixed effect was measured by \( f^2 \) (Aiken et al., 1991). According to Lorah (2018), the effect size measure \( f^2 \) was a standardized measure that was less particular to a given sample, thereby allowing researchers to compare the effect of a given predictor across studies with different sample sizes. The equation of this effect size measure is: \( f^2 = \frac{R^2_g}{1-R^2_g} \), where \( R^2_g \) is the variance explained for a model with the given effect and \( R^2_g \) is the variance explained for a model without the given effect. Lorah (2018) had detailed how to calculate \( R^2_g \), which was followed to estimate \( f^2 \) for each fixed effect in this study. The \( f^2 \) values of .02, .15, and .35 represent small, medium, and large effect sizes, respectively. Two-tailed tests were conducted to avoid inaccurate and biased results. Analyses were conducted using SPSS 26.0.

According to the methodological research in Diez-Roux (2000) and Lorah (2018) and recently published empirical multilevel studies (Beilmann et al., 2018; Chan, 2020; Rammstedt et al., 2017; Tybur et al., 2016), the following equations were used to describe the multilevel analysis. COVID-19 is COVID-19 severity for the state \( i \) within division \( j \); \( \beta_0 \) is the intercept of COVID-19 severity in division \( j \); all other \( \beta \)s are slopes of the relationships between COVID-19 severity and its state-level predictors in division \( j \); \( \epsilon_{ij} \) is the random error at a state level; \( \gamma_0 \) is the grand intercept; \( \epsilon_{ij} \) is the random error at a division level.

Level-1 (State-level): \( \text{COVID-19}_i = \beta_0 + \beta_1 \text{(latitude)} + \beta_2 \text{(longitude)} + \beta_3 \text{(parasite stress)} + \beta_4 \text{(social vulnerability)} + \beta_5 \text{(population density)} + \beta_6 \text{(airport traffic)} + \beta_7 \text{(population aged 65 or above)} + \beta_8 \text{(COVID-19 testing rate)} + \beta_9 \text{(partisanship)} + \beta_{10} \text{(strength of family ties)} + \beta_{11} \text{(religious participation)} + \beta_{12} \text{(marriage-divorce interest index)} + \beta_{13} \text{(religion-secularism interest index)} + \epsilon_{ij} \)

Level-2 (Division-level): \( \beta_0 = \gamma_0 + \epsilon_{ij} \)

Results and discussion

The relationship between marriage-divorce interest index and COVID-19 severity was non-significant in a multilevel analysis considering the issue of spatial autocorrelation and controlling for covariates (Table 1). As shown in Table 1, religion-secularism interest index significantly predicted state-level COVID-19 severity, \( B = -0.01, SE = 0.11, p_{\text{two-tailed}} = .015 \) and the effect size was medium, \( f^2 = .151 \). Gollwitzer et al. (2020) showed that partisanship was a significant predictor of COVID-19 response, but this study found that the state-level partisanship did not significantly predict state-level COVID-19 severity. As expected, other predictors such as social vulnerability and population density were also significant predictors of COVID-19 severity, but airport traffic had the largest effect, \( f^2 = .511 \), on COVID-19 severity, \( B = 16.91, SE = 0.06, p_{\text{two-tailed}} = .002 \). Given that the religion-secularism interest index was highly related to religiosity estimated with Gallup survey data and significantly correlated with ingroup assortative sociality in Fincher and Thornhill (2012) and collectivism index in Vandello and Cohen (1999), findings in Study 1a partially supported the proposal that religiosity is an important extended element of ingroup assortative sociality (Fincher & Thornhill, 2012) and serves as a disease-avoidance strategy at a group level (Fincher et al., 2008). Because the Google Trends data used in the present study were recorded before the outbreak of COVID-19 (i.e., from 2004 to 2019), it is likely that ingroup assortative sociality could be a proactive response of the behavioral immune system (Ackerman et al., 2018). By establishing and maintaining ingroup coalitions, people who are at greater risks of exposing to infectious diseases could isolate themselves from outgroup members, thereby avoiding the transmission and infection of novel infectious diseases in the long run (Ackerman et al., 2018; Fincher & Thornhill, 2012; Fincher et al.,...
Based on the findings, it would be worthwhile to further test whether and how state-level ingroup assortative sociality variables could predict county-level COVID-19 severity. Indeed, using multilevel analysis to examine the effects of macro-level predictors on micro-level outcome variables is popular in different research areas such as psychological and sociological studies (Barni et al., 2016; Beilmann et al., 2018; Chan, 2020; Rammstedt et al., 2017; Wei et al., 2017), given that multilevel analysis can capture meaningful effects of macro-level predictors on micro-level outcomes (Wei et al., 2017) to yield accurate estimation of the existence of multilevel relationships (Beilmann et al., 2018). Thus, the replicability and validity of the findings in Study 1a would be greatly strengthened when the state-level ingroup assortative sociality variables were found to significantly predict county-level COVID-19 severity.

### Study 1b

Study 1b used multilevel analyses to test how state-level ingroup assortative sociality variables would predict county-level COVID-19 severity when county- and state-level covariates were controlled.

### Methods

#### Counties involved in the analysis

A total of 3,135 counties with identifiable FIPS codes and COVID-19 epidemiological data in the New York Times dataset (https://github.com/nytimes, as accessed on 31 December 2020) were included.

#### Measures

**County-level variables.** COVID-19 severity was measured by the method described in Study 1a. Given the relatively lower daily death rates of 1,794 counties, overall doubling time of deaths was not calculated. Because the estimated reproductive ratio in Ives and Bozzuto (2021) did not reflect the actual and most updated COVID-19 transmission pattern within U.S. counties, it was unsuitable to include the estimated reproductive ratio for computing the COVID-19 severity index. Data on latitude, longitude, elderly population and population density were obtained from Ives and Bozzuto (2021). SVI was obtained from the Agency for Toxic Substances and Disease Registry (http://ghdx.healthdata.org/), as these infectious diseases were indicators of state-level parasite-stress index (Fincher & Thornhill, 2012). Moreover, the 2016 U.S. county-level presidential results were obtained from the Github dataset (https://github.com/tommcg) to measure county-level partisanship using the method described in Study 1a.

**State-level variables.** The macro-level variables were airport traffic, COVID-19 testing rate, strength of family ties, religious participation, marriage-divorce interest index, and religion-secularism interest index examined in Study 1a.

#### Statistical approach.

Missing values were estimated using an EM method. Multilevel analysis was conducted according to the procedure described in previous research (Barni et al., 2016; Beilmann et al., 2018; Chan, 2020; Rammstedt et al., 2017). In the multilevel model, the intercept representing mean COVID-19 severity was allowed to vary randomly by level 2 unit and an unconditional model was specified to serve to partition the variance between the micro- and macro-level units (Lorah, 2018). Next, a micro-level model with county-level predictors was specified. To examine how state-level ingroup assortative sociality variables would explain the variance of county-level COVID-19 severity, a macro-level model built upon the preceding model was specified. $f^2$ was used to describe the magnitude of a given fixed effect (Lorah, 2018). To describe the proportion of variance in the county-level COVID-19 severity accounted for by the macro-level unit (cluster) membership, the Intraclass Correlation Coefficient (ICC) was calculated (Lorah, 2018). Two-tailed tests were conducted. The following equations were used to describe the two levels of the multilevel analysis. COVID-19 severity ($y_{ij}$) is COVID-19 severity for county $i$ within state $j$; $\beta_{0ij}$ is the intercept of COVID-19 severity in state $j$; all other $\beta$ are slopes of the relationships between COVID-19 severity and its county-level predictors in state $j$; $\varepsilon_{ij}$ is the random error at a county level; $\gamma_{00}$ is the overall intercept; all other $\gamma$s are the fixed effects of state-level variables; $u_{0j}$ is the random error at a state level.

**Level-1 Model (County-level):** COVID-19 severity ($y_{ij}$) = $\beta_{0j} + \beta_{1j}$(latitude) + $\beta_{2j}$(longitude) + $\beta_{3j}$(population density) + $\beta_{4j}$(population aged 65 or above) + $\beta_{5j}$(social vulnerability) + $\beta_{6j}$(parasite stress) + $\beta_{7j}$(partisanship) + $\varepsilon_{ij}$

**Level-2 Model (State-level):** $\beta_{0j} = \gamma_{00} + \gamma_{01}$(airport traffic) + $\gamma_{02}$(COVID-19 testing rate) + $\gamma_{03}$(strength of family ties) + $\gamma_{04}$(religious participation) + $\gamma_{05}$(marriage-divorce interest index) + $\gamma_{06}$(religion-secularism interest index) + $u_{0j}$

### Results and discussion

First, an unconditional model showed that state membership explained 26% of the variance in county-level COVID-19 severity, which was a large effect (Hox, 2010). Thus, it was plausible to use multilevel analysis to examine the effects of contextual variables on...
the micro-level outcome variable. As shown in Table 2, the ICC value decreased to .13 when micro-level predictors were accounted for, suggesting that 13% of the variance in county-level COVID-19 severity could be attributed to macro-level variables. When contextual variables were included (Level-2 Model), the ICC value decreased to .10 and it was found that marriage-divorce interest index, $B = -0.01, SE = 0.02, p_{\text{two-tailed}} = .035$, and religion-secularism interest index, $B = -0.00, SE = 0.04, p_{\text{two-tailed}} = .044$, significantly predicted micro-level COVID-19 severity, albeit their effect sizes were relatively small, $0.007 \leq f^2 s \leq 0.012$.

In summary, the above multilevel findings provided partial support to the parasite-stress theory of sociality at a county-level (Fincher et al., 2008). Consistent with Fincher and Thornhill (2012)’s argument that religiosity is a costly signal that honestly reveals one’s commitment to ingroup members, it was found that religiosity remained a robust predictor for both state- (Study 1a) and county-level (Study 1b) COVID-19 severity when a series of covariates were controlled. Because data on religiosity were recorded before the outbreak of COVID-19 in the United States, the present findings provided support to the present argument that religiosity is a proactive response of human behavioral immune system (Ackerman et al., 2018) and a disease-avoidance strategy (Fincher & Thornhill, 2012) at a group level.

In order to test the proposal that ingroup assortative sociality was a reactive response to COVID-19 (Karwowski et al., 2020; Sorokowski et al., 2020) using ecological and objective data collected from a large population (Alper, 2019; Lai et al., 2017; Pelham et al., 2018), Study 2 examined whether COVID-19 threat would predict ingroup assortative sociality using time series epidemiological data on COVId-19 and time series web search data on religion and family ties.

### Study 2a

Study 2a investigated how weekly progression of COVID-19 severity would predict American people’s ingroup assortative sociality tendencies as measured with weekly Google search data. As the ingroup assortative sociality indices estimated with web search data had satisfactory external validity with ingroup assortative sociality indices in Vandello and Cohen, 1999 and Fincher and Thornhill (2012), if progression of COVID-19 severity could significantly and positively predict search volume for ingroup assortative sociality elements (Alper, 2019; Pelham et al., 2018), it could partially suggest that infectious diseases promote ingroup assortative sociality at a group-level (Fincher & Thornhill, 2012). This study employed multilevel analysis to nest weekly epidemiological and web search data within states.

### Methods

#### States and weeks involved in the analysis

States were those investigated in Study 1a and a total of 52 consecutive weeks (from 05 January 2020 (the first week) to 27 December 2020 (the last week)) were examined for each state.

#### Measures

**Weekly-level variables.** This study obtained weekly Google search data (see Study 1a for the search terms used) to calculate the weekly indices for the two extended elements of ingroup assortative sociality (see Study 1a for the calculation). Moreover, this study used weekly doubling time, weekly reproductive ratio, and weekly case fatality ratio to calculate the weekly COVID-19 severity (see Study 1a for how COVID-19 severity indicators were calculated).

**Table 2**

The effects of ingroup assortative sociality and covariates on county-level COVID-19 severity in a multilevel analysis in Study 1b (N = 3,135).

| Variables                                | Level-1 Model ICC = .13 | Level-2 Model ICC = .10 |
|------------------------------------------|-------------------------|-------------------------|
|                                          | Effect size $f^2$ | B | SE | df | t    | Effect size $f^2$ | B | SE | df | t   |
| County-level predictors:                 |                         |   |    |    |     |                         |   |    |    |     |
| Latitude                                 | .020                    | −0.01 | 0.02 | 139.31 | −3.28** | .001                    | −0.01 | 0.03 | 335.02 | −2.53* |
| Longitude                                | .040                    | 0.01  | 0.02 | 65.03   | 4.77*** | .028                    | 0.01  | 0.02 | 60.08   | 4.41*** |
| Population density                       | .040                    | 0.00  | 0.01 | 3091.80 | 6.62*** | .033                    | 0.00  | 0.01 | 3097.66 | 6.50*** |
| Population aged 65 or above              | .017                    | −0.02 | 0.01 | 3125.72 | −7.93*** | .021                    | −0.02 | 0.01 | 3119.51 | −8.01*** |
| Social vulnerability                     | .002                    | 0.05  | 0.01 | 3125.57 | 1.16    | .002                    | 0.05  | 0.01 | 3116.75 | 1.19   |
| Parasite stress                          | 0          | 0.02  | 0.02 | 3088.08 | 0.83    | 0          | 0.01  | 0.02 | 3072.31 | 0.77   |
| Partisanship                             | .059                    | −0.40 | 0.01 | 2883.10 | −8.54*** | .036                    | −0.39 | 0.01 | 3028.76 | −8.19*** |
| State-level predictors:                  |                         |   |    |    |     |                         |   |    |    |     |
| Airport traffic                          | 0.05                   | −0.00 | 0.02 | 39.93   | −1.97*  | 0.04                    | 0.12  | 0.04 | 41.46   | 2.96** |
| COVID-19 testing rate                    | .024                    | 0.12  | 0.04 | 41.46   | 2.96**  | .024                    | 0.12  | 0.04 | 41.46   | 2.96** |
| Strength of family ties                  | 0          | −0.00 | 0.03 | 56.06   | −0.28   |
| Religion participation                   | 0          | −0.00 | 0.03 | 48.63   | −1.00   |
| Marriage-divorce interest index          | .012                    | −0.01 | 0.02 | 39.46   | −2.18*  |
| Religion-secularism interest index       | .007                    | −0.00 | 0.04 | 46.62   | −2.07*  |

*Note. a = Negative values were fixed to 0. Two-tailed tests were conducted. *$p < .1$, **$p < .05$, ***$p < .01$, ****$p < .001$.}
State-level variables. State-level variables were marriage-divorce interest index, religion-secularism interest index, ingroup assortative sociality variables and parasite-stress index in Fincher and Thornhill (2012) and collectivism index in Vandello & Cohen, 1999. Partisanship was included as it was related to ingroup assortative sociality (Chen & Rohla, 2018; Margolis, 2018). Given socioeconomically development was a strong predictor of individualism (Santos et al., 2017), per capita personal income was controlled. Last, latitude and longitude were employed to account for the geographic effects on ingroup assortative sociality (Fincher & Thornhill, 2012; Van de Vliert et al., 2013; Vandello & Cohen, 1999).

Statistical approach. Missing values were estimated with an EM method. Following the strategy in Santos et al. (2017), Study 2a used multilevel analysis to examine the weekly data nested within states and treat the proposed predictors as fixed effects. The analytical procedures were the same as detailed in Study 1b except that the lowest level in the multilevel model was formed by the weekly data. The intercepts of mean weekly ingroup assortative sociality indices estimated with Google search data were allowed to vary randomly by level 2 unit (i.e., U.S. states). In the weekly-level models, the predictive effects of COVID-19 severity on ingroup assortative sociality were examined by using COVID-19 severity in the present week (week x) to predict ingroup assortative sociality indices in that same week, controlling for ingroup assortative sociality indices in the prior week (week x–1) (Alper, 2019; Pelham et al., 2018). Finally, state-level variables were used to predict the variance of intercept of weekly-level model across states. The following equations were used to describe the multilevel analysis. Ingroup assortative sociality in the present week represents for marriage-divorce interest index or religion-secularism interest index in the present week i within state j; \( \beta_0 \) is the intercept of the present-week ingroup assortative sociality in state j; all other \( \beta \)s are slopes of the relationships between the present-week ingroup assortative sociality and its weekly-level predictors in state j; \( \gamma \) is the random error at a weekly level; \( \gamma_0 \) is the grand mean; all other \( \gamma \)s are the slopes of the state-level predictors; \( u_0 \) is the random error at a state level.

Level-1 Model (Weekly-level): Ingroup assortative sociality in the present week \( y_j = \beta_{0j} + \beta_{ij}(\text{ingroup assortative sociality in the prior week}) + \beta_{02}(\text{COVID-19 severity in the present week}) + \epsilon_j \)

Level-2 Model (State-level): \( \beta_{0j} = \gamma_{00} + \gamma_{01}(\text{strength of family ties}) + \gamma_{02}(\text{religious participation}) + \gamma_{03}(\text{marriage-divorce interest index}) + \gamma_{04}(\text{religion-secularism interest index}) + \gamma_{05}(\text{marriage-divorce interest index}) + \gamma_{06}(\text{parasite stress}) + \gamma_{07}(\text{collectivism}) + \gamma_{08}(\text{per capita personal income}) + \gamma_{09}(\text{latitude}) + \gamma_{10}(\text{longitude}) + u_{0j} \)

Results and discussion

First, when accounting for the prior week (week x–1) marriage-divorce interest index, COVID-19 severity in the present week (week x) did not predict the search volume for marriage in the same week, \( B = 0.59, SE = 0.46, p_{\text{two-tailed}} = .195 \), and controlling for state-level predictors did not alter this non-significant relationship, \( B = 0.62, SE = 0.46, p_{\text{two-tailed}} = .176 \) (Table S1). Second, controlling for the prior week religion-secularism interest index resulted in a marginally significant relationship between COVID-19 severity and interest in religion in the present week, \( B = 0.89, SE = 0.50, p_{\text{two-tailed}} = .074 \), and this relationship became significant when controlling for state-level predictors, \( B = 1.01, SE = 0.50, p_{\text{two-tailed}} = .046, \) but the effect size was small, \( f^2 = .001 \) (Table S2). Across all analyses, ingroup assortative sociality indices in a given week were significantly predicted by the indices for the week immediately prior to the to-be-predicted week (Tables S1 and S2), which were consistent with Pelham et al. (2018).

Given that a greater level of perceived pathogen threat significantly predicted a higher level of ingroup bias (Faulkner et al., 2004; Karwowski et al., 2020; Murray & Schaller, 2012; Sorokowski et al., 2020; Wu & Chang, 2012), it is likely that greater concerns about COVID-19 could activate ingroup assortative sociality as a disease-avoidance strategy. Early research showed that manipulating people to perceive an increased risk of parasitic infection resulted in their greater ethnocentrism (Navarrete & Fessler, 2006), xenophobia (Faulkner et al., 2004) and conformity (Wu & Chang, 2012). Recent studies reported that increasing people’s perceived COVID-19 threat promoted their ingroup favoritism and outgroup avoidance (Karwowski et al., 2020; Sorokowski et al., 2020). Thus, after examining the effects of actual COVID-19 severity, Study 2b was conducted to examine how collective levels of ingroup assortative sociality would increase from the previous week when collective COVID-19 concerns were heightened in a given week.

Study 2b

As Google Trends had been used by recent research to monitor people’s restlessness toward COVID-19 infections (Husnayain et al., 2020) and examine people’s perceived COVID-19 threat (Du et al., 2020; Effenberger et al., 2020; Li et al., 2020; Mavragani & Gillas, 2020), Google search data on COVID-19 were examined.

Methods

States and weeks involved in the analysis
States and weeks were exactly those investigated in Study 2a.

Measures
Measures were exactly those employed in Study 2a except that the weekly-level predictor was COVID-19 concern, which was
measured by the weekly-average RSV score of virus topic coronavirus and search term coronavirus (Du et al., 2020; Mavragani & Gkillas, 2020). Because the RSV scores were often less than one in most states during the first two weeks of 2020 and Google Trends did not provide exact values for these less-than-one RSV scores, this study fixed these RSV scores to 0.

**Statistical approach**

Statistical analyses were conducted according to the methods described in Study 2a and the following equations were used to describe the multilevel analysis.

Level-1 Model (Weekly-level): Ingroup assortative sociality in the present week \( \gamma_{ij} = \beta_0 + \beta_1 (\text{ingroup assortative sociality in the prior week}) + \beta_2 (\text{COVID-19 concern in the present week}) + \epsilon_{ij} \)

Level-2 Model (State-level): \( \beta_0 = \gamma_{00} + \gamma_{01} (\text{strength of family ties}) + \gamma_{02} (\text{religious participation}) + \gamma_{03} (\text{marriage-divorce interest index}) + \gamma_{04} (\text{religion-secularism interest index}) + \gamma_{05} (\text{partisanship}) + \gamma_{06} (\text{parasite stress}) + \gamma_{07} (\text{collectivism}) + \gamma_{08} (\text{per capita personal income}) + \gamma_{09} (\text{latitude}) + \gamma_{10} (\text{longitude}) + u_j \)

**Results and discussion**

First, the relationship between COVID-19 concern and search volume for marriage was significant even when accounting for the prior-week marriage-interest index, \( B = 0.04, SE = 0.01, p_{\text{two-tailed}} = .005 \), and this significant relationship persisted after accounting for state-level predictors, \( B = 0.04, SE = 0.02, p_{\text{two-tailed}} = .004 \), although the effect size was relatively small \( f^2 = .001 \) (Table 3). Second, when COVID-19 concern was in the collective consciousness in a given week, collective levels of interest in religious terms increased from the previous week, accounting for the prior-week religion-secularism interest index, \( B = 0.18, SE = 0.02, p_{\text{two-tailed}} < .001 \), and controlling for state-level predictors did not alter this significant effect of COVID-19 concern on religiosity, \( B = 0.16, SE = 0.02, p_{\text{two-tailed}} < .001 \). Compared with other predictors, the effect of COVID-19 concern on religiosity was larger (see \( f^2 \) Table 4). Across all analyses, ingroup assortative sociality indices in week \( x-1 \) significantly predicted ingroup assortative sociality indices in week \( x \), which were consistent with Pelham et al. (2018).

Collectively, the present findings extended the parasite-stress theory of sociality (Fincher & Thornhill, 2012; Fincher et al., 2008) by showing that collective concerns about the novel coronavirus promoted ingroup assortative sociality in the United States. Thus, it was likely that ingroup assortative sociality was a reactive response to a higher level of perceived pathogen threat as documented in previous experimental studies (Faulkner et al., 2004; Karwowski et al., 2020; Murray & Schaller, 2012; Sorokowski et al., 2020; Wu & Chang, 2012). Comparatively, perceived COVID-19 threat tended to have a larger effect on religiosity than family ties, which might suggest that religiosity could be a more important extended element of ingroup assortative sociality (Fincher & Thornhill, 2012).

Moreover, as COVID-19 is a life-threatening novel infectious disease (Pollard et al., 2020) that have caused a large number of deaths in the United States (Weinberger et al., 2020) and religiosity served as a terror management process when mortality was in the collective consciousness (Alper, 2019; Pelham et al., 2018), it was likely that religiosity could be used as a strategy to manage the terror of death among American people during the deadly pandemic.

| Table 3 |
|---|
| The effect of weekly-level COVID-19 concern on weekly-level marriage-divorce interest index in a multilevel analysis in Study 2b (N = 2,652). |

| Variables | Level-1 Model ICC = .13 | Level-2 Model ICC = .12 |
|---|---|---|
| | Effect size | B | SE | df | t | Effect size | B | SE | df | t |
| Weekly-level predictors: | | | | | | | | | | |
| Marriage-divorce interest index in the prior week | .020 | 0.05 | 0.02 | 2597.56 | 2.38* | .020 | 0.05 | 0.02 | 2434.38 | 2.63* |
| COVID-19 concern in the present week | .001 | 0.04 | 0.01 | 2547.99 | 2.83** | .001 | 0.04 | 0.02 | 2397.68 | 2.89** |
| State-level predictors: | | | | | | | | | | |
| Strength of family ties | 0* | 0.90 | 1.12 | 35.76 | 0.80 |
| Religious participation | 0* | 0.32 | 0.20 | 35.83 | 1.62 |
| Marriage-divorce interest index | 0* | −0.04 | 0.25 | 35.74 | −0.16 |
| Religion-secularism interest index | 0* | 0.05 | 0.13 | 35.74 | 0.34 |
| Partisanship | 0* | 0.07 | 0.09 | 35.76 | 0.85 |
| Parasite stress | 0* | −1.80 | 2.02 | 35.77 | −0.89 |
| Collectivism | .002 | −0.33 | 0.25 | 35.78 | −1.33 |
| Per capita personal income | .024 | 0.00 | 0.00 | 35.75 | 0.51 |
| Latitude | 0* | −0.07 | 0.36 | 35.74 | −0.20 |
| Longitude | 0* | 0.03 | 0.09 | 35.74 | 0.33 |

*Note. a = Negative values were fixed to 0. Two-tailed tests were conducted. *p < .05, **p < .01.*
Thornhill, 2012), it could suggest that people who are dedicated to religious groups or have greater interests in religion are more

Fincher (2014a) and Thornhill and Fincher (2014b) that ingroup assortative sociality is an aspect of behavioral immune system, the study found that searching COVID-19 information via Google promoted ingroup assortative sociality. As postulated in Thornhill and

assortative sociality (Fincher

self-motivated to isolate themselves from outgroup members (Fincher

infectious diseases. Instead, since web search data capture people

data (Fincher

Furthermore, past research mainly examined the effects of ingroup assortative sociality using either historical pathogen prevalence

honest signal of group membership (Fincher

Thornhill, 2008, 2012; Fincher et al., 2008) or laboratory experiments (Faulkner et al., 2004; Karwowski et al., 2020; Navarrete & Fessler, 2006; Wu & Chang, 2012), instead of people’s collective reactions during a deadly pandemic such as the current COVID-19.

Although previous studies have shown that pathogen prevalence was related to ingroup assortative sociality (Fincher & Thornhill, 2008, 2012; Fincher et al., 2008; Tybur et al., 2016), this research provided further solid evidence for the effect of ingroup assortative sociality on mitigating a novel infectious disease which has led to a global health crisis (Pollard et al., 2020). Although Fincher and Thornhill (2012) propose that strength of family ties and religiosity are two extended elements of ingroup assortative sociality, the current findings showed that religiosity had a relatively stronger effect on mitigating the current COVID-19 pandemic than did family ties. This finding is consistent with previous research showing that religiosity was a strategy avoiding parasitic infection (Fincher & Thornhill, 2008) and partially consistent with the finding that religious people had a lower risk of getting sick (Ahrenfeldt et al., 2018). According to Fincher and Thornhill (2012), religiosity is a costly signal, which reliably shows one’s strong commitment and loyalty to ingroup members, as religious people make great efforts to fully incorporate religious beliefs and practices into their lives. As religiosity is an honest signal of group membership (Fincher & Thornhill, 2008) and shows one’s ingroup embeddedness (Fincher & Thornhill, 2012), it could suggest that people who are dedicated to religious groups or have greater interests in religion are more self-motivated to isolate themselves from outgroup members (Fincher & Thornhill, 2012), which could help them avoid getting novel infectious diseases.

Because the parasite-stress theory does not conceive that an immediate infectious disease threat would promote immediate ingroup assortative sociality (Fincher & Thornhill, 2008, 2012; Fincher et al., 2008), it was found that progression of actual COVID-19 severity only weakly predicted ingroup assortative sociality indices when epidemiological and web search time series data were analyzed. Instead, since web search data capture people’s information-seeking behaviors (Li et al., 2020) and that seeking for COVID-19 information induced ingroup bias as a reactive response to immediate (perceived) COVID-19 threat (Sorokowski et al., 2020), the current study found that searching COVID-19 information via Google promoted ingroup assortative sociality. As postulated in Thornhill and Fincher (2014a) and Thornhill and Fincher (2014b) that ingroup assortative sociality is an aspect of behavioral immune system, the present finding connects the parasite-stress theory of sociality and the behavioral immune system theory to show that infectious diseases may encourage ingroup assortative sociality indirectly via a high level of concern about parasitic infection at a group level.

Pelham et al. (2018) questioned how a pathogen perspective would contribute to the understanding of changes of the collective levels of interests in religious search terms. The present research responded to this issue by showing that searching for the novel coronavirus via Google was related to people’s religiosity, thereby providing support to previous experimental research, which found

### Table 4

The effect of weekly-level COVID-19 concern on weekly-level religion-secularism interest index in a multilevel analysis in Study 2b (N = 2,652).

| Variables                                | Level-1 Model ICC = .08 | Level-2 Model ICC = .05 |
|------------------------------------------|-------------------------|-------------------------|
|                                          | Effect size  | B     | SE    | df | t     | Effect size | B     | SE    | df | t     |
|                                          | f²           |       |       |    |      | f²          |       |       |    |      |
| Weekly-level predictors:                 |             |       |       |    |      |             |       |       |    |      |
| Religion-secularism interest index in the prior week | .038         | 0.13  | 0.02  | 2592.40 | 6.96*** | .030         | 0.13  | 0.02  | 2430.72 | 6.53*** |
| COVID-19 concern in the present week    | .028         | 0.18  | 0.02  | 2552.94 | 9.92*** | .033         | 0.16  | 0.02  | 2401.25 | 9.94*** |
| State-level predictors:                  |             |       |       |    |      |             |       |       |    |      |
| Strength of family ties                  | .002         | 1.25  | 0.83  | 35.61 | 1.50  |             |       |       |    |      |
| Religious participation                 | 0.0         | 0.12  | 0.15  | 35.54 | 0.79  |             |       |       |    |      |
| Marriage-divorce interest index         | 0.0         | –0.01 | 0.19  | 35.52 | –0.05 |             |       |       |    |      |
| Religion-secularism interest index      | 0.0         | 0.01  | 0.10  | 35.52 | 0.09  |             |       |       |    |      |
| Partisanship                            | 0.0         | 0.08  | 0.06  | 35.57 | 1.21  |             |       |       |    |      |
| Parasite stress                         | 0.0         | –0.29 | 1.51  | 35.52 | –0.19 |             |       |       |    |      |
| Collectivism                            | 0.004        | –0.33 | 0.19  | 35.63 | –1.77* |             |       |       |    |      |
| Per capita personal income              | 0.01         | 0.00  | 0.00  | 35.52 | 0.16  |             |       |       |    |      |
| Latitude                                | 0.005        | –0.52 | 0.27  | 35.64 | –1.94 |             |       |       |    |      |
| Longitude                               | 0.000        | 0.07  | 0.07  | 35.56 | 1.06  |             |       |       |    |      |

Note. a = Negative values were fixed to 0. Two-tailed tests were conducted. *p < .1, **p < .001.

### General discussion

The present research provides evidence that: 1) ingroup assortative sociality could function proactively to defend U.S. people against the novel coronavirus, 2) ingroup assortative sociality could also be a reactive response to the novel coronavirus, and 3) compared with family ties, religiosity might be a more important extended element of ingroup assortative sociality during the deadly pandemic. Thus, the current findings partially support that ingroup assortative sociality is a disease-avoidance strategy at a group level (Fincher & Thornhill, 2008; Fincher et al., 2008), which is an adaptive response to heightened parasite-stress (Fincher & Thornhill, 2012). Because the present research used objective epidemiological data on COVID-19 severity and employed web search data to capture the overall picture of a large population, instead of relying on a limited number of self-report measures (Alper, 2019; Lai et al., 2017; Maclnnis & Hodson, 2015; Pelham et al., 2018), the current findings could have high ecological validity (Lai et al., 2017). Furthermore, past research mainly examined the effects of ingroup assortative sociality using either historical pathogen prevalence data (Fincher & Thornhill, 2008, 2012; Fincher et al., 2008) or laboratory experiments (Faulkner et al., 2004; Karwowski et al., 2020; Navarrete & Fessler, 2006; Wu & Chang, 2012), instead of people’s collective reactions during a deadly pandemic such as the current COVID-19.
that activating people’s thoughts of infectious diseases promoted their ingroup assortative sociality such as ethnocentrism (Navarrete & Fessler, 2006), xenophobia (Paulkner et al., 2004) and conformity (Wu & Chang, 2012). The current findings also provided ecological support to recent experimental studies, which showed that manipulating participants to perceive a higher level of COVID-19 threat resulted in their increased conservatism and outgroup prejudice (Karwowski et al., 2020; Sorokowski et al., 2020). Moreover, as coronavirus related searches captured one’s fear and worry of COVID-19 (Du et al., 2020), ingroup assortative sociality might serve as a terror management process (Pelham et al., 2018). Thinking about death increases people’s defense of their cultural worldviews (Burke et al., 2010) and subtle cues related to death could activate people’s terror management (Pelham et al., 2018). Given that the novel coronavirus is a globally health crisis (Pollard et al., 2020) that has led to high death tolls in the United States (Weinberger et al., 2020), the longitudinal relationship between coronavirus-related search and religion-related search could suggest that religiosity may play an important role in the terror management process among American people during the deadly pandemic.

Overall, the present research suggests that religiosity is an important extended element of ingroup assortative sociality (Fincher & Thornhill, 2012), which may function proactively to defend U.S. people against actual COVID-19 threat and help them manage the terror of death during the deadly pandemic. The findings in Study 1 that state-level religiosity was a robust predictor of state-level and county-level COVID-19 severity support that parasite-stress theory could explain group-level ingroup assortative sociality phenomenon (Fincher & Thornhill, 2008, 2012; Fincher et al., 2008). Since web search data capture information-seeking behaviors of a large population (Alper, 2019; Lai et al., 2017; Pelham et al., 2018), the findings in Study 2 that when concerns about COVID-19 were in the collective consciousness in a given week, collective levels of ingroup assortative sociality increased from the previous week may offer further support to the behavioral immune system theory and terror management theory as perceiving a heightened COVID-19 threat has recently been found to induce a series of reactive responses such as conservatism (Karwowski et al., 2020) and outgroup prejudice (Sorokowski et al., 2020), which are also typical terror management processes (Burke et al., 2013).

Given that pathogen prevalence was strongly related to ingroup assortative sociality globally (Fincher & Thornhill, 2012; Fincher et al., 2008; Thornhill et al., 2010), it is plausible that the present findings are not only specific to the United States. Future studies are recommended to investigate the relation between COVID-19 pandemic and ingroup assortative sociality in other countries. Although the marriage-divorce interest index had shown satisfactory convergent validity with ingroup assortative sociality measures (Fincher & Thornhill, 2012; Vandello & Cohen, 1999), the search keywords involved were more focused on the interest in establishing intimate and committed romantic relationships, which may not fully reflect different aspects of family ties. Thus, future research could use other Google search terms or methods to investigate the role of family ties in the COVID-19 pandemic. In addition, since the effect sizes of the relationships between COVID-19 threat (actual and perceived) and ingroup assortative sociality indices were relatively small, it would be worthwhile to explore other possible factors in the process so that a fuller understanding of the phenomenon about infectious diseases and the related theories could be achieved.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ijintrel.2021.07.010.

References

Ackerman, J. M., Hill, S. E., & Murray, D. R. (2018). The behavioral immune system: Current concerns and future directions. Social and Personality Psychology Compass, 12(2), Article e12371. https://doi.org/10.1111/spc3.12371.

Adedokun, K. A., Olarinnmoye, A. O., Mustapha, J. O., & Kamorudeen, R. T. (2020). A close look at the biology of SARS-CoV-2, and the potential influence of weather conditions and seasons on COVID-19 case spread. Infectious Diseases of Poverty, 9(1), 1–5. https://doi.org/10.1186/s40249-020-00688-1.

Agency for Toxic Substances and Disease Registry. (2020). CDC SVI data and documentation download. https://www.astdr.cdc.gov/placeandhealth/hsi/data_documentation_download.html.

Ahrenfeldt, L. J., Möller, S., Hvidt, N. C., & Lindahl-Jacobsen, R. (2018). Religiousness and lifestyle among Europeans in SHARE. Public Health, 165, 74–81. https://doi.org/10.1016/j.puhe.2018.09.009.

Aiken, L. S., West, S. G., & Reno, R. R. (1991). Multiple regression: Testing and interpreting interactions. Sage.

Alper, S. (2013). Does the association between illness-related and religious searches on the internet depend on the level of religiosity? Social Psychological and Personality Science, 12(4), 497–505. https://doi.org/10.1177/1948550612462323.

Acora, Y. S., McKee, M., & Stuckler, D. (2019). Google Trends: Opportunities and limitations in health and health policy research. Health Policy, 123(3), 338–341. https://doi.org/10.1016/j.healthpol.2019.01.001.

Barber, N. (2013). Country religiosity declines as material security increases. Cross-Cultural Research, 47(1), 42–50. https://doi.org/10.1177/1069377112463328.

Barni, D., Vieno, A., Roccato, M., & Russo, S. (2016). Basic personal values, the country and the fear of crime. Social Indicators Research, 129(3), 1057–1074. https://doi.org/10.1007/s11205-015-1161-9.

Bellmann, M., Köts-Ausmeen, L., & Realo, A. (2018). The relationship between social capital and individualism–collectivism in Europe. Social Indicators Research, 137(2), 641–664. https://doi.org/10.1007/s11205-017-1414-4.

Burke, B. L., Kosloff, S., & Landau, M. J. (2013). Death goes to the polls: A meta-analysis of mortality salience effects on political attitudes. Political Psychology, 34(2), 183–200. https://doi.org/10.1111/pops.12005.
Burke, B. L., Martens, A., & Faucher, E. H. (2010). Two decades of terror management theory: A meta-analysis of mortality salience research. Personality and Social Psychology Review, 14(2), 155–195. https://doi.org/10.1177/1088868309352321.

Cashdan, E., & Steele, M. (2013). Pathogen prevalence, group bias, and collectivism in the standard cross-cultural sample. Human Nature, 24(1), 59–75. https://doi.org/10.1007/s12110-012-9159-3.

CDC COVID-19 Response Team. (2020). Geographic differences in COVID-19 cases, deaths, and Incidence-United States, February 12-April 7, 2020. Morbidity and Mortality Weekly Report, 69(15), 465–471. https://doi.org/10.15585/mmwr.mm6915e4.

Chan, H.-W. (2020). When do values promote pro-environmental behaviors? Multilevel evidence on the self-expression hypothesis. Journal of Environmental Psychology, 71, Article 103161. https://doi.org/10.1016/j.jenvp.2019.103161.

Chen, M.-K., & Rohila, R. (2018). The effect of partisanship and political advertising on close family ties. Science, 360(6392), 1020–1024. https://doi.org/10.1126/science.aay1433.

Clay, R., Terrizzi, J. A., Jr., & Shook, N. J. (2012). Individual differences in the behavioral immune system and the emergence of cultural systems. Social Psychology, 43(4), 174–184. https://doi.org/10.1027/0266-4335.a000118.

Connor, P., Sarafidis, V., Zythpr, M. J., Keltner, D., & Chen, S. (2019). Income inequality and White-on-Black racial bias in the United States: Evidence from project impact and Google Trends. Psychological Science, 30(2), 205–222. https://doi.org/10.1177/0956797618810027.

Diez-Roux, A. V. (2000). Multilevel analysis in public health research. Annual Review of Public Health, 21(1), 171–192. https://doi.org/10.1146/annurev.publhealth.21.1.171.

Dilmaghani, M. (2020). Who is not afraid of Richard Dawkins? Using google trends to assess the reach of influential atheists across Canadian secular groups. Studies in Religion/Sciences Religieuses, 49(2), 268–289. https://doi.org/10.1007/s13100-020-00017-3.

Du, H., Yang, J., King, R. B., Yang, L., & Chi, P. (2020). COVID-19 increases online searches for emotional and health-related terms. Scientific Reports, 10(1), 1053. https://doi.org/10.1038/s41598-020-56375-6.

Effenberger, M., Kronbichler, A., Shin, J. I., Mayer, G., Tilg, H., & Perco, P. (2020). Association of the COVID-19 pandemic with internet search volumes: A google trends analysis. Journal of Intercultural Relations, 81, 195–197. https://doi.org/10.1177/0956797619854153.

Fincher, C. L., & Thornhill, R. (2012). Parasite-stress promotes in-group assortative sociality: The cases of strong family ties and heightened religiosity. Behavioral and Brain Sciences, 35(2), 61–79. https://doi.org/10.1017/S0140525X12000002.

Fincher, C. L., Thornhill, R., Murray, D. R., & Schaller, M. (2008). Pathogen prevalence predicts human cross-cultural variability in individualism/collectivism. Proceedings of the Royal Society B: Biological Sciences, 275(1640), 1279–1285. https://doi.org/10.1098/rspb.2008.0994.

Gokmen, Y., Baskici, C., & Ercil, Y. (2020). The impact of national culture on the increase of COVID-19: A cross-country analysis of European countries. Brain Sciences, 10(4), 174–201. https://doi.org/10.3390/brainsci10040201.

Grossmann, I., & Varnum, M. E. (2015). Social structure, infectious diseases, disasters, secularism, and cultural change in America. Psychological Science, 35(10), 324–325. https://doi.org/10.1177/0956797615628833.

Huang, F., Ding, H., Liu, Z., Wu, P., Zhu, M., Li, A., & Zhu, T. (2020). How fear and collectivism influence public preventive intention towards COVID-19 infection: A study based on big data from the social media. China, 2020. Eurosurveillance, 25(3), Article e2003117. https://doi.org/10.2807/1560-7917.es.2020.25.3.e2003117.

Husain, I., Briggs, B., Lefebvre, C., Cline, D. M., Stopyra, J. P., O’Reilly, R. P., & Lydon, S. (2020). Who is afraid of Richard Dawkins? Using google trends to assess the reach of influential atheists across Canadian secular groups. International Journal of Infectious Diseases, 95, Article 1053. https://doi.org/10.1016/j.ijid.2020.04.033.

Ives, A. R., & Bozzuto, C. (2021). Estimating and explaining the spread of COVID-19 at the county level in the USA. Nature Human Behaviour, 5(11), 1186–1197. https://doi.org/10.1038/s41562-021-00965-0.

Lai, K., Lee, Y. X., Chen, H., & Yu, R. (2017). Research on web search behavior: How online query data inform social psychology. Applied Psychology: Health and Well-Being, 9(2), 225–252. https://doi.org/10.1111/aphw.12237.

Legendre, P. (1993). Spatial autocorrelation: Trouble or new paradigm? Human Ecology, 21(1), 1–17. https://doi.org/10.1007/BF02206028.

Lorah, J. (2018). Effect size measures for multilevel models: Definition, interpretation, and TIMSS example. International Journal of Intercultural Relations, 81(2), 168–180. https://doi.org/10.1016/j.ijintrel.2018.04.001.

MacInnis, C. C., & Hodson, G. (2015). Do American states with more religious or conservative populations search more for sexual content on Google? Archives of Sexual Behavior, 44(4), 137–147. https://doi.org/10.1007/s10508-014-0361-4.

Margolis, M. F. (2018). How politics affects religion: Partisanship, socialization, and religiosity in America. The Journal of Politics, 80(1), 30–43. https://doi.org/10.1086/694668.
