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# What doesn't kill you makes you "smarter": The long-term association between exposure to epidemic and cognition

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## ABSTRACT

Emerging epidemics have devastating impacts on people's lives and livelihoods. However, acting as a severe health shock, exposure to an epidemic may induce positive changes in health behaviors among survivors, thereby leading to long-lasting improvement in population health. This study examined the long-term association between exposure to the 2002–2004 severe acute respiratory syndrome outbreak and middle-aged and older Chinese adults' cognition assessed in 2011–2015. Drawing on data from the 2011–2015 China Health and Retirement Longitudinal Study, we found that community exposure to the outbreak was associated with significantly higher scores on episodic memory, after adjusting for demographic characteristics, adulthood socioeconomic status and health, and community socioeconomic conditions. No such a significant association was found for mental intactness. Mediation analysis showed that community exposure to the epidemic was associated with increased participation in social activities, maintaining close family relationships with adult children and grandchildren, and increased participation in regular physical exercise, all of which were positively associated with cognitive functioning in middle-aged and older Chinese adults. These findings suggest that positive post-epidemic behavioral changes are possible and may have long-term health benefits for survivors.

## 1. Introduction

Despite a continued decrease in the burden of infectious diseases on a global scale, they still account for nearly 20% of deaths and remain the leading cause of years of life lost for certain vulnerable populations (GBD 2017 Causes of Death Collaborators, 2018). Among infectious diseases, lower respiratory infections are a leading cause of mortality worldwide for people of all ages, especially young children and older adults in low- and middle-income countries (Troeger et al., 2018). On the other hand, emerging infectious diseases have increased significantly since 1940 due to changes in socioeconomic, environmental, and ecological conditions (Jones et al., 2008). Emerging infectious diseases cause substantial damage to public health and the global economy. Notable examples during the last two decades include the 2002–2004 severe acute respiratory syndrome (SARS) outbreak, the 2009 swine flu pandemic, the 2012 Middle East respiratory syndrome coronavirus outbreak, and the ongoing coronavirus disease 2019 (COVID-19) pandemic.

SARS and COVID-19 are caused by two related virus strains—SARS-CoV-1 and SARS-CoV-2. The SARS outbreak started in China in

November 2002, and the major part of the outbreak lasted about 8 months, leading to more than 8,000 cases and 800 deaths in 29 countries and territories (WHO, 2004). The World Health Organization (WHO) declared the SARS outbreak contained in early July 2003, although a few additional SARS cases were reported until May 2004 (WHO, May 18, 2004). Similar to COVID-19, middle-aged and older people were at a higher risk of SARS infection, partly because they were more likely to have severe underlying medical conditions such as heart conditions, respiratory disease, and diabetes than younger people (CDC, 2020). In China, the median age of people with SARS was 42 years old, and the case fatality ratios were much higher for those between 45 and 64 (15%) or 65 and older (52%) than those between 25 and 44 (6%) (WHO, 2003).

Despite the devastating impacts of emerging epidemics on public health and the economy, recent research has revealed a silver lining. Acting as a severe health shock, exposure to an epidemic may induce positive changes in health behaviors among survivors, thereby leading to a long-lasting improvement in population health. For example, one recent study found that in Mexico, the 2009 H1N1 pandemic caused positive changes in hygiene practices such as frequent hand washing and increased use of hand sanitizers, which led to fewer diarrhea-related

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cases among young children in 2010–2012 (Agüero and Beleche, 2017). Another study also found that among middle-aged and older Chinese adults, those who lived in communities with a SARS outbreak in 2002–2004 were more likely to seek a physical examination, have their blood pressure checked, and participate in regular physical exercise after the SARS epidemic, compared with those who lived in communities not affected by the epidemic (Zou et al., 2021).

In fact, ancient insight from philosophy and religion indicates that adversity, a life crisis, and trauma can be potential sources of positive changes (Grace et al., 2015; Tedeschi and Calhoun, 2004). Psychologists have theorized that transformative personal growth (e.g., new appreciation for life, newfound sense of personal strength, and improved relationships with others) occurs after surviving traumatic life events (Tedeschi & Calhoun, 1995, 2004). This post-traumatic growth theory has been applied to studies of psychological well-being and social relationships among patients who had severe personal health problems (Grace et al., 2015; McGrath, 2011) and survivors of natural disasters (Canevello et al., 2016; Dunn et al., 2014; Jin et al., 2014; Kaniasty, 2020; Wu et al., 2016). In this study, we applied and extended post-traumatic growth theory to examine the long-term cognitive health benefits of surviving a disease epidemic and the potential behavioral mediators.

Specifically, the current study examined the long-term association between exposure to the SARS epidemic in 2002–2004 and cognition in 2011–2015 among middle-aged and older Chinese adults. To do this, we drew on data from a nationally representative sample of middle-aged and older Chinese adults. We exploited the spatial variation in the SARS outbreak and compared survey participants whose communities were affected by the epidemic and those whose communities were spared. We choose cognition as the outcome of interest because for older adults, cognitive decline implies reduced ability to plan for and manage the demands of many daily tasks and ultimately, to live independently and practice self-care (Blazer et al., 2015). Understanding the risk factors of cognitive decline has important scientific and policy implications for successful aging in low- and middle-income countries like China, where population aging is accelerating.

We argue that a SARS outbreak in the community would pose an imminent public health threat to the residents, resulting in a collective trauma. The post-traumatic growth theory predicts that survivors of a SARS outbreak in the community might experience such positive psychosocial changes as greater appreciation of health and life, changed priorities in life (e.g., valuing health, balancing between work and life), and more intimate relationships with others. These psychosocial changes could further lead to behavioral changes such as increased participation in regular physical exercise, social activities, and close intergenerational relationships. In turn, these behavioral changes contribute positively to cognitive functioning in middle and older ages.

### 1.1. Theoretical background

Personal growth may coexist with suffering and psychological distress in the aftermath of traumatic events, despite any devastating damage incurred during the events. Tedeschi and Calhoun (1996, 2004) defined post-traumatic growth as the positive cognitive, emotional, and behavioral changes experienced by individuals whose development has surpassed the pre-traumatic status quo. A distinct feature of post-traumatic growth is that these positive changes go beyond an ability to resist hardship and adversity (i.e., resilience) caused by traumatic events or a return to baseline functioning in terms of self-perception, relationships with others, and opening new life possibilities (i.e., recovery).

According to Tedeschi and Calhoun (1996, 2004), traumatic events can severely challenge individuals' assumptive world—their understanding about the proximate causes and the reasons why things happen, and core beliefs about the general purpose and meaning of life. In an attempt to cope with or survive trauma psychologically, people begin to

cognitively restructure their basic assumptions about the world in a more nuanced and complex form, in light of the changed reality of their life after trauma, which leads to personal growth. Tedeschi and Calhoun (1996, 2004) have theorized five major domains of post-traumatic growth: a new and greater appreciation of life and changed priorities in life; a newfound sense of personal strength; recognition of new possibilities or paths in life; warmer, more intimate relationships with others; and spiritual development. Using population-based samples, recent research has found the coexistence of post-traumatic stress disorder and post-traumatic growth among survivors of such natural disasters as earthquakes (Jin et al., 2014; Wu et al., 2016), tsunamis (Tang, 2006), and hurricanes (Dunn et al., 2014). These studies relied on self-reported post-traumatic growth such as changing self-perception, new life priorities, and enhanced relationships with other people as psychological health outcomes. However, they rarely examined positive changes in cognition, behavior, or physical health in a more objective manner. Therefore, these studies were limited in ruling out the possibility of illusory cognitive mechanisms. That is, self-reported post-traumatic growth may not be genuine but instead represents a self-preservation or illusory coping strategy (Grace et al., 2015).

This study extended the literature on post-traumatic growth by conceiving disease epidemics as collective traumatic events and focusing on long-term behavioral changes and cognitive health. Unlike natural disasters like earthquakes, hurricanes, floods, and wildfires, disease epidemics usually do not cause substantial material losses (e.g., damage to personal belongings, property, and public infrastructure) or massive, permanent population displacement (Watson et al., 2007). The primary threats of disease epidemics are posed to human health and life. In addition, a disease epidemic may last weeks or months, if not years—much longer than some natural disasters, causing prolonged mental and physical burdens. In the aftermath of an epidemic, survivors may perceive their exposure to the disease as a “wake-up call” that offers them a second chance if they can embrace a healthy lifestyle (McGrath, 2011). This sense of a wake-up call may be particularly strong in the case of a new, seemingly mysterious disease epidemic such as SARS.

The SARS epidemic was caused by a new infectious disease that led to hundreds of deaths. During the early stage of the SARS outbreak, there was a dearth of scientific information about the cause of this novel disease, its mode of transmission, or effective treatment. In fact, there is still no cure or vaccine for SARS, and treatment is mainly supportive. Encountering such an unknown, highly contagious disease outbreak, both young and older adults frequently experience negative emotional responses such as shock, fear, anxiety, and sadness (Yeung and Fung, 2007). As people endure these negative emotions for months, they might gradually change their world views and perceptions of priorities in life. For example, in a survey conducted at the height of the SARS epidemic (May and June 2003), about 60% of Chinese participants reported positive changes brought by the SARS outbreak to their lives, including self-evaluating; having a new appreciation of life, family, and friendships; caring more about what's happening in the world; and valuing personal health, exercise, and rest more than work (Ji et al., 2004). In another survey carried out in Hong Kong when the epidemic was ending, more than one third of the respondents reported that they were willing to spend more money and time to maintain their health, compared to the pre-SARS period (Lau et al., 2005).

Motivated by the heightened levels of SARS-related fears, residents in mainland China, Hong Kong, Taiwan, Singapore, and Canada, where local outbreaks occurred, engaged in both direct and indirect preventive health behaviors to reduce the risk of infection (Bennett et al., 2015; Chang and Sivam, 2004; Lau et al., 2005; Tam et al., 2004). Direct preventive behaviors focused on reducing exposure to the SARS virus, such as wearing a face mask, washing hands frequently, monitoring body temperature daily, and avoiding public places and people who were perceived to be at a higher risk of SARS (e.g., those who had a fever, sneezed, or recently traveled from a SARS-affected region). Indirect preventive behaviors focused on boosting the immune system

through, for example, physical exercise, eating a balanced diet, and getting sufficient sleep. Throughout the SARS epidemic, many people considered these preventive measures as the only known means that could effectively mitigate the risk of contracting this potentially fatal disease (Tam et al., 2004).

As an indirect preventive health behavior, physical exercise is particularly relevant to the current study. Regular physical exercise is widely accepted as an effective and low-cost health behavior to strengthen the immune system and improve the body's ability to combat viral infections (da Silveira et al., 2020). Post-traumatic growth would suggest that in absence of an effective medical treatment even years after the epidemic, people who survived SARS infection or close exposure may develop a new appreciation of life. More importantly, they may value regular physical exercise as a long-term, cost-effective lifestyle and prioritize it in daily life. Consistent with this conjecture, a recent study has found that older Chinese adults were more likely to practice physical exercise regularly if their community had experienced a SARS outbreak (Zou et al., 2021).

Additionally, regular practice of physical activities has been associated with many cognitive health benefits. For example, both experimental and clinical studies have reported that physical exercise induces structural and functional changes in the brain such as increased gray matter volume in the frontal and hippocampal regions and reduced damage in the gray matter. These changes help enhance executive function and memory abilities in both young and older adults (Hötting and Röder, 2013; Mandolesi et al., 2018). Many studies have also demonstrated that regular physical exercise protects against aging-related cognitive decline (Niemann et al., 2014; Yaffe et al., 2009) and the risk of developing dementia (Mandolesi et al., 2017). Therefore, survivors of the SARS epidemic may enhance their cognitive functioning by adopting and prioritizing regular physical exercise as a long-term, routine preventive health behavior.

Another domain of post-traumatic growth that is particularly relevant to the current study pertains to improved relationships with others, especially those who have undergone the same suffering (Tedeschi & Calhoun, 1996, 2004). Living through such major disasters as epidemics, earthquakes, and hurricanes takes a toll on people's mental health, causing a surge in stress, anxiety, and even depression. People often resort to kinship support and social support to cope with these negative emotions during and after disasters. Furthermore, coping with a natural disaster is not only an individual experience but also a communally shared experience. Shared experience of surviving a natural disaster can instigate a strong sense of shared suffering, empathy, mutual support, and social connectedness, which can propel survivors to prosocial actions and improve interpersonal relationship quality in terms of satisfaction, commitment, closeness, and trust (Canevello et al., 2016; Fredman et al., 2010; Kaniasty, 2020).

However, unlike such natural disasters as earthquakes, hurricanes, or wildfires, the contagious nature of an epidemic entails self-isolation or even mandatory quarantine as a public health intervention, thereby further exacerbating the detrimental mental health effect. As a result, people may develop an even stronger craving for social connectedness and engagement during or after an epidemic. For example, when comparing the SARS period with the pre-SARS period, Hong Kong residents reported that they cared more about their family members' feelings, shared feelings with others more frequently, and felt their family members and friends to be more supportive (Lau et al., 2006). In Beijing, college students who were quarantined on campus during the height of the SARS epidemic reported that they appreciated family and friends more than before and felt closer to them (Ji et al., 2004). In Japan, individuals' past experiences with natural disasters tended to increase both the number of voluntary associations in which they participate and their degree of involvement (J. Lee and Fraser, 2019; Yamamura, 2016).

Numerous studies have also shown that older adults who are more socially engaged experience less cognitive decline and a reduced risk of

developing dementia (Burn and Szoek, 2015; Hilbrand et al., 2017). In particular, several longitudinal studies have shown that frequent face-to-face contact with adult children and taking care of grandchildren are associated with better attention, episodic memory, and mental intactness among middle-aged and older Asian adults (S. H. Lee and Kim, 2016; Pan et al., 2020; Xu, 2021). Therefore, survivors of the SARS epidemic may enhance their cognitive functioning by improving their relationships with families and friends and participating in social activities.

Using observed variables from our data, Fig. 1 summarizes the theoretical framework. We argued that a SARS outbreak in the community was a collective traumatic event shared by residents. Due to the highly contagious transmission of SARS, the entire community would be put into lockdown if there was an outbreak (WHO, 2003), and the community residents were likely to feel collectively heightened fears of imminent public health threat, regardless of their individual-specific exposure, because SARS hit home both figuratively and literally (Kaniasty, 2020). As a novel, highly contagious, and potentially fatal disease, a local SARS outbreak could pose a serious challenge to the community residents' assumptive world and induce such changes in their cognitive schemas as having new appreciation and higher prioritization of life, health, family, friends, and other social relationships. In turn, these changes in beliefs and values could lead to changes in individuals' health and social behaviors, some of which could have a lasting positive impact on cognitive functioning even years later after the epidemic. We proposed the following hypotheses to be tested in this study:

**Hypothesis 1.** (overall effect): Community exposure to SARS during 2002–2004 was associated with better cognitive functioning in 2011 in middle-aged and older Chinese adults.

**Hypothesis 2.** (mediation effect): Community exposure to SARS was associated with closer intergenerational relationship (2a), increased participation in social activities (2b), and increased participation in regular physical exercise (2c), all of which were associated with better cognitive functioning in middle-aged and older Chinese adults.

## 2. Data and methods

### 2.1. Study participants

The data were drawn from the China Health and Retirement Longitudinal Study (CHARLS), a nationally representative longitudinal survey of adults aged 45 or older and their spouses, if available. CHARLS sampled 17,705 residents from 150 counties across 28 provinces in China. The national baseline survey of CHARLS was conducted in 2011, with a response rate of 80.5% (Zhao et al., 2014). The 2011 baseline survey included a community module collecting data from local officials about current socioeconomic conditions and community histories. In 2014, a follow-up survey was conducted to collect data on respondents' retrospective life histories, including health behaviors and health care utilization prior to the 2011 baseline survey. We used data from the 2011 baseline survey in the main analysis because the baseline sample was nationally representative (after weighting), and it collected the key independent variable of community exposure to SARS in this study. Due to longitudinal sample attritions over time, we only used data from later waves in the sensitivity analyses to examine whether our results from the 2011 baseline were robust during the post-SARS period of 2011–2015.

We started constructing the analytic sample by restricting the sample to 17,247 main respondents and their spouses who were 45 years old or older at baseline after excluding younger spouses under age 45. To ensure that community exposure to a SARS outbreak was correctly identified, we dropped 1,262 respondents whose place of residence before 2003 could not be established in the CHARLS data. In other words, we further restricted the sample to 15,985 respondents who

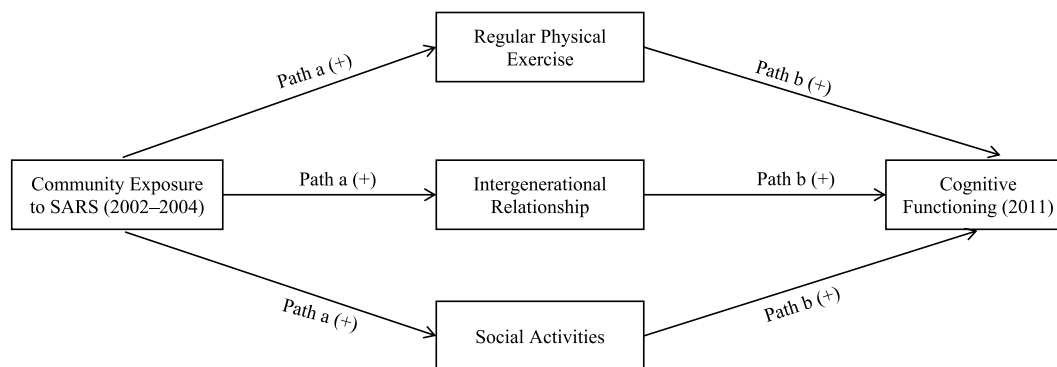


Fig. 1. Conceptual pathways linking community exposure to SARS to cognitive functioning.

either had been living in the same community since birth or had moved to their current community before 2003 so that we could use the community history data from the 2011 CHARLS to accurately capture their exposure to the SARS epidemic.

We then narrowed the analytic sample by using data from the 2011 community survey of CHARLS, in which local officials were asked to enumerate natural disasters and epidemics that occurred in the past. Using this information, we identified 62 communities (across 38 prefectures) where SARS outbreaks occurred. We considered the 2,079 respondents who lived in these communities at the time of the SARS epidemic as having community exposure to SARS, or the treatment group, in this study. Accordingly, we considered those who lived in the same prefectures but different communities where no SARS outbreaks occurred as the appropriate control group. The control group included 2,743 respondents living in 73 communities that were not exposed to SARS.

Finally, we excluded 986 respondents who had missing data on the cognitive outcomes and another 120 respondents who had missing data on the independent variables. The analytic sample for the main analysis consisted of 1,619 respondents living in 62 SARS-exposed communities and 2,097 respondents living in 72 nonexposed communities. For the mediation analysis, the sample size was further reduced to 3,179, mainly due to missing data on a mediator measured in the 2014 life history survey.

## 2.2. Dependent variables

Following recent analyses of the CHARLS data (Xu et al., 2018; Zhang et al., 2018, 2019), we constructed three dependent variables of cognitive function: episodic memory, mental intactness, and cognitive summary score. First, episodic memory was assessed by immediate and delayed recall of 10 words. Ten Chinese nouns were read to participants, who were then asked to immediately recall, in any order, as many words as possible. Four minutes later, participants were asked to recall the same list of 10 words. Scores of immediate and delayed recall were coded separately as the number of words correctly repeated, each ranging from 0 to 10. A single score of episodic memory was calculated by averaging the scores of immediate and delayed recalls (average recall). Second, mental intactness was constructed as a summary score of the serial 7s test, time orientation, and visuoconstruction from the Telephone Interview of Cognitive Status battery (Luo et al., 2019; Pan et al., 2020; Xu et al., 2018). The serial 7s test (5 points) asked respondents to subtract 7 from 100 up to five times. The time orientation task (5 points) asked respondents to name the current date (year, month, and day), day of the week, and season of the year. The visuoconstruction task (1 point) asked the respondents to redraw a picture of two overlapped pentagons shown to them. The third cognitive measure was calculated as the summary score of episodic memory and mental intactness, reflecting respondents' overall cognitive status with values

ranging from 0 to 21.

## 2.3. Independent variables

The key independent variable of interest was community exposure to SARS, coded 1 if there was a SARS outbreak in the respondent's community during the 2002–2004 epidemic or coded 0 otherwise. The SARS epidemic was a nationally salient public health crisis in China, and it occurred less than a decade before the 2011 baseline survey of CHARLS. Therefore, the retrospective recall of local SARS outbreaks by community officials was likely to be reliable. As of 2011, the entire country of China was divided into 345 prefectures, each of which consisted of several counties, resulting in 3,872 counties nationwide. For the sake of confidentiality, CHARLS only released geographic information down to the prefecture level. Fig. 2 shows the map of the prefectures where at least one of the surveyed communities experienced a SARS outbreak (treatment group) and those where none of the surveyed communities experienced an outbreak (control group).

We controlled for respondents' demographic, socioeconomic, and health characteristics. The demographic characteristics included age groups (younger than 50, 50–59, 60–69, and 70 or older), gender (male or female), marital status (married or not), and number of living adult children. The socioeconomic characteristics included educational attainment (completed primary education or not) at the individual level, annual household consumption per capita (in 1,000 RMB), the rural–urban status of communities, and interviewers' ratings of community economic conditions on a 7-point Likert scale, ranging from 1 (*very poor*) to 7 (*very rich*). We collapsed the 7-point Likert scale into three categories, "poor or very poor," "average," and "rich or very rich," to avoid small cell sizes. Health characteristics included number of self-reported chronic conditions (range: 0–14).

## 2.4. Mediators

All three mediators were constructed as dichotomous variables. Participation in social activities indicates whether respondents ever participated (0 = *no*, 1 = *yes*) in at least one of the following nine social activities in the past month: (a) interacting with friends; (b) playing mahjong, chess, or cards or going to a community club; (c) providing help to family, friends, or neighbors who did not live with the respondent and did not pay for the help; (d) attending a sport, social, or other kind of club; (e) taking part in a community-related organization; (f) doing volunteer or charity work; (g) caring for a sick or disabled adult who did not live with the respondent and did not pay for the help; (h) attending an educational or training course; and (i) other. Intergenerational relationship indicates whether respondents were engaged (0 = *no*, 1 = *yes*) in at least one of the following family activities: (a) having weekly in-person contact with adult children; (b) having weekly in-person contact with parents or parents-in-law; and (c) providing care

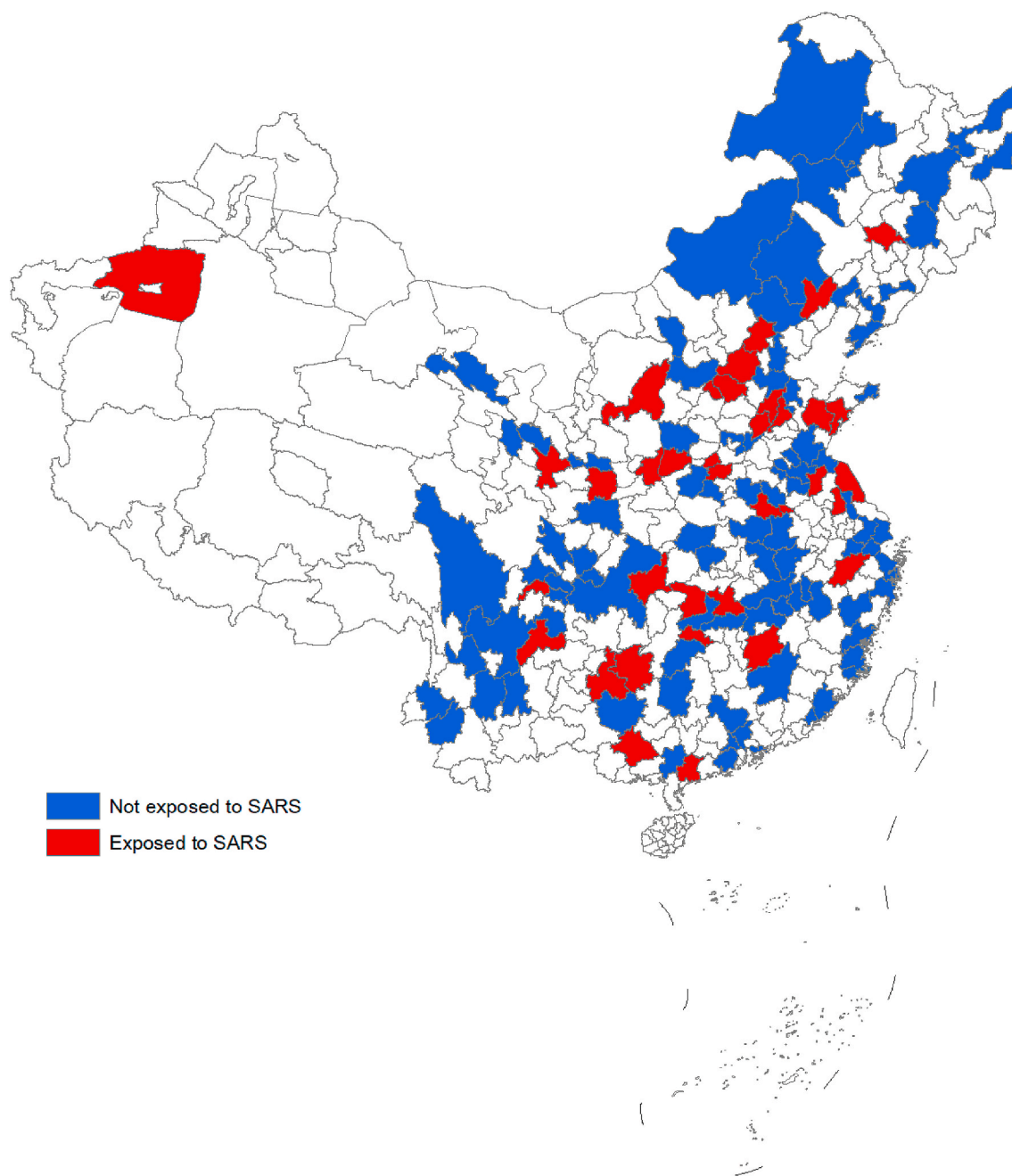


Fig. 2. Geographic distribution of SARS outbreaks at the prefecture level from the 2011 community survey of CHARLS.

to grandchildren in the past year. The third mediator—participation in regular physical exercise—was drawn from the 2014 life history survey. Using retrospective self-reports of health behaviors, we constructed a dichotomous variable indicating whether in the years after the 2002–2004 SARS epidemic, respondents ever participated in regular physical exercise for at least one year (Zou et al., 2021).

2.5. Statistical methods

The main analysis of this study involved two steps. First, we examined the association between community exposure to SARS in 2002–2004 and cognitive functioning in 2011 (i.e., Hypothesis 1) by estimating the following regression model:

$$Y_{ijp}^{2011} = \alpha + \beta \times SARS_{jp}^{2002-2004} + \gamma X_{ijp}^{2011} + \theta Z_{jp}^{2011} + \delta_p + \varepsilon_{ijp} \quad (1)$$

where  $Y_{ijp}^{2011}$  denotes the cognitive outcome variable for  $i$ th respondent living in  $j$ th community of  $p$ th prefecture;  $SARS_{jp}^{2002-2004}$  is the key independent variable indicating whether  $j$ th community of  $p$ th prefecture had a SARS outbreak in 2002–2004 or not;  $X_{ijp}^{2011}$  is a vector of all individual- and household-level control variables measured in 2011; and  $Z_{jp}^{2011}$  represents all community-level control variables. This model also controlled for prefecture fixed effects, denoted by  $\delta_p$ . Robust standard errors were calculated to adjust for sample clustering at the community level.

Second, we examined the extent to which the association between community exposure to SARS and cognitive functioning could be accounted for by the three mediators (i.e., Hypotheses 2a–2c) through path analysis. The regression coefficient  $\beta$  as specified in Equation (1) corresponds to path  $c$  (not shown), representing the total effect, or the

effect without mediation in mediation analysis. We then regressed potential mediators on community exposure to SARS, while adjusting for other control variables, to obtain the estimates of path *a* (see Fig. 1). Finally, we added the mediators as independent variables to Equation (1) and obtained the estimates of path *b* (see Fig. 1) and path *c'* (not shown). We calculated the product of path *a* and path *b* for each mediator as the estimate of the indirect effect; that is, the association between community exposure to SARS and cognitive functioning explained by a potential mediator. A path *c'* represents the effect of community exposure to SARS on a health outcome after accounting for the mediators. We calculated bootstrap standard errors with 2000 replications for statistical inference (Preacher and Hayes, 2008).

### 3. Results

#### 3.1. Descriptive results

Table 1 summarizes the descriptive statistics for the dependent and independent variables. All variables were measured at the 2011 baseline except for regular physical exercise, which was measured in the 2014 life history survey. In terms of the dependent variables, respondents whose communities experienced a SARS outbreak scored on average significantly higher on episodic memory (3.81) than those whose communities were not affected (3.50). The former also had on average a significantly higher score on mental intactness (7.81 versus 7.60, respectively), though the advantage was relatively smaller, compared to episodic memory. As a result, the respondents who were exposed to SARS had a significantly higher average cognitive summary score

**Table 1**  
Descriptive statistics of the dependent and independent variables.

	Exposed to SARS		Unexposed		$\Delta$ Mean
	N	Mean	N	Mean	
<i>Dependent variables</i>					
Episodic memory (range: 0–10)	1,619	3.81	2,097	3.50	0.31***
Mental intactness (range: 0–11)	1,619	7.81	2,097	7.60	0.21*
Cognitive summary (range: 0–21)	1,619	11.62	2,097	11.10	0.52***
<i>Adulthood control variables</i>					
Age					
Younger than 50	1,619	0.22	2,097	0.21	0.01
50–59	1,619	0.34	2,097	0.39	–0.05**
60–69	1,619	0.30	2,097	0.28	0.02
70+	1,619	0.15	2,097	0.13	0.02†
Gender (1 = female, 0 = male)	1,619	0.50	2,097	0.49	0.00
Primary school or higher (1 = yes, 0 = no)	1,619	0.65	2,097	0.59	0.05***
Married (1 = yes, 0 = no)	1,619	0.89	2,097	0.90	–0.01
Household consumption per capita (1,000 yuan)	1,619	11.48	2,097	8.46	3.02***
Living children ( <i>n</i> )	1,619	2.56	2,097	2.62	–0.06
Self-reported chronic conditions ( <i>n</i> , range: 0–14)	1,619	1.53	2,097	1.41	0.12*
Rural–urban residence (1 = rural, 0 = urban)	1,619	0.47	2,084	0.70	–0.23***
Community economic condition					
Poor	62	0.23	72	0.36	–0.14†
Ordinary	62	0.40	72	0.40	0.00
Rich	62	0.37	72	0.24	0.13†
<i>Mediators</i>					
Participation in social activities (1 = yes, 0 = no)	1,619	0.51	2,096	0.49	0.02
Intergenerational relationship (1 = weekly contact, 0 = no)	1,615	0.93	2,097	0.88	0.05***
Regular physical exercise (1 = yes, 0 = no)	1,343	0.19	1,840	0.13	0.06***

Note: All variables were measured at the 2011 baseline of CHARLS except regular physical exercise, which was measured in the 2014 life history survey. †*p* < .10; \**p* < .05; \*\**p* < .01; \*\*\**p* < .001.

(11.62) than those who were not (11.01).

Turning to the independent variables, there was few differences based on SARS exposure in terms of demographic characteristics (age, gender, marital status, and number of adult children). However, compared with those whose communities were not affected, the respondents whose communities experienced a SARS outbreak appeared to have higher socioeconomic status. For example, they were more likely to have completed primary school or higher education (65% versus 59%), had a significantly higher average level of annual household consumption per capita (11,480 versus 8,460 yuan), and were less likely to live in rural areas (47% versus 70%). On the other hand, those who were exposed to SARS reported significantly more chronic conditions (1.53 versus 1.41). In terms of the mediators, those who were exposed to SARS were significantly more likely to maintain a close intergenerational family relationship (93% versus 88%) and participate in regular physical exercise (19% versus 13%) than those who were not exposed. There was no statistically significant difference in participation in social activities.

#### 3.2. Regression estimates

The regression estimates are shown in the top panel of Table 2. According to the estimates, living in communities that experienced a SARS outbreak was significantly associated with a 0.201-point higher score on episodic memory (measured on a scale of 0–10) nearly a decade later, after adjusting for adulthood control variables and prefecture fixed effects. The association was not statistically significant for mental intactness or the cognitive summary score. The bottom panel of Table 2 shows the regression estimates after we applied five multiple imputations for missing data using chained equations. The sample size increased by about 30%, but the results remained qualitatively unchanged. Living in communities that experienced a SARS outbreak was significantly associated with a 0.150-point higher score on episodic memory nearly a decade later, after adjusting for adulthood control variables and prefecture fixed effects. However, the association was not statistically significant for mental intactness or the cognitive summary score.

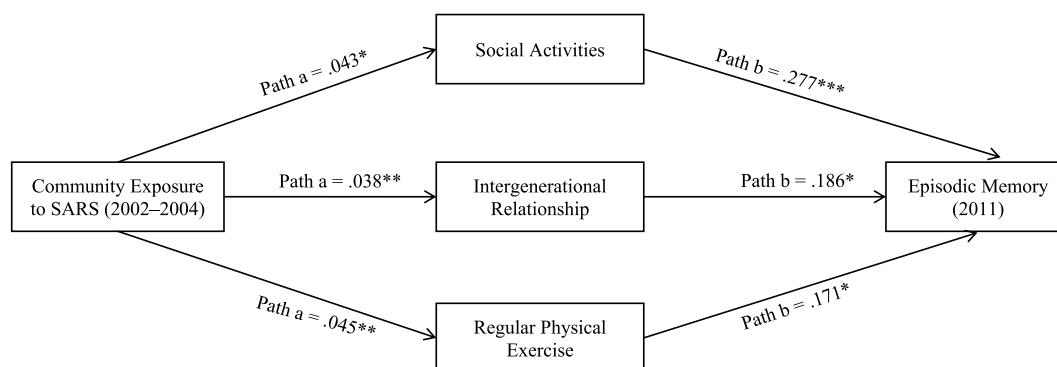
#### 3.3. Mediation analysis

We only performed mediation analysis for episodic memory because we found no significant association for mental intactness and only marginally significant association for the cognitive summary score in our main analysis. Fig. 3 depicts the path coefficients from the mediation analysis for episodic memory measured in 2011 (*N* = 3,179). The

**Table 2**  
Regression estimates of the association between community exposure to SARS during 2002–2004 and cognitive functioning in 2011 among Chinese adults aged 45 years old or older.

	2011 Baseline Cognitive Outcomes		
	Episodic Memory	Mental Intactness	Cognitive Summary
<i>Complete-case analysis</i>			
Community exposure to SARS (ref: no)	.201** (.064)	.005 (.087)	.206 (.125)
Adulthood control variables	Yes	Yes	Yes
Prefecture fixed effects	Yes	Yes	Yes
Observations	3,716	3,716	3,716
Adjusted <i>R</i> <sup>2</sup>	.234	.370	.399
<i>Multiple imputation for missing data</i>			
Community exposure to SARS (ref: no)	.150* (.062)	.061 (.087)	.168 (.127)
Adulthood control variables	Yes	Yes	Yes
Prefecture fixed effects	Yes	Yes	Yes
Observations	4,822	4,822	4,822

Note: Clustered standard errors at the community level are in parentheses. †*p* < .10; \**p* < .05; \*\**p* < .01; \*\*\**p* < .001.



**Fig. 3.** Path coefficients from mediation analysis of community exposure to SARS during 2002–2004 and episodic memory in 2011 ( $N = 3,179$ ). Note: The coefficient estimates were obtained after adjusting for adulthood control variables and prefecture fixed effects. † $p < .10$ ; \* $p < .05$ ; \*\* $p < .01$ ; \*\*\* $p < .001$ .

coefficient estimates were obtained after adjusting for the adulthood control variables and prefecture fixed effects. Analyses showed evidence of all three mediators at work. Community exposure to SARS was positively associated with participation in social activities ( $\beta = 0.043$ ,  $p < .05$ ), close intergenerational relationships ( $\beta = 0.038$ ,  $p < .01$ ), and participation in regular physical exercise ( $\beta = 0.045$ ,  $p < .01$ ). In turn, each mediator was positively associated with episodic memory. Specifically, participation in social activities was associated with a 0.277-point higher score on episodic memory. A close intergenerational relationship was associated with a 0.186-point higher score on episodic memory. Participation in regular physical exercise was associated with a 0.171-point higher score on episodic memory, although this association was marginally significant. Nevertheless, these three mediators together only accounted for about 15% ( $\frac{.181-.154}{.181} \times 100\%$ ) of the association between community exposure to SARS and episodic memory.

### 3.4. Sensitivity analysis

To assess the influence of potential outliers, we repeated the main analysis after excluding communities with only five eligible respondents. As shown in the top panel of Appendix Table A1, community exposure to SARS was still positively associated with episodic memory ( $\beta = .190$ ,  $p < .01$ ) measured in 2011. As an alternative, we excluded respondents from Beijing and Guangdong Province, the two regions that were hit the hardest by the SARS epidemic in China (Fang et al., 2009). Despite a notable reduction in the sample size, the results remained qualitatively unchanged (see the bottom panel of Appendix Table B1) for episodic memory ( $\beta = 0.192$ ,  $p < .01$ ).

A major concern in observational studies like ours pertains to the challenge of endogeneity. For example, people who were actively engaged in social activities might have increased the risk of spreading SARS in their communities in the first place. If this was the case, our regression estimates would be biased because we could not control for people's social behaviors or health status prior to the 2002–2004 SARS epidemic in CHARLS. We attempted to address this challenge by using distance to the nearest train station, reported by local officials in the 2011 community survey of CHARLS, as an instrumental variable.

Our rationale was based on the geographic spread of SARS in China (Fang et al., 2009). The SARS epidemic originated in Guangdong Province, one of the most important domestic migration destinations in Southern China and the early SARS epicenter. About three months later, Beijing emerged as the second epicenter in northern China, even though it was more than 1,000 miles away from Guangdong Province. There was evidence that SARS spread from Beijing to its surrounding areas (including Tianjin, Hebei Province, Shanxi Province, and Inner Mongolia) via public transportation routes, resulting in several local outbreaks (Fang et al., 2009). Therefore, we expected that the communities in closer proximity to train stations might be at an elevated risk of

spreading SARS. On the other hand, the location of train station was usually determined by higher-level governments beyond the jurisdiction of local communities. In addition, our sample was restricted to middle-aged and older adults who were long-term residents in their communities. Therefore, distance to the nearest train station could be exogenous to individuals' behaviors. According to the estimates (see the top panel of Appendix Table A2), community exposure to SARS was marginally associated with a 0.314-point higher score on episodic memory ( $p = .076$ ), but not associated with mental intactness or cognitive summary score.

Next, we assessed whether the association between community exposure to SARS and cognitive functioning still held when using longitudinal data from 2011, 2013, and 2015 waves of CHARLS. We did not include data from the latest 2018 wave due to substantial changes in the cognitive tests. We estimated growth curve models of the three cognitive outcomes with random effects to capture the between-person variability in the individual intercepts and slopes. All the variables were time-varying except community exposure to SARS, gender, and participation in regular physical exercise. As shown in the bottom panel of Appendix Table B2, the coefficient estimates from the growth curve models were smaller than those from the models of the 2011 baseline data. Nevertheless, community exposure to SARS was still positively associated with episodic memory ( $\beta = 0.102$ ,  $p < .01$ ).

We also repeated the mediation analysis for episodic memory using longitudinal data from 2011, 2013, and 2015 waves ( $N = 9,670$ ). As shown in Appendix Figure B1, most path coefficient estimates were qualitatively the same as those from the 2011 baseline data with two exceptions. First, the association between community exposure to SARS and participation in social activities became marginally significant ( $\beta = 0.021$ ,  $p = .078$ ). Second, the association between close intergenerational relationships and episodic memory was no longer significant. Nevertheless, participation in social activities and regular physical exercise remained important mediators.

Last, we explored potential variation in the association between community exposure to SARS and cognition by age since cognitive decline is age-related. We divided the sample into two subsamples (45–60 and 61 years or older) and reestimated the regression models using the 2011 baseline data. As shown in Appendix Table A3, the positive association between community exposure to SARS and episodic memory remained significant in both age groups. Interestingly, for the relatively younger group, community exposure to SARS was negatively associated with mental intactness. For the older group, community exposure to SARS was positively associated with both mental intactness and the cognitive summary score. Together, these findings suggested a stronger cognitive benefit of SARS exposure for older adults.



#### 4. Discussion

In this study, we conceptualized community exposure to SARS as a traumatic event and examined post-traumatic growth nearly a decade after the epidemic ended. Using data from a nationally representative longitudinal survey, we focused on cognitive health among middle-aged and older Chinese adults and examined potential behavioral mediators. Our measures of the mediating behavioral changes were based on self-reported activities (e.g., participation in social activities and in-person contact with family members) rather than self-reported changes in values or feelings (e.g., new appreciation of life, new priorities in life, and sense of close relationship with others). Similarly, our outcome measures of cognitive health were derived from cognitive tests administered during household interviews rather than subjective self-appraisals. These advantages in measurements allowed us to overcome the limitations in distinguishing genuine post-traumatic growth from illusory coping strategies in the literature (Grace et al., 2015).

We found evidence supporting **Hypothesis 1**—community exposure to SARS during 2002–2004 was associated with better episodic memory in 2011, after controlling for demographic and socioeconomic characteristics in adulthood. This association was robust in subsamples in which potential outliers were excluded and in a larger sample that pooled data from the 2011–2015 waves of CHARLS. However, no significant association was found for mental intactness. The lack of a significant association for mental intactness is consistent with other recent research reporting limited variation in the measure of mental intactness among CHARLS respondents (Xu, 2021; Zhang et al., 2019). Our measure of mental intactness focused on time orientation, attention, and visuospatial skills, which may involve a different part of the brain and neurological process than those responsible for episodic memory (Xu et al., 2018). Much of our analytic sample were middle-aged and older adults younger than 70. They might be relatively too young to experience notable decline in mental intactness. As a result, insufficient variation in the measure of mental intactness might have prohibited us from detecting any small yet statistically significant difference. Given the lack of a significant association for mental intactness, it was not surprising that community exposure to SARS was only marginally associated with a higher cognitive summary score.

We also found evidence supporting **Hypotheses 2** regarding the three mediators of episodic memory. Previous research on SARS focused on short-term behavioral changes that occurred either in the midst of the epidemic or a few months after the epidemic ended (for an exception, see Zou et al., 2021). Combining retrospective history data on individuals and communities with contemporary data, we demonstrated that community exposure to SARS was associated with increased participation in regular physical exercise, closer relationships with adult children and grandchildren, and increased participation in social activities. These findings are consistent with several domains of post-traumatic growth, as theorized by Tedeschi and Calhoun (1996, 2004). More importantly, these findings suggest that not only have SARS survivors developed a new appreciation and higher prioritization of life, health, exercise, family, and friends during the epidemic (Ji et al., 2004; Lau et al., 2005, 2006), but they have also managed to sustain these positive changes years after the epidemic ended. In turn, they enjoyed long-term benefits to their cognitive functioning as they aged. Our findings highlight the scientific value of applying post-traumatic growth theory to life course research on the long-term health consequences of epidemics in an aging population.

Our findings should be interpreted in the light of several limitations. First, because CHARLS did not collect data on respondents' cognitive functioning, health behavior, or social engagement right before or during the SARS epidemic, we cannot conclude causal effects of SARS on the behavioral mediators or cognitive outcomes in this study. In a sensitivity analysis, we used community distance to the nearest train station as a plausible instrumental variable to address the challenge of endogeneity. However, like other observational studies, the validity of

this approach relies on the assumption of exclusion that cannot be verified. Second, our key independent variable was measured at the community level and thus, did not capture within-community heterogeneity. Individuals' experience of a SARS outbreak in the community could vary substantially. Although some individuals might be infected and experience severe trauma, others might perceive low levels of risk if they were young, generally healthy, and lived alone (Tam et al., 2004). On the other hand, some people who lived in communities without a SARS outbreak might still experience SARS-related fears and anxiety, given the unprecedented, explosive spread of a novel epidemic. Without directly measuring individuals' exposure to and experience of the SARS epidemic, our estimates of the long-term associations of SARS with behavioral changes and cognitive health may be biased. Third, we only investigated three potential mediators, again due to limited available data. They together explained a small proportion of the association between community exposure to SARS and cognitive functioning. Future research is needed to explore other mediators at work.

Despite these limitations, this study adds to a small yet growing literature on the long-term positive impacts of disease epidemics and pandemics in modern society (Agüero and Beleche, 2017; Zou et al., 2021). The ongoing COVID-19 pandemic has had devastating impacts on population health, human lives, the global economy, and social inequalities, among others. Nevertheless, findings from the current study are encouraging because they suggest that at least for pandemic survivors, positive health-related changes are possible. An important challenge that lies ahead is how to seize the momentum of positive changes in health and social behaviors to make them last.

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#### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.socscimed.2021.114389>.

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