



COVID-19 pandemic and mental health problems of adults in United States: mediating roles of cognitive concerns and behavioral changes

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Abstract

Objectives We examined the associations of statewide COVID-19 conditions (i.e., state-level case and death rates) with individual-level Generalized Anxiety Disorder (GAD) and Major Depression Disorder (MDD) focusing on the salient mediating roles of individual-level cognitive concerns and behavioral changes.

Methods Using a national representative sample of adults in the United States ($n = 585,073$), we fitted logistic regressions to examine the overall associations between the COVID-19 pandemic and GAD/MDD. We employed a causal mediation analysis with two mediators: cognitive concerns (i.e., concerns on going to the public, loss of income, food insufficiency, housing payment, and the economy) and behavioral changes (i.e., taking fewer trips, avoiding eating-out, more online-purchase, more curbside pick-up, and cancelling doctor's appointments).

Results We found relationships of statewide COVID-19 cases with GAD (odds ratio [OR] = 1.06; 95% confidence interval [CI] = 1.05, 1.07) and MDD (OR = 1.08; 95% CI = 1.07, 1.09). The ORs were mediated by cognitive concerns for GAD (OR = 1.02, proportion mediated: 29%) and MDD (OR = 1.01, 17%). Another salient mediator was behavioral changes for GAD (OR = 1.02, 31%) and MDD (OR = 1.01, 15%). Similar associations were found with statewide COVID-19 death.

Conclusions Our mediation analyses suggest that cognitive concerns and behavioral changes are important mediators of the relationships between statewide COVID-19 case/death rates and GAD/MDD. COVID-19 pandemic may involve individual-level concerns and behavior changes, and such experiences are likely to affect mental health outcomes. Public health approaches to alleviate adverse mental health consequences should take into account the mediating factors.

Keywords COVID-19 cases and deaths · Generalized Anxiety Disorder (GAD) · Major Depression Disorder (MDD) · Mediation · Cognitive concerns · Behavioral changes

Introduction

Recent studies have suggested mental health consequences of the COVID-19 pandemic [24, 25, 43]. For example, the risk for anxiety disorders, including panic disorder, obsessive–compulsive disorder, and phobias became higher after the outbreak of COVID-19 [44]. A national representative study in the United States (U.S.) also reported that the prevalence of depression symptoms during the pandemic was more than threefold higher compared to the pre-pandemic period [20]. Cognitive concerns and behavioral changes, or more broadly lifestyle quality changes, due to perceived threats of COVID-19 and local lockdowns may play salient roles in the adverse mental health outcomes [11, 34]. Alarming COVID-19 trends on news media and the internet may have an adverse effect on the fear of infection and concerns about uncertainty [40]. In addition,

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social distancing measures and stay-at-home orders, as well as working from home, can also have negative effects on mental health because of reduced physical activities and limited socialization [36, 53, 75]. Carnahan et al. [13] proposed two plausible pathways of anxiety and depression due to the pandemic: (1) looming cognitive style and (2) intolerance of uncertainty. Looming cognitive style refers to a maladaptive cognition that an individual interprets and simulates perceptions of ambiguous threats as intensifying and rapidly approaching [51]. The ambiguous threats of COVID-19 due to daily exposures to media and news regarding the number of cases and deaths are closely associated with this construct, and such individual cognitive style has been shown as a risk factor for anxiety and depression [74]. The intolerance of uncertainty is defined as the tendency to a negative reaction to uncertain situations on cognitive, emotional, and behavioral levels based on negative beliefs about uncertainty and its implications [10]. The unexpected fatal cases, as well as stay-at-home and lockdown orders, may lead to the maladaptive reaction to the uncertain situations, causing negative cognitive and behavioral changes [12]. Intolerance of uncertainty has been strongly linked to anxiety and depression [10].

As such, cognitive concerns and behavioral changes may play important mediating roles in the relationship between the COVID-19 pandemic and adult mental illnesses. Given the yearlong and worsening trends of COVID-19 case and death rates along with the accumulated mental health consequences, it is crucial to understand the causal mechanisms to facilitate the public health strategies. To the best of our knowledge, no previous population-based studies have examined whether cognitive concerns and behavioral changes may be mediating factors in the relationship between statewide COVID-19 and mental health. Thus, we also explored the mediating roles of cognitive concerns and behavioral changes in the relationship of statewide COVID-19 case/

death rates with Generalized Anxiety Disorder (GAD) and Major Depression Disorder (MDD), as diagrammed in Fig. 1.

Methods

Data source

The Household Pulse Survey (HPS) is a national representative survey administered by the U.S. Census Bureau jointly with the U.S. National Center for Health Statistics (NCHS) and other federal agencies. It measures mental health impacts of the COVID-19 pandemic on adult Americans [63]. The survey consists of three phases in 2020: phase 1 (April 23–July 21), phase 2 (August 19–October 26), and phase 3 (October 28–December 21). We used the Public Use File (PUF) of phase 2 and 3 of HPS (August 19–December 21) because survey questions that are related to potential mediator variables of this study (i.e., cognitive concerns and behavioral changes of individual survey respondents) were introduced in phase 2 (see Supplemental Table 1 for detailed sample size by survey phase and week) [64].

Study variables

Descriptive statistics of all variables for the total sample, as well as by the status of GAD and MDD, are found in Table 1.

Outcomes: mental health problems

Two self-reported measures of GAD and MDD, PHQ-2 [5] and GAD-2 [48], respectively, were utilized as noted by other COVID-19 studies and surveys on mental health [17, 45, 63]. The questions measure the frequency of depression and anxiety symptoms in the past seven days

Fig. 1 Conceptual model of relationship between statewide COVID-19 condition and mental health problems and its partial mediators: U.S. Census Bureau's Household Pulse Survey, August 19–December 21, 2020

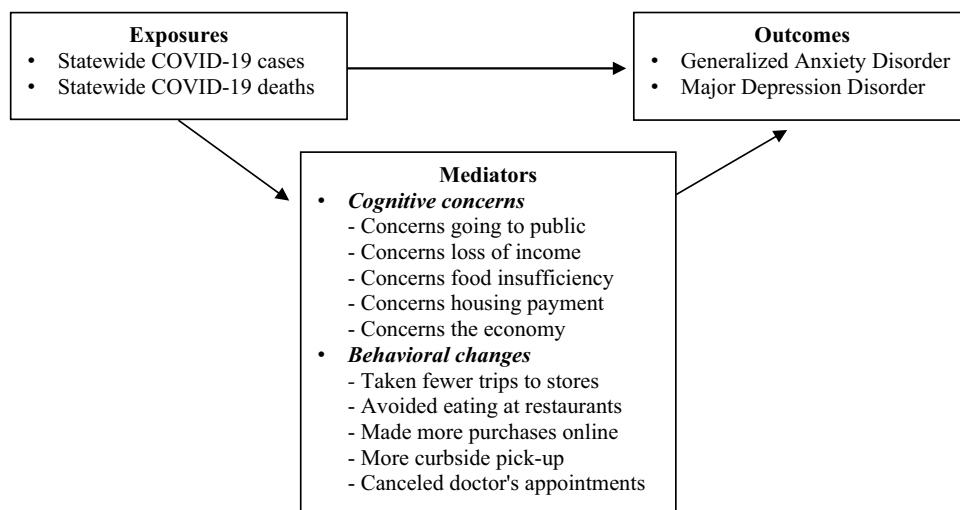


Table 1 Descriptive statistics of statewide COVID-19 condition and health variables: U.S. Census Bureau's Household Pulse Survey, August 19–December 21, 2020

Variables	Full sample (<i>n</i> = 585,073), %, Mean (SD)	Generalized anxiety disorder		Major depression disorder	
		Yes (<i>n</i> = 188,311), %, Mean (SD)	No (<i>n</i> = 396,762), %, Mean (SD)	Yes (<i>n</i> = 134,087), %, Mean (SD)	No (<i>n</i> = 450,986), %, Mean (SD)
Mediators, mean (SD)					
<i>Cognitive concerns</i>					
Cognitive concerns (0 to 5)	1.831 (1.36)	2.47 (1.31)	1.497 (1.263)	2.544 (1.31)	1.57 (1.283)
Concerns going to the public	0.563 (0.497)	0.665 (0.473)	0.509 (0.5)	0.65 (0.478)	0.531 (0.5)
Concerns the loss of income	0.257 (0.437)	0.383 (0.486)	0.191 (0.393)	0.401 (0.49)	0.204 (0.403)
Concerns food insufficiency	0.506 (0.5)	0.697 (0.46)	0.407 (0.492)	0.742 (0.438)	0.42 (0.494)
Concerns housing payment	0.157 (0.364)	0.26 (0.439)	0.104 (0.305)	0.286 (0.452)	0.11 (0.313)
Concerns the economy	0.35 (0.477)	0.467 (0.499)	0.288 (0.453)	0.468 (0.499)	0.307 (0.461)
<i>Behavioral changes</i>					
Behavioral changes (0 to 5)	2.369 (1.538)	2.815 (1.439)	2.136 (1.538)	2.771 (1.431)	2.222 (1.55)
Taken fewer trips to stores	0.693 (0.462)	0.808 (0.395)	0.633 (0.483)	0.812 (0.392)	0.65 (0.478)
Avoided eating at restaurants	0.587 (0.493)	0.698 (0.46)	0.529 (0.5)	0.69 (0.463)	0.549 (0.498)
Made more purchases online	0.529 (0.5)	0.578 (0.494)	0.504 (0.5)	0.556 (0.497)	0.519 (0.5)
More curbside pick-up	0.272 (0.445)	0.327 (0.469)	0.243 (0.429)	0.308 (0.462)	0.259 (0.438)
Canceled doctor's appointments	0.29 (0.454)	0.408 (0.492)	0.229 (0.42)	0.408 (0.492)	0.247 (0.432)
Covariates, % of sample					
<i>Demographic characteristics</i>					
Age					
18–24 (Ref)	6.7	9.1	5.4	10.7	5.2
25–34	17.9	23.1	15.1	23.6	15.8
35–44	17.8	20.2	16.5	18.8	17.4
45–54	16.9	17.1	16.9	16.5	17.1
55–64	18.4	16.3	19.4	16.1	19.2
65+	22.3	14.2	26.6	14.3	25.3
Gender					
Female (Ref)	52.1	59.3	48.3	56.3	50.5
Male	47.9	40.7	51.7	43.7	49.5
Race/ethnicity					
Non-Hispanic White (Ref)	66.0	64.1	67.1	62.0	67.5
Non-Hispanic Black	10.1	10.2	10.0	11.3	9.6
Non-Hispanic A&PI	4.9	3.7	5.5	4.0	5.3
Non-Hispanic other	3.8	4.7	3.3	4.8	3.4
Hispanic	15.2	17.3	14.1	17.9	14.2
Marital status					
Unmarried (Ref)	42.2	50.5	37.9	55.3	37.5
Married	57.8	49.5	62.1	44.7	62.5
Children in household					
No child (Ref)	63.1	60.4	64.5	61.9	63.5
One or more children	36.9	39.6	35.5	38.1	36.5
Household size					
Single person (Ref)	8.6	8.3	8.8	9.2	8.4
2-person	34.0	30.1	36.0	29.4	35.6
3-person	19.8	20.8	19.3	20.7	19.5
4-person	18.4	19.5	17.8	18.9	18.2
5-person	9.9	10.8	9.5	10.7	9.7
6 or more persons	9.3	10.6	8.7	11.2	8.6

Table 1 (continued)

Variables	Full sample (<i>n</i> = 585,073), %, Mean (SD)	Generalized anxiety disorder		Major depression disorder	
		Yes (<i>n</i> = 188,311), %, Mean (SD)	No (<i>n</i> = 396,762), %, Mean (SD)	Yes (<i>n</i> = 134,087), %, Mean (SD)	No (<i>n</i> = 450,986), %, Mean (SD)
<i>Socioeconomic status (SES)</i>					
Education					
Less than high school (Ref)	6.6	7.8	5.9	8.6	5.8
High school	28.8	28.2	29.2	31.3	27.9
Some college & AA	30.7	33.3	29.3	34.6	29.2
BA +	34.0	30.8	35.6	25.5	37.0
Household income					
Less than \$25,000 (Ref)	13.8	18.7	11.2	21.6	10.9
\$25,000–49,999	23.6	26.7	22.1	28.8	21.7
\$50,000–74,999	17.9	18.1	17.9	17.9	17.9
\$75,000–99,999	13.8	12.6	14.5	11.8	14.6
\$100,000–\$149,999	15.6	12.9	17.1	11.3	17.2
\$150,000 and above	15.2	11.0	17.3	8.6	17.6
Work status					
No work (Ref)	41.2	44.3	39.6	47.9	38.7
Work	58.8	55.7	60.4	52.1	61.3
Tenure of residence					
Rental housing unit (Ref)	30.2	39.2	25.5	41.8	26.0
Owner housing unit	69.8	60.8	74.5	58.2	74.0
<i>Self-rated health and healthcare access</i>					
Self-rated health					
Excellent (Ref)	17.1	9.0	21.3	7.6	20.5
Very good	32.4	24.3	36.6	21.0	36.6
Good	30.6	33.0	29.4	33.4	29.6
Fair	16.1	25.6	11.1	28.4	11.6
Poor	3.8	8.1	1.6	9.6	1.7
Insurance status					
Private (Ref)	48.7	46.8	49.7	43.2	50.7
Public	17.1	19.3	16.0	21.1	15.7
Both private and public	19.1	15.2	21.1	15.0	20.6
Other	5.5	5.7	5.4	6.0	5.4
None	9.6	12.9	7.8	14.7	7.7
Delayed medical care					
No (Ref)	33.3	49.9	24.5	50.8	26.8
Yes	66.7	50.1	75.5	49.2	73.1
Did not get medical care					
No (Ref)	24.7	39.4	17.0	41.1	18.7
Yes	75.3	60.6	83.0	58.9	81.3
Did not get mental health counseling					
No (Ref)	11.0	24.8	3.7	27.8	4.8
Yes	89.0	75.2	96.3	72.1	95.2
<i>Socioeconomic hardship</i>					
Employment income loss					
No (Ref)	54.2	40.5	61.4	38.6	59.9
Yes	45.8	59.5	38.6	61.4	40.1
Food insufficiency					
No (Ref)	60.7	41.0	70.9	36.2	69.6

Table 1 (continued)

Variables	Full sample (<i>n</i> = 585,073), %, Mean (SD)	Generalized anxiety disorder		Major depression disorder	
		Yes (<i>n</i> = 188,311), %, Mean (SD)	No (<i>n</i> = 396,762), %, Mean (SD)	Yes (<i>n</i> = 134,087), %, Mean (SD)	No (<i>n</i> = 450,986), %, Mean (SD)
Yes	39.3	59.0	29.1	63.8	30.4
Housing instability					
No (Ref)	89.4	83.3	92.6	81.9	92.1
Yes	10.6	16.7	7.4	18.0	7.9
Expense difficulty					
No (Ref)	45.5	24.3	56.5	20.8	54.5
Yes	54.5	75.7	43.4	79.2	45.5
K-12 school closure					
No (Ref)	93.1	91.6	94.0	91.5	93.7
Yes	6.9	8.4	6.0	8.5	6.3
<i>Location of residence</i>					
15 largest MSAs					
Non-MSA	100.0	34.0	66.0	26.7	73.3
MSA	100.0	35.1	64.9	27.1	72.9
50 States and Washington, D.C.					
Northeast state	100.0	33.6	66.4	25.0	75.0
Midwest state	100.0	32.8	67.2	25.5	74.5
South state	100.0	34.3	65.7	27.4	72.6
West state	100.0	36.2	63.8	28.2	71.8
Exposures	<i>Mean</i>	<i>S.D</i>	<i>Median</i>	<i>Min</i>	<i>Max</i>
State COVID-19 cases per 1000 persons	0.2868	0.1382	0.2632	0.0252	1.1600
State COVID-19 deaths per 1000 persons	0.0068	0.0042	0.0057	0.0004	0.0202

A&PI Asian and Pacific Islander, AA some college or associate degree, BA + bachelor's degree or higher, MSA metropolitan statistical area

(see Supplemental Table 2 for detailed survey questionnaire prompts and answer options). The question for both PHQ-2 and GAD-2 is “over the last 7 days, how often have you been bothered by any of the following problems?”, and the two items of PHQ-2 are “having little interest or pleasure in doing things” and “feeling down, depressed, or hopeless”; and two items of GAD-2 are “feeling nervous, anxious or on edge” and “not being able to stop or control worrying”. For a given item, numeric values were assigned to answer options: not at all (= 0), several days (= 1), more than half the days (= 2), and nearly every day (= 3). Scores from each question were summed and categorized for binary diagnoses: more than three points from PHQ-2 as MDD and more than three points from GAD-2 as GAD. The threshold points of PHQ-2 and GAD-2 have been validated for diagnosed MDD and GAD [5, 48].

Exposures: statewide COVID-19 case and death rates

Statewide COVID-19 cumulative case and death rates per 1000 population was retrieved from COVID-19 Data Tracker provided by the U.S. Centers for Disease Control

and Prevention (CDC) [65]. Daily cumulative counts are averaged to match the survey weeks of HPS, and the average is divided by 1000 population and multiplied by 100. The same calculation was applied to the statewide weekly COVID-19 deaths.

Mediators: cognitive concerns and behavioral changes

Cognitive concerns during the COVID-19 pandemic were measured by five individual-level items: (1) concerns going to the public, (2) concerns the loss of income, (3) concerns food insufficiency, (4) concerns housing payment loss, and (5) concerns the overall economy (see Supplemental Table 2 for detailed survey questionnaire prompts and answer options). All measures were coded using the given binary responses (yes/no). Sum of all the items was used in the regression models as a single measure of cognitive concerns (ranging from 0 to 5) that reflect all of the five individual-level items (see Table 1 for descriptive statistics). To validate the scale variable, we performed three sub-analyses, including (1) principal component analysis (PCA), (2) exploratory

factor analysis (EFA), and (3) confirmatory factor analysis (CFA), on the five individual items (see methodological details in [59–61]). Each sub-analysis resulted in a single most important factor (or component) which was then correlated with the scale mediator. A strong and positive correlation (Pearson correlation coefficient (r) between 0.9010 and 0.9983) was found as shown in Supplemental Table 3, confirming the validity of the scale measure of cognitive concerns.

In the same way, behavioral changes due to the pandemic were measured by five individual-level items: (1) taken fewer trips to stores, (2) avoided eating at restaurants, (3) made more purchases online, (4) made more purchases by curbside pick-up, and (5) canceled doctor's appointments. Likewise, a sum of the five items was utilized in the models as a single scale of behavioral changes and was validated by correlation tests as shown in Supplemental Table 3 (r between 0.9859 and 0.9995).

Covariates: individual and household-level variables

Potential individual and household-level confounding covariates are derived from HPS data, including demographic characteristics, socioeconomic status (SES), self-rated health and healthcare access, socioeconomic hardships, and location of residence as noted by previous COVID-19 studies on mental health determinants during the pandemic [30, Mergel et al. 2021; [71] (see Supplemental Table 2 for detailed survey questionnaire prompts and answer options). Demographic variables include age group, gender, race and ethnicity, marital status, household size, and the number of children. SES includes education, household income, work status, and housing tenure. We include self-rated health condition and insurance status as health-related covariates. Pandemic-specific health variables, such as delay of medical care, cancellation of medical care, and cancellation of mental health counseling or therapy, are also included in the models.

A wide range of pandemic hardships was measured by five individual-level variables: (1) employment income loss [23, 46], (2) food insufficiency [2, 73], (3) housing instability [37, 47], (4) expense difficulty [63], and (5) K-12 school closure [45]. Employment income loss identifies if a respondent or his/her household member(s) lost employment income since March 13, 2020. Food insufficiency specifies whether a respondent did not have enough of the kinds of food he/she wanted to eat in the past week. Housing instability identifies if a respondent did not pay his/her last month's rent or mortgage on time. Expense difficulty specifies whether a respondent's household has at least a little difficulty in paying for usual expenses in the past week. K-12 school closure identifies if a respondent reports that classes usually

taught in person at the school to the children in his/her household were canceled.

A further time-invariant variable added in the models is the location of residence in one of the 50 states and the District of Columbia. We also included if a respondent resided in the 15 largest metropolitan statistical areas (MSAs) to consider variations in mental health outcomes among urban residents.

Data analysis

We used Stata/MP version 13.1 (StataCorp, College Station, TX) to conduct all data analyses. The respondents' individual and household-level characteristics were described using weighted data. We fitted logistic regressions for the mediation analysis: (1) the associations of statewide COVID-19 condition with cognitive concerns and behavioral changes with the covariates, and (2) the associations of the pandemic with mental health outcomes with potential mediators and the covariates. The covariates in all models included demographic characteristics (age, gender, race/ethnicity, marital status, children in household, and household size), socioeconomic status (education, household income, work status, and tenure of residence), health status and healthcare access (self-rated health, insurance status, delay of medical care, cancellation of medical care, and cancellation of mental health counseling), socioeconomic hardships (income loss, food insufficiency, housing instability, expense difficulty, and K-12 school closure), and location of residence (state and MSA) [8, 15, 16, 39, 50, 52, 67, 72].

We employed causal mediation analyses (*paramed* in Stata/MP 13.1; [19] based on theoretical assumptions and implementation methods developed by VanderWeele [66, 68, 69, 70]. The causal mediation analysis allows the decomposition of a total effect to direct and indirect effects, based on the counterfactual framework [6]. It can also address a limitation of the conventional mediation analysis by Baron and Kenny [7], no interactions between the exposure and mediator. Given the nature of observational data, we estimated natural direct and indirect effects using 500 bootstrapping resamples to produce 95% bias-corrected confidence intervals (CIs) for the direct and indirect effects. The natural indirect effect represents the effect of the COVID-19 on mental health outcomes due to the effect that the pandemic has on cognitive concerns and behavioral changes. We examined cross-product terms for exposure and mediator, and the causal mediation analysis was employed allowing the interactions in case of evidence of exposure–mediator interactions. In addition, we estimated proportions mediated from the formula: $OR [\text{indirect effect}] / OR [\text{total effect}] \times 100\%$.

Results

Cognitive concerns and behavioral changes as mediators

Table 2, panel (a) shows a significant relationship of statewide COVID-19 case rate with GAD (odds ratio [OR] = 1.06; 95% confidence interval [CI] = 1.05, 1.07) and MDD (OR = 1.08; 95% CI = 1.07, 1.09) after adjusted for all covariates (see Supplemental Table 4 for full

estimation results). The associations with GAD were mediated by cognitive concerns (OR = 1.02; 95% CI = 1.02, 1.02, proportion mediated: 29%) and MDD (OR = 1.01; 95% CI = 1.01, 1.01, 17% mediated). The ORs of statewide COVID-19 cases with GAD and MDD was also attenuated by behavioral changes for GAD (OR = 1.02; 95% CI = 1.02, 1.02, 33% mediated) and MDD (OR = 1.01; 95% CI = 1.01, 1.01, 17% mediated).

Table 2, panel (b) presents that the mediating roles of cognitive concerns and behavioral changes were significant for statewide COVID-19 death rate but the

Table 2 Logistic regression models for cognitive–behavioral changes as mediators between statewide COVID-19 condition and mental health problems: U.S. Census Bureau’s Household Pulse Survey,

August 19–December 21, 2020. (a) Relationship between COVID-19 case and mental health. (b) Relationship between COVID-19 death and mental health

Mediator variables	COVID-19 Case–GAD relationship ^a				COVID-19 Case–MDD relationship ^a			
	OR	(95% CI)	<i>p</i>	% of Total Effect ^b	OR	(95% CI)	<i>p</i>	% of Total Effect ^b
Cognitive concerns as mediator								
Cognitive concerns								
Direct	1.043	(1.035, 1.052)	<.001	71	1.068	(1.059, 1.078)	<.001	83
Indirect	1.017	(1.016, 1.018)	<.001	29	1.013	(1.012, 1.014)	<.001	17
Total	1.060	(1.053, 1.07)	<.001	100	1.081	(1.072, 1.091)	<.001	100
Behavioral changes as mediator								
Behavioral changes								
Direct	1.041	(1.034, 1.05)	<.001	69	1.070	(1.062, 1.08)	<.001	85
Indirect	1.018	(1.018, 1.02)	<.001	31	1.011	(1.011, 1.013)	<.001	15
Total	1.060	(1.052, 1.069)	<.001	100	1.082	(1.074, 1.092)	<.001	100
Mediator variables	COVID-19 Death–GAD relationship ^a				COVID-19 Death–MDD relationship ^a			
	OR	(95% CI)	<i>p</i>	% of Total effect ^b	OR	(95% CI)	<i>p</i>	% of Total effect ^b
Cognitive concerns as mediator								
Cognitive concerns								
Direct	1.142	(1.118, 1.167)	<.001	79	1.171	(1.146, 1.198)	<.001	85
Indirect	1.033	(1.03, 1.036)	<.001	21	1.025	(1.023, 1.028)	<.001	15
Total	1.179	(1.155, 1.205)	<.001	100	1.201	(1.174, 1.228)	<.001	100
Behavioral changes as mediator								
Behavioral changes								
Direct	1.139	(1.116, 1.163)	<.001	79	1.174	(1.149, 1.201)	<.001	88
Indirect	1.032	(1.03, 1.035)	<.001	21	1.021	(1.019, 1.023)	<.001	12
Total	1.175	(1.152, 1.2)	<.001	100	1.198	(1.173, 1.226)	<.001	100

See Supplemental Table 2 for full estimation results. The unweighted sample size was $n = 585,073$. OR odds ratio, CI confidence interval. The ORs are for the relationship between statewide COVID-19 condition and mental health problems

^aThe mediated model includes cognitive–behavioral changes as the mediator variable, statewide COVID-19 condition as the predictor variable, and mental health problems as the outcome variable. Covariates included demographic characteristics (age, gender, race/ethnicity, marital status, children in household, and household size), socioeconomic status (education, household income, work status, and tenure of residence), health status (self-rated health and insurance status), socioeconomic hardships (income loss, food insufficiency, housing instability, expense difficulty, and K-12 school closure) and location of residence (state and metropolitan statistical area)

^bTo calculate how much the OR for statewide COVID-19 condition was attenuated when the mediator variable was added, we used the following formula: $OR [indirect\ effect] / OR [total\ effect] \times 100\%$

proportions of mediation effects were lower for death rates than case rates. For example, the indicator of cognitive concerns mediated the COVID-19 case–GAD relationship by 29%, whereas it mediated the COVID-19 death–GAD relationship only by 21%. The mediating role of behavioral changes for the COVID-19 case–GAD relationship (33%) was also 1.5 times of that for COVID-19 death–MDD relationship (21%).

Individual cognitive concerns and behavioral changes as mediators

Tables 3 shows the mediating effects of individual items within cognitive concerns and behavioral changes for the relationship of statewide COVID-19 case/death rates with GAD/MDD (see Supplemental Table 5 for full estimation results). We run mediation analysis ten times for ten individual items, respectively, to avoid multicollinearity between items (r between -0.001 and 0.3925) as shown in Supplemental 6. As for the statewide COVID-19 case and mental health relationship (Table 3, panel a), the indirect effects of cognitive concerns (ranging from no effect to 28% mediated) and for behavioral changes (1 to 21% mediated) varied substantially, suggesting the partial mediating effects of cognitive concerns and behavioral changes in the relationship between COVID-19 case and mental health and their large variations. The mediating roles appear to be strongest for concerns about going to the public (28 and 11% for GAD and MDD, respectively), avoiding eating at restaurants (21 and 10%), taking fewer trips to stores (15 and 9%), and making more purchases online (19 and 8%). Whereas, the mediating effects of other cognitive concerns and behavioral changes, such as concerns about the economy (2 and 1% for GAD and MDD, respectively) and making more purchases by curbside pick-up (6 and 1%), are relatively small. The analyses shown in Table 3 suggest that, taken together, most of the cognitive concerns and behavioral changes examined in this study mediate the relationship between statewide COVID-19 pandemic and mental health, and some individual cognitive concerns and behavioral changes much more strongly than others.

Discussion

To our knowledge, this is the first population-based study of the relationship of statewide COVID-19 pandemic with individual-level GAD and MDD with a special focus on the mediating roles of cognitive concerns and behavioral changes. We found relationships of statewide COVID-19 case and death rates with GAD and MDD, in addition to the salient mediating roles of cognitive concerns and

behavioral changes. Our results are consistent with early studies about other nations, including China, Italy, and Netherland [54, 57, 62].

Few previous studies have explored whether cognitive concerns and behavioral changes might be mediators of the relationship between pandemic and mental health, and if so, to what extent the relationship is mediated. In our study, individual cognitive concerns and behavioral changes were partial but strong mediators of the relationship between pandemic condition and mental health outcomes. Particularly, the strongest mediating factors were cognitive concerns and behavioral changes that were closely related to limited outdoor activities and socialization opportunities, such as concerns about going to the public, avoiding eating at restaurants, taking fewer trips to stores, and making more purchases online. This novel finding suggests that one of the major mechanisms that link the COVID-19 pandemic and mental illnesses may be cognitive concerns and behavioral changes particularly due to the reduced outdoor activities and limited social interactions. These individual-level cognitive concerns and behavioral changes may be observed by aggregated-level indicators such as outdoor mobility and small business closures that are known to be associated with aggravated mental health outcomes [47].

Our results suggest that population health strategies should aim to address the amental health crisis during the COVID-19 pandemic based on the causal mechanisms (i.e., mediating roles of cognitive concerns and behavioral changes) that were found in this study. Despite the effectiveness of stay-at-home and business lockdown orders in curbing spreads of the virus, an additional public health attention should be given to the mental health consequences of such interventions [14]. Especially, the strongest mediator was the concern about going to the public (28 and 11% for GAD and MDD, respectively), and this finding indicates that social isolations due to the pandemic may be critical public health threats as well as important points of intervention. Particularly, the initial fear and concerns in the first months of 2020 drove decisions to isolate people from one another, which was witnessed at first with an extreme recalibration of how we network with others in daily lives [21, 22]. Also disappeared were incidental and unplanned interactions in restaurants and local stores, both of which were revealed as strong mediators in our study: avoiding eating at restaurants (15 and 9% for GAD and MDD, respectively) and taking fewer trips to stores (15 and 9%).

An additionally important mediator found in our study is making more purchases online (15 and 7% for GAD and MDD, respectively). Considering an upsurge of online activity and possible connections to mental health during the

Table 3 Logistic regression models for individual cognitive–behavioral changes as mediators between statewide COVID-19 condition and mental health problems: U.S. Census Bureau’s Household Pulse Survey, August 19–December 21, 2020. (a) Relationship between COVID-19 case and mental health. (b) Relationship between COVID-19 death and mental health

Mediator variables	COVID-19 Case–GAD relationship ^a				COVID-19 Case–MDD relationship ^a			
	OR	(95% CI)	<i>p</i>	% of Total effect ^b	OR	(95% CI)	<i>p</i>	% of Total effect ^b
(a) Relationship between COVID-19 case and mental health: Cognitive concerns as mediator								
Concerns going to the public								
Direct	1.042	(1.035, 1.051)	< .001	72	1.073	(1.064, 1.082)	< .001	89
Indirect	1.016	(1.015, 1.017)	< .001	28	1.008	(1.008, 1.01)	< .001	11
Total	1.058	(1.051, 1.067)	< .001	100	1.082	(1.073, 1.091)	< .001	100
Concerns the loss of income								
Direct	1.054	(1.046, 1.062)	< .001	95	1.074	(1.065, 1.084)	< .001	97
Indirect	1.003	(1.003, 1.003)	< .001	5	1.002	(1.002, 1.003)	< .001	3
Total	1.056	(1.049, 1.065)	< .001	100	1.076	(1.067, 1.086)	< .001	100
Concerns food insufficiency								
Direct	1.057	(1.049, 1.065)	< .001	96	1.076	(1.067, 1.085)	< .001	97
Indirect	1.002	(1.002, 1.004)	< .001	4	1.003	(1.002, 1.004)	< .001	3
Total	1.059	(1.051, 1.068)	< .001	100	1.078	(1.07, 1.088)	< .001	100
Concerns housing payment								
Direct	1.056	(1.049, 1.065)	< .001	99	1.077	(1.069, 1.087)	< .001	100
Indirect	1.000	(1.001, 1.001)	< .001	1	1.000	(1.001, 1.001)	< .001	0
Total	1.057	(1.049, 1.065)	< .001	100	1.078	(1.069, 1.088)	< .001	100
Concerns the economy								
Direct	1.058	(1.051, 1.067)	< .001	98	1.080	(1.072, 1.09)	< .001	99
Indirect	1.001	(1.001, 1.003)	< .001	2	1.001	(1.001, 1.002)	< .001	1
Total	1.060	(1.052, 1.068)	< .001	100	1.081	(1.073, 1.091)	< .001	100
Behavioral changes as mediator								
Taken fewer trips to stores								
Direct	1.050	(1.043, 1.059)	< .001	85	1.074	(1.066, 1.084)	< .001	91
Indirect	1.008	(1.008, 1.01)	< .001	15	1.007	(1.007, 1.008)	< .001	9
Total	1.059	(1.052, 1.068)	< .001	100	1.082	(1.073, 1.092)	< .001	100
Avoided eating at restaurants								
Direct	1.047	(1.039, 1.055)	< .001	79	1.074	(1.065, 1.083)	< .001	90
Indirect	1.012	(1.012, 1.013)	< .001	21	1.008	(1.008, 1.009)	< .001	10
Total	1.059	(1.052, 1.068)	< .001	100	1.083	(1.074, 1.092)	< .001	100
Made more purchases online								
Direct	1.048	(1.041, 1.057)	< .001	81	1.075	(1.067, 1.085)	< .001	92
Indirect	1.011	(1.011, 1.012)	< .001	19	1.006	(1.005, 1.007)	< .001	8
Total	1.060	(1.052, 1.068)	< .001	100	1.082	(1.073, 1.091)	< .001	100
More curbside pick-up								
Direct	1.056	(1.048, 1.064)	< .001	94	1.081	(1.072, 1.09)	< .001	99
Indirect	1.003	(1.003, 1.004)	< .001	6	1.001	(1.001, 1.002)	< .001	1
Total	1.059	(1.052, 1.068)	< .001	100	1.082	(1.073, 1.091)	< .001	100
Canceled doctor’s appointments								
Direct	1.058	(1.05, 1.067)	< .001	98	1.080	(1.072, 1.09)	< .001	99
Indirect	1.001	(1.001, 1.002)	< .001	2	1.001	(1.001, 1.002)	< .001	1
Total	1.059	(1.052, 1.068)	< .001	100	1.082	(1.073, 1.091)	< .001	100

Table 3 (continued)

Mediator variables	COVID-19 death–GAD relationship ^a				COVID-19 Death–MDD Relationship ^a			
	OR	(95% CI)	<i>p</i>	% of Total Effect ^b	OR	(95% CI)	<i>p</i>	% of Total Effect ^b
(b) Relationship between COVID-19 death and mental health: Cognitive concerns as mediator								
Concerns going to the public								
Direct	1.140	(1.118, 1.164)	<.001	80	1.179	(1.153, 1.206)	<.001	90
Indirect	1.031	(1.029, 1.034)	<.001	20	1.017	(1.016, 1.019)	<.001	10
Total	1.175	(1.152, 1.2)	<.001	100	1.198	(1.172, 1.226)	<.001	100
Concerns the loss of income								
Direct	1.171	(1.148, 1.195)	<.001	97	1.188	(1.162, 1.216)	<.001	98
Indirect	1.004	(1.004, 1.006)	<.001	3	1.003	(1.003, 1.005)	<.001	2
Total	1.176	(1.153, 1.2)	<.001	100	1.192	(1.167, 1.22)	<.001	100
Concerns food insufficiency								
Direct	1.176	(1.153, 1.2)	<.001	97	1.194	(1.168, 1.221)	<.001	97
Indirect	1.005	(1.003, 1.007)	<.001	3	1.005	(1.004, 1.008)	<.001	3
Total	1.181	(1.158, 1.206)	<.001	100	1.200	(1.174, 1.228)	<.001	100
Concerns housing payment								
Direct	1.177	(1.154, 1.201)	<.001	100	1.197	(1.171, 1.224)	<.001	100
Indirect	1.000	(1.001, 1.001)	.006	0	1.000	(1.001, 1.001)	.006	0
Total	1.177	(1.154, 1.202)	<.001	100	1.197	(1.171, 1.225)	<.001	100
Concerns the economy								
Direct	1.176	(1.153, 1.2)	<.001	99	1.196	(1.171, 1.224)	<.001	99
Indirect	1.002	(1.001, 1.004)	.037	1	1.002	(1.001, 1.004)	.037	1
Total	1.178	(1.155, 1.203)	<.001	100	1.198	(1.172, 1.226)	<.001	100
Behavioral changes as mediator								
Taken fewer trips to stores								
Direct	1.162	(1.139, 1.186)	<.001	92	1.186	(1.161, 1.214)	<.001	94
Indirect	1.012	(1.011, 1.014)	<.001	8	1.010	(1.009, 1.012)	<.001	6
Total	1.176	(1.153, 1.201)	<.001	100	1.198	(1.173, 1.226)	<.001	100
Avoided eating at restaurants								
Direct	1.151	(1.128, 1.175)	<.001	85	1.182	(1.157, 1.209)	<.001	91
Indirect	1.022	(1.021, 1.025)	<.001	15	1.016	(1.015, 1.018)	<.001	9
Total	1.177	(1.153, 1.201)	<.001	100	1.201	(1.175, 1.228)	<.001	100
Made more purchases online								
Direct	1.150	(1.128, 1.174)	<.001	86	1.184	(1.158, 1.211)	<.001	93
Indirect	1.022	(1.021, 1.024)	<.001	14	1.012	(1.01, 1.014)	<.001	7
Total	1.176	(1.153, 1.2)	<.001	100	1.198	(1.172, 1.225)	<.001	100
More curbside pick-up								
Direct	1.169	(1.146, 1.193)	<.001	96	1.195	(1.169, 1.222)	<.001	99
Indirect	1.006	(1.005, 1.007)	<.001	4	1.001	(1.001, 1.003)	<.001	1
Total	1.175	(1.153, 1.2)	<.001	100	1.197	(1.171, 1.224)	<.001	100
Canceled doctor's appointments								
Direct	1.178	(1.155, 1.203)	<.001	100	1.199	(1.173, 1.226)	<.001	100
Indirect	0.999	(0.999, 1.001)	.105	–	0.999	(0.999, 1.001)	.106	–
Total	1.177	(1.154, 1.202)	<.001	100	1.198	(1.172, 1.226)	<.001	100

See Supplemental Table 3 for full estimation results. The unweighted sample size was $n=585,073$. OR odds ratio, CI confidence interval. The ORs are for the relationship between statewide COVID-19 condition and mental health problems

^aThe mediated model includes cognitive–behavioral changes as the mediator variable, statewide COVID-19 condition as the predictor variable, and mental health problems as the outcome variable. Covariates included demographic characteristics (age, gender, race/ethnicity, marital status, children in household, and household size), socioeconomic status (education, household income, work status, and tenure of residence), health status (self-rated health and insurance status), socioeconomic hardships (income loss, food insufficiency, housing instability, expense difficulty, and K-12 school closure) and location of residence (state and metropolitan statistical area)

^bTo calculate how much the OR for statewide COVID-19 condition was attenuated when the mediator variable was added, we used the following formula: $OR [\text{indirect effect}] / OR [\text{total effect}] \times 100\%$

COVID-19 pandemic, it is needed to offer individual and community-level interventions to address the inevitability of loneliness and its consequences [4]. Additional efforts should be made to ensure mental health equity among generally disadvantaged people, including racial and ethnic minorities, seniors, homeless people, and those with chronic mental problems [18, 25, 32, 35, 49]. Existing free and confidential hotlines can be also extended to provide immediate mental healthcare for vulnerable subpopulations during the pandemic, including children [3, 27], pregnant women [29], the elderly [42], healthcare workers [33, 54], physicians [1], and young adults [9]. In addition to such secondary and tertiary prevention for the mental health crisis, primordial and primary prevention strategies should be provided to address such inevitable loneliness and social isolation. For example, recent digital technologies may help develop virtual venues and online platforms to bridge the social distance as well as to support mental health [38]. In fact, recent studies reported preventing effects of online meetings on mental health outcomes, and such virtual settings should be supported more widely in various situations, including schools, workplaces, and religious venues [55, 58].

In the bigger picture, it may be a moment of opportunity—and challenges—for population health science [24]. Much remains to be studied about the COVID-19 and mental health, including the specifics of the virus itself and cognitive concerns and behavioral changes that may mitigate its spread. As noted by many scholars, we expect that the next years will result in deep insights to inform and be informed by population health science that will guide how we prepare for future pandemics [24, 41].

Strengths and limitations

Strengths of the HPS data are its large-scale population representative sample. Broad dimensions of cognitive-behavioral changes and socioeconomic experiences during the COVID-19 pandemic, as well as mental health outcomes, were measured comprehensively in the HPS, rather than specific health and medical conditions surveyed in other data. Furthermore, the biweekly survey cycle of the HPS enabled to build a pooled-cross-sectional data and incorporate temporal sequences between exposure, mediator, and outcome variables. The temporality suggests valid associations between pandemic conditions and mental health, in addition to the moderating roles of cognitive-behavioral changes. We also allowed possible interactions between the exposure and mediator variables to overcome the limitation of the conventional mediation approach (see Supplemental Table 7 for detailed comparisons between interaction models and conventional non-interaction models).

Our analysis is not without limitations. The pooled-cross-sectional design of this study is limited to interpreting the

results as a causal nature of associations. Although experimental and longitudinal designs have strengths in causal inferences, very few examples of large-scale longitudinal designs exist in COVID-19 research due to limited data availability in the yearlong pandemic. Second, HPS is limited in terms of survey scope, and we could not consider a full range of factors, such as previous GAD and MDD episodes, which are relevant to the associations between COVID-19 pandemic and mental health [26]. In addition, statewide or local lockdown and reopening policies may affect not only cognitive-behavioral changes but mental health, suggesting further research that reflects multiple aspects and varying degree of statewide policies. A geographically finer data might allow to exploring the moderating roles of cognitive-behavioral changes in different geographic levels [31]. The survey items for GAD and MDD were short forms of original long-form surveys, and there are potential misclassification issues due to the truncated questionnaire. However, the misclassifications would be non-differential, thus the expected bias may be toward the null, which suggests potentially stronger associations. Finally, the COVID-19 case and death rates provided by CDC may contain errors, particularly the case rate. There are a series of contributors of such estimation errors as proposed by Sen-Crowe et al. [56]. For example, individuals who tested COVID-19 more than one time could be double-counted. On the other hand, the death rate, despite some delay in the processing of death certificate, is relatively reliable statistics, as the mandatory reporting system can capture all death related to the SARS-CoV-2 virus based on the CDC protocol [28]. Despite the errors, we adopted the CDC dataset, because it is the only available and authoritative one that covers national surveillance data.

Conclusions

Overall results support the hypothesis that COVID-19 cases and death rates are associated with higher rates of cognitive concerns and behavioral changes, and these factors partially mediate the relationship between COVID-19 pandemic and mental health. Public awareness and fear of infections due to the general trend of COVID-19, as well as behavioral changes in daily life, are salient factors that determine mental health among adults in the U.S. These results should be considered when developing public health strategies (e.g., reopening, travel, and quarantine policies) to address the pandemic and subsequent mental health crisis. In sum, our results suggest that population health strategies aimed at addressing the mental health crisis during the COVID-19 pandemic should consider the causal mechanism (i.e., mediating roles of cognitive concerns and behavioral changes) that was found in this study.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s00127-022-02265-3>.

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