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Association of COVID-19 Misinformation with Face Mask Wearing and Social Distancing in a Nationally Representative US Sample

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ABSTRACT

Wide-spread misinformation about the COVID-19 pandemic has presented challenges for communicating public health recommendations. Should campaigns to promote protective behaviors focus on debunking misinformation or targeting behavior-specific beliefs? To address this question, we examine whether belief in COVID-19 misinformation is directly associated with two behaviors (face mask wearing and social distancing), and whether behavior-specific beliefs can account for this association and better predict behavior, consistent with behavior-change theory. We conducted a nationally representative two-wave survey of U.S. adults from 5/26/20-6/12/20 (n = 1074) and 7/15/20-7/21//20 (n = 889; follow-up response 83%). Scales were developed and validated for COVID-19 related misinformation beliefs, social distancing and face mask wearing, and beliefs about the consequences of both behaviors. Cross-lagged panel linear regression models assessed relationships among the variables. While belief in misinformation was negatively associated with both face mask wearing (B = −.27, SE =.06) and social-distancing behaviors (B = −.46, SE =.08) measured at the same time, misinformation did not predict concurrent or lagged behavior when the behavior-specific beliefs were incorporated in the models. Beliefs about behavioral outcomes accounted for face mask wearing and social distancing, both cross-sectionally (B =.43, SE =.05; B =.63, SE =.09) and lagged over time (B =.20, SE = 04; B =.30, SE =.08). In conclusion, belief in COVID-19-related misinformation is less relevant to protective behaviors, but beliefs about the consequences of these behaviors are important predictors. With regard to misinformation, we recommend health campaigns aimed at promoting protective behaviors emphasize the benefits of these behaviors, rather than debunking unrelated false claims.

Introduction

Throughout the coronavirus pandemic (COVID-19), false and misleading information – or "misinformation" – about the disease has proliferated across both mainstream and social media (Depoux et al., 2020; Kouzy et al., 2020; Mian & Khan, 2020). These rumors include myths about the origins of the virus (e.g., the virus was man-made), unfounded claims about the severity of the virus (e.g., the virus is less deadly than the seasonal flu), and false statements about the existence of a vaccine or cure (e.g., the malaria drug Hydroxychloroquine is an effective treatment) (Brennen et al., 2020; Sharma et al., 2020). An important health communication question is whether belief in misinformation decreases engagement in protective health behaviors. If so, it may be worthwhile to identify effective communication approaches to help combat misinformation. If not, communication strategies might instead focus on targeting other beliefs, particularly those that are proven to be associated with protective health behaviors.

In the current two-wave survey study involving a nationally representative sample, we assess the relationship between belief in COVID-19 misinformation and two CDC-recommended protective behaviors: social distancing and wearing face masks (Centers for Disease Control and Prevention, 2020). In addition, we consider the role of specific beliefs about the consequences of these behaviors (i.e. behavior-specific outcomes and norms). Ultimately, we ask whether there is a need for corrective communication efforts to address COVID-19 misinformation, or if addressing beliefs directly linked to protective behaviors is a more promising health campaign strategy.

Past studies

Concern about misinformation predates the COVID-19 pandemic. Much attention has been paid to the proliferation of political misinformation, particularly in the wake of the 2016 U.S. presidential election (Guess et al., 2020), and how to effectively counter it (Cook et al., 2015). Misinformation is comparatively understudied in the health domain (Kreps & Kriner, 2020; Southwell et al., 2019). There is some evidence that belief in specific false health information is associated with undesirable outcomes, including lowered vaccination rates (Jolley & Douglas, 2014; Oliver & Wood, 2014), reduced contraceptive use (Thorburn & Bogart, 2005), and nonadherence to antiretroviral treatment (Bogart et al., 2010), although overall, the research is limited and the findings mixed (Nan et al., in press).

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Emerging research on the behavioral effects of COVID-19 misinformation is similarly inconsistent. To date, many of the available studies are still in preprint form. All focus on the relationship between false beliefs and behaviors (or intentions to undertake behaviors). While some studies find associations between belief in COVID-19 misinformation and reduced self-protective behaviors (Allington et al., 2020; Banai et al., 2020; Bertin et al., 2020; Bierwiaczonek et al., 2020; Erceg et al., 2020; Sternisko et al., 2020; Swami & Barron, 2020; Teovanovic et al., 2020), others find no evidence of associations (Alper et al., 2020; Díaz & Cova, 2020). Still others find associations for some behaviors but not others (Imhoff & Lamberty, 2020; Pummerer & Sassenberg, 2020). These inconsistent results may be driven by the varying quality, size, and representativeness of samples, by the validity of measures employed, or by the variety of assessed self-protective behaviors, ranging from social distancing and containment, to hygiene and hoarding tendencies, to future intentions to vaccinate. Inconsistency may also be driven by varying depth and breadth of assessed misinformation, false beliefs, rumors, and conspiracy theories. Some studies focused on just a few false beliefs (e.g., "Coronavirus was developed and spread around the world by certain people for their own purposes"; Alper et al., 2020; Sternisko et al., 2020) whereas others developed multi-item misinformation scales, assessing a broader span of beliefs, ranging from possible treatments ("Colloidal silver is a potentially good cure for this coronavirus strain"; Erceg et al., 2020) to origins ("5 G electromagnetic field exposure played a role in the coronavirus pandemic"; Teovanovic et al., 2020).

These early studies provide some evidence that beliefs in certain kinds of COVID-19 misinformation are associated with self-protective behaviors. However, none of these studies systematically assess misinformation-behavior associations while taking into account potential associations between the behaviors and their related beliefs. The current study will add to that evidence base, featuring research that relies on a large, nationally representative longitudinal survey and uses validated measures directly assessing major constructs. This study evaluates whether belief in misinformation remains associated with protective behaviors when adjusting for beliefs about the consequences of these behaviors.

An observed negative association of belief in misinformation and protective behaviors would not establish that false belief correction will influence behaviors or merits priority attention in a communication campaign. COVID-19 misinformation often does not, on its face, directly relate to the protective behaviors. For example, rumors about the origins of the viral outbreak are not explicitly linked to consequences of face mask wearing or social distancing. Major theories of behavior prediction, including the reasoned actioned approach, hypothesize that behavior is influenced by behavior-specific beliefs, such as anticipated outcomes of the behavior (behavioral beliefs), whether significant others would approve of the behavior (normative beliefs), and perceived ability to perform the behavior (control beliefs) (Fishbein & Ajzen, 2010; Fishbein et al., 2001). Based on these theories, misinformation unrelated to specific behaviors would not directly influence behavior. Instead, beliefs about the consequences of the behaviors would account for, or mediate, any association of misinformation and behavior.

The present study

We conducted a nationally representative two-wave survey of 1074 adults living in the United States first interviewed between May 26-June 12, 2020 (T1) and then again between July 15–21, 2020 (T2). The follow up response rate was quite high: 83%. Respondents at both waves reported their level of agreement with highly proliferated unfounded rumors about COVID-19, the frequency with which they engaged in activities which were inconsistent with strict social distancing and stay-at-home recommendations, and how often they wore a face mask or other covering while engaging in activities for which face masks are recommended. We also measured and created parallel scales for beliefs about the perceived consequences of both social distancing and face mask wearing. Drawing from the reasoned actioned approach, we asked about specific outcomes and norms relevant to each behavior (Fishbein & Ajzen, 2010).

Adjusting for causally prior potential confounders, we first measured the cross-sectional associations between overall endorsement of false statements and each protective behavior, and then addressed whether the observed associations were accounted for by the measured beliefs about the consequences of those behaviors. We predicted *a priori* that the role of misinformation would be minimized in the presence of these related behavioral beliefs (https://aspredicted.org/blind.php?x=g2eq8w). Longitudinal analyses were employed to strengthen claims of influence; we measured the association between T1 beliefs and T2 behavior, adjusting for T1 behavior and all measured confounders. Finally, to test for reciprocal influence, we conducted a parallel analysis to see whether T1 behavior predicted T2 belief, adjusting for T1 belief and confounders.

Methods

Participants

A nationally representative sample of 1,074 adult U.S. residents were recruited from Social Science Research Solutions (SSRS)'s Opinion Panel (Social Science Research Solutions (SSRS), n.d.) and completed surveys online or by phone (cell phone and landline) in English or Spanish. In the first wave (T1), the cooperation rate for the survey was 54% (recruitment rate with the underlying panel varies from 2% to 4% depending on the mode of recruitment). The sample included residents from each U.S. state and survey weights developed by SSRS were used to ensure that participants matched the U.S. population on key demographic variables. Characteristics of original T1 survey participants are summarized in Table 4. The follow-up round (T2), on average undertaken six weeks later, successfully re-recruited 889 of these respondents (83%). The study was approved by the University of Pennsylvania IRB as exempt; study subjects provided prior consent to participate in the Opinion Panel.

Measures

Participants were asked a series of questions about their COVID-19-related beliefs and behaviors, as well as other personal characteristics. We constructed multi-item scales representing belief in misinformation, engagement in social distancing, face mask wearing, beliefs about the benefits of social distancing, and beliefs about the benefits of face mask wearing. Scales were used to represent each of these variables to capture the richness of each concept of interest and avoid potential bias or measurement error that could be caused by reliance on single-item measures. We assessed the internal consistency of the items composing each scale using Cronbach's alpha; used principal components analysis (PCA) to test whether all items would load onto a single factor; and, where possible, measured the correlation between the summed scale and another measure of the same construct. The complete survey instrument used in this study can be requested from the authors.

Face mask wearing scale

To measure participants' use of face masks, respondents were asked whether they had engaged in specific activities over the past week (presented in random order), and if they had, the frequency with which they had worn a face mask while engaging in those activities. The language of the questions can be found in Table 1. There was high consistency across items (T1 and T2 alphas = .88; .93) with all items loading on a single dimension in PCA. Respondents were separately asked "When you went outside your home in the past 7 days, how often did you wear a mask or other face covering?" Responses to this question were highly correlated with the scale (T1 and T2: r = .73; .61), providing further evidence for the validity of the scale.

Social-distancing scale

To measure the extent to which participants had followed social-distancing recommendations over the past week, respondents were asked whether they had engaged in several activities (presented in random order), six of which would necessarily involve violating social-distancing recommendations. These six items were measured dichotomously as yes/no and responses were summed to create a scale. Respondents were moderately consistent across the six activities (T1 and T2 alphas = .65 and .68); both loaded on single dimensions in the PCA. The full language of the questions is presented in Table 2. In a separate question, respondents were asked "Social distancing is staying at least 6 feet away from other people in public places. In the past 7 days, how often have you practiced social distancing?" The correlations between responses to this question and the summed scale were .57 (T1) and .55 (T2), providing further evidence for scale validity.

Misinformation belief scale

A set of 10 items was used to measure the extent to which participants agreed with misinformation about COVID-19. We compiled misinformation from a variety of sources, including fact-checking organizations (*WHO Myth Busters*), databases (Poynter's International Fact-Checking Network, n.d; Wikipedia's page on "Misinformation Related to the COVID-19 Pandemic"), and articles (Brennen et al., 2020; Erceg et al., 2020; Pennycook et al., 2020; Sharma et al., 2020). We focused on eight misinformation items while developing our scale due to their prominence in the media (Brennen et al., 2020) and because they formed a single dimension in the PCA. Items were presented in random order and measured on a 4-point scale (1 = *strongly disagree*, 4 = *strongly agree, with a 'not sure' alternative scored at the midpoint of the scale*). Respondents were consistent in their tendency to agree or disagree with false beliefs (both T1 and T2 alphas = .84). The language of the questions, including the left-out items, and the (weighted T1 and T2) proportion of respondents who answered each question are presented in Table 3.

Face mask/social distance behavior-specific belief scales

Participants were asked to agree or disagree with parallel batteries of six items about the behavioral outcomes (five items each) and norms (one item each) of social distancing or wearing face masks (Fishbein & Ajzen, 2010): "How much do you (disagree) or (agree) that if you [maintain social distance]/[wear a mask or other face covering in public places]

Table 2. Past-week compliance with social-distancing recommendations (% following distancing rules, T1 and T2) N = 889, weighted data.

In the last seven days, have you done any the following?	T1 (%)	T2 (%)	Change (%)
Gone out to a restaurant, bar, or other indoor place where people gather (% no)	73.6	67.2	−6.4
Gone inside a friend, neighbor, or relative's residence that is not your own (% no)	58.4	56.9	−1.5
Had visitors such as friends, neighbors or relatives inside your residence (% no)	56.0	53.4	−2.6
Remained in your residence at all times, except for essential activities or exercise (% yes)	59.2	55.2	−4.0
Had close contact – within about 6 feet – with people who do not live with you (% no)	30.1	26.8	−3.3

Table 1. Past-week compliance with face mask wearing while engaging in activities for which face masks are recommended: Percentage who did each activity, and the percentage of those who wore face masks every time, N = 889, weighted data.

How often did you wear a mask or other face covering in the past 7 days when you were doing each of the following activities never, some of the time, most of the time, every time:	T1 (%)		T2 (%)		Change (%)
	did activity	wore mask every time	did activity	wore mask every time	
Getting fresh air or exercising outdoors	89.1	14	86.9	14.7	0.7
Shopping for groceries or other necessities	88.4	69.1	91.5	82.8	13.7
Walking a dog or other pet	46.0	11.5	42.5	14.3	2.8
Meeting people socially outside	69.5	26.4	70.0	36.1	9.7
Taking a child outside to play	38.0	18.1	33.6	22.4	4.3
Meeting people socially indoors	66.2	23.9	65.0	28.3	5.0
Working at a job outside your home	48.9	42.2	48.3	53.1	8.9

Table 3. Misinformation beliefs; percentages answering strongly disagree or disagree (weighted data, N = 889).

	T1	T2	Change (%)
How much do you (disagree) or (agree) with the following statements:	% disagree		
Coronavirus is probably a hoax	81.3	83.7	2.4
Public health authorities are exaggerating the seriousness of coronavirus	56.7	60.2	3.5
A vaccine for the coronavirus is now available	67.3	66.5	−.8
The malaria drug Hydroxychloroquine is an effective treatment for coronavirus	49.7	44.9	−4.8
A cure for coronavirus has been found	64.3	65.5	1.2
Information about treatments for coronavirus is being suppressed by those who want the pandemic to continue	55.0	55.5	0.5
Coronavirus was created in a lab	33.0	35.2	2.2
The coronavirus is not more dangerous than the seasonal flu	61.7	62.1	0.4
*If people wear masks it will slow the development of widespread immunity to coronavirus**	34.4	–	–
*if people social distance it will slow the development of widespread immunity to coronavirus**	25.2	–	–

every day for the next two weeks: you will protect more vulnerable people in our society, you will help the healthcare system so that people who need urgent medical care will receive it, you will slow the spread of the coronavirus, it will prevent you from transmitting coronavirus to others, your family and friends will approve of your decision, you will be less likely to get sick." Respondents were randomly asked the face mask or social-distancing battery first, and the six items within each battery were presented in random order. Responses within each scale were highly consistent (T1 and T2 face mask alphas = .93 and .94; social distance alphas = .92 and .93) and consistently formed single dimensions on the PCA. Respondents who reported high favorable belief scores for face mask wearing also reported high scores for beliefs about social distancing (both T1 and T2 r = .90).

Analyses

We report distributions of responses on each item and scale, bivariate correlations between beliefs in misinformation, wearing face masks, social distancing, and beliefs about the consequences of wearing face masks and social distancing as well as a set of potential confounders (Table 4). We conducted a series of linear regression analyses using MPlus 8.3. Samples were weighted to represent the US population; the parameters were estimated with maximum likelihood with robust standard errors (MLR). Missing values were handled using the full information maximum likelihood (FIML) method.

We first fit a series of cross-sectional models to test whether belief in misinformation was significantly associated with face mask wearing and social distancing scales, and whether these relationships remained significant when controlling for potential confounders. Next, we assessed whether the relationships between belief in misinformation and wearing face masks or social distancing remained when adjusting for beliefs about the positive consequences of those behaviors. We then conducted longitudinal analyses, fitting cross-lagged panel correlation models predicting behaviors and beliefs at T2 from T1 measures of those variables. To allow for measurement of over-time change, the final analyses include only the 83% of respondents who provided information for T1 and T2 (n = 889).

Results

Descriptive data

Face mask wearing is inconsistently performed and is contingent on the activity (Table 1). At T1, between 38% and 89% of respondents reported engaging in each activity, and there was variation in face mask wearing frequency, depending on the behavior. For example, at T1 14% of respondents wore masks every time they went out for fresh air or for exercise, compared to 69% who always wore masks while shopping for groceries or other necessities. Over the six-week period between waves, respondents retained for both waves reported increases in face mask wearing, particularly for grocery shopping (+ 14%) and for meeting with people outside (+ 10%).

Between 30% and 74% reported specific behaviors consistent with social distancing at T1, with the lowest level of compliance reflecting entertaining others in one's own home (Table 2). While face mask wearing increased over the six weeks between waves, respondents reported less social distancing, including less staying away from restaurants (−6%) and less remaining at home (−4%).

Most of the eight false beliefs that made up the misinformation belief scale garnered substantial disagreement at T1 (more than 55% disagreed with 6 of 8) (Table 3). Still, about 35% of the sample were unsure or agreed with at least half of the false beliefs; only 9% strongly disagreed with all eight. About 43% were not sure or agreed with the statement that public health authorities were exaggerating the seriousness of COVID-19, with 45% not sure or agreeing with the claim that "Information about treatments for coronavirus is being suppressed by those who want the pandemic to continue." These proportions stayed consistent over time, with less than a 5-point change from T1 to T2 for each item. As will be shown below, the mean summed scale score did not change between waves. Table 4 presents univariate information and the bivariate associations of the five T1 scales with each other, with the T2 scales, and with the potential confounders.

Cross-sectional results

We measured cross-sectional associations between belief in misinformation and protective behaviors, controlling for potential confounders, and then controlling for behavior-specific beliefs. At T1, face mask wearing was negatively correlated with belief in misinformation (r = −.21) but was much more associated with beliefs around face mask wearing (r = .43). Similarly, at T1, social-distancing behavior was negatively correlated with belief in misinformation (r = −.21) but much more associated with beliefs around social distancing (r = .38). As previously noted, the two behavioral belief scales were highly inter-correlated (r = .90), likely reflecting their parallel question structure, but we did not use these scales concurrently in any multivariate analyses.

Table 4. Univariate information and correlations of primary variables with each other and with potential confounders, weighted results. (Limited to 889 respondents for T1 and T2, population-weighted).

		Univariate information (M/sd) or %	Time 1 Measures				
			Face mask wearing	Pro-Face mask wearing beliefs	Social Distancing	Pro-social distancing beliefs	Misinfo scale
Time 1 measures	Face mask wearing (1–4)	2.3 (.92)					
	Pro-Face mask wearing beliefs (1–4)	3.2 (.80)	.43				
	Social Distancing (1–5)	2.8 (1.5)	.43	.39			
	Pro-social distancing beliefs (1–4)	3.3 (.75)	.43	.90	.38		
	Misinformation scale	2.0 (.65)	−.21	−.51	−.21	−.50	
	Education in years (1–20)	14.1 (2.8)	−.06	.08	−.01	.09	−.34
	Age (years)	47.6(18)	.06	.05	.18	.05	−.11
	Gender (M = 1; F = 2; other = missing)	51% F	.14	.10	.10	.11	.06
	Income (5 k to 150 k+)	68 k (50)	−.12	.01	−.09	.01	−.21
	Black vs all others	11%	.12	.01	.00	.04	.03
	White vs all others	72%	−.17	−.08	−.03	−.05	.00
	Latinx/Hispanic vs all others	16%	.19	.11	.03	.09	.03
	Marital status (partner vs not)	63%	−.10	−.05	.05	−.04	.01
	HH size (1–16)	2.9 (1.6)	−.04	−.04	−.05	−.05	.10
	Kids < 18 or not.	32%	−.07	−.04	−.07	−.04	.14
	Employed or not (pre-pandemic)	56%	−.01	−.06	−.12	−.09	−.04
	Health insured or not	90%	.03	−.01	−.06	.00	−.01
	Home owned vs. rented	65%	.26	.08	.02	.07	.09
	Northeast	18%	.14	.08	.01	.06	−.03
	Northcentral	21%	−.16	−.04	−.04	−.06	−.05
	South	37%	−.03	−.01	−.01	.00	.10
	West	24%	.07	−.03	.03	.00	−.04
Time 2 measures	Face mask wearing	2.6 (.88)	.65	.42	.28	.40	−.19
	Pro-face mask beliefs	3.4 (.76)	.40	.76	.32	.75	−.55
	Social distancing	2.6 (1.6)	.34	.32	.56	.34	−.18
	Pro-social distancing beliefs	3.4 (.72)	.40	.74	.36	.75	−.52
	Misinformation scale	2.0 (.66)	−.21	−.51	−.21	−.49	.84

With a few exceptions, the potential confounders were not substantially correlated (|r| < .20) with the focus scales. Belief in misinformation was less common among respondents with higher levels of education (r = −.34) and among higher income respondents (r = −.23); face mask wearing was more common among those who rented rather than owned their own homes (r = .26). All of the remaining 72 correlations between the T1 scales and potential confounders were between −.20 and +.20.

Table 4 also shows the consistent negative relationships between belief in misinformation and each of the protective behaviors at both waves of measurement (r = −.21 in every case). Table 5 elaborates this result with a series of cross-sectional multivariate analyses (using all of the T1 cases). Models 1a and 2a show the simple bivariate unstandardized associations between belief in misinformation and each of the behaviors; models 1b and 2b show the misinformation coefficients for each behavior when the full set of potential confounders are entered into the equations. Finally, models 1c and 2c show the coefficients when the confounders, belief in misinformation, and the relevant behavioral beliefs are included.

The cross-sectional association of belief in misinformation with both protective behaviors not only remains significant but increases in magnitude when the confounders are incorporated in the models. However, this pattern changes once the relevant behavioral beliefs are added to the equations. For face mask wearing, the association of belief in misinformation is effectively accounted for – the significant unstandardized coefficient found

Table 5. Cross-sectional protective behaviors regressed on Misinformation, Confounders and Behavioral Beliefs. Results of MPlus FIML linear regression models (Unstandardized coefficients and standard errors).

	Face mask wearing			Social distancing		
	Model 1a: simple	Model 1b: Adjusted for confounders	Model 1c: Including behavioral beliefs and confounders	Model 2a: simple	Model 2b: Adjusted for confounders	Model 2c: Including behavioral beliefs and confounders
Misinformation	**−.27 (.06)**	**−.34 (.05)**	−.06 (.06)	**−.46 (.08)**	**−.55 (.09)**	−.17 (.10)
Face mask behavioral beliefs			**.43 (.05)**			
Social distancing behavioral beliefs						**.63 (.09)**
R-square	.035	.236	.325	.039	.127	.192

Note. Bolded results p <.001; effective weighted n = 1,074 for all models; missing values (between 0–92 by equation) were handled using full information maximum likelihood method (FIML); parameters were estimated using maximum likelihood with robust standard errors (MLR) with sampling weights via MPlus 8.3. Confounders listed in Table 4. See Supplemental Table S2 for parameter estimates of confounders in models 1c and 2c.

in Model 1b (B = −.33, se = .05) becomes small and not different from zero in Model 1c (B = −.05, se = .06) while the coefficient for the newly entered face mask wearing beliefs variable is large (B = .43, se = .05). The same pattern appears for social distance behaviors. The Model 2b confounder-controlled coefficient (B = −.53, se = .09) falls sharply in Model 2c (B = −.15, se = .10), and behavioral beliefs are strongly related to social-distancing behavior (B = .62, se = .09). The complete equations, including coefficients for the confounders, can be found in the online supplement. Multicollinearity between the behavioral beliefs and misinformation measures did not threaten these estimates (VIF<1.40). These baseline cross-sectional results are virtually unchanged whether the dropouts between T1 and T2 are included or excluded.

Longitudinal results

The cross-sectional analyses establish that the association between misinformation and behavior disappears once beliefs about the consequences of those behaviors are statistically controlled. However, the belief-behavior regressions – adjusted for confounders – do not establish a causal order between the beliefs and behavior; it is possible that behavior actually leads to beliefs. The next longitudinal analyses ask whether the beliefs are not only associated with behaviors, but also predict them. Do beliefs at T1 predict behavior at T2 when adjusted for behavior at T1? Figure 1(a) (for face mask wearing) and Figure 1(b) (for social distancing) present cross-lagged panel models, weighted and incorporating confounders. As shown in these figures, for both behaviors, T1 beliefs are substantial lagged predictors of T2 behavior (B = .20 (.04) for mask wearing and B = .31 (.08) for social distancing), over and above the substantial associations of T1 behavior and T2 behavior and the cross-sectional relationships of T1 belief and T1 behavior. In addition, there is evidence of a smaller but significant lagged reciprocal effect of T1 behavior on T2 beliefs for both behaviors. In contrast, and consistent with the cross-sectional results, belief in misinformation at T1 does not predict either T2 behavior when T1 behavior and T1 beliefs are controlled (face mask wearing partial correlation = .00; social-distancing partial correlation = .04).

Discussion

Overall, there is substantial evidence for both the quality of and variation in our five core variables. These measures are all substantially associated with one another. Misinformation beliefs did not shift over time; face mask wearing increased and social distancing decreased slightly. We found the cross-sectional associations (at both T1 and T2) of both protective behaviors (face mask wearing and social distancing) with belief in misinformation are significant and negative, even after adjusting for potential confounders. However, the relationships between belief in misinformation and protective behaviors are smaller than the relationships between the protective behaviors and their related beliefs. Further, misinformation-protective behaviors associations disappear after adjusting for behavioral beliefs. In longitudinal analyses, we found that behavior-specific beliefs (and not belief in misinformation) were significant lagged predictors of protective behaviors, further supporting an inference that these beliefs are not only correlated with behavior but also predict change in those behaviors.

We pre-registered a hypothesis related to the original T1 cross-sectional study that the association of misinformation beliefs with protective behaviors would be minimized in comparison with behavior-specific beliefs (https://aspredicted.org/blind.php?x=g2eq8w); the results both do and do not conform to the pre-registered hypothesis. The misinformation measure is substantially associated with both of the protective behaviors even when we adjust for a wide range of potential confounders, consistent with some prior studies. On the other hand, as predicted, belief in misinformation is less associated with those behaviors than the behavioral beliefs directly tied to those behaviors, and the association between belief in misinformation and protective behaviors largely disappears when the analysis adjusts for behavioral beliefs, both cross-sectionally and in the lagged analyses. We recognize that there are multiple interpretations consistent with those results.

Interpretation 1: Beliefs about consequences lead to adoption of protective behaviors (although there is reciprocal influence as well). The particular beliefs measured may be specifically influential or may be indicators of a set of beliefs that underpin a strong positive attitude toward the behaviors.

Interpretation 2: It may also be that misinformation does influence behavior, but its influence is entirely mediated through the behavioral beliefs (consistent with the reasoned action approach).

Interpretation 3: On the other hand, misinformation may have no substantive role in influencing behavior, even indirectly. The association of beliefs about behavioral consequences and misinformation might be a reflection of influences (in opposite directions) by common external forces. However, only beliefs about consequences affect adoption of protective behaviors.

All three of these interpretations are consistent with regard to their conclusion about a potential path to influencing protective behaviors: engaging with behavioral beliefs rather than misinformation. A final interpretation recognizes a limitation of the research design, and while not challenging the disregard of misinformation, is less confident about the promise of a campaign focused on behavioral beliefs.

Interpretation 4: Some unmeasured confounders, such as skepticism around public health concerns, affect all measured variables (belief in misinformation, behavioral beliefs, and protective behaviors) and account for the observed cross-sectional and lagged associations of the beliefs and behavior. For this interpretation to be true, those unmeasured confounders would need to be independent of the measured confounders, which were shown not to reduce the effects of beliefs. Also, they would have to have time varying effects; to explain the lagged effects of beliefs measured at T1 on behavior measured at T2, unmeasured confounders would need to have both effects on belief at T1 and effects on behavior at T2 that were not accounted for by their effects on behavior at T1.

This study has clear strengths. To our knowledge, it is the first to engage with and compare the effects of misinformation in the context of behavioral beliefs on COVID-19-related protective behaviors. There is good evidence for the validity of the focus measures. The large sample is drawn from an established nationally representative panel. The two rounds of data

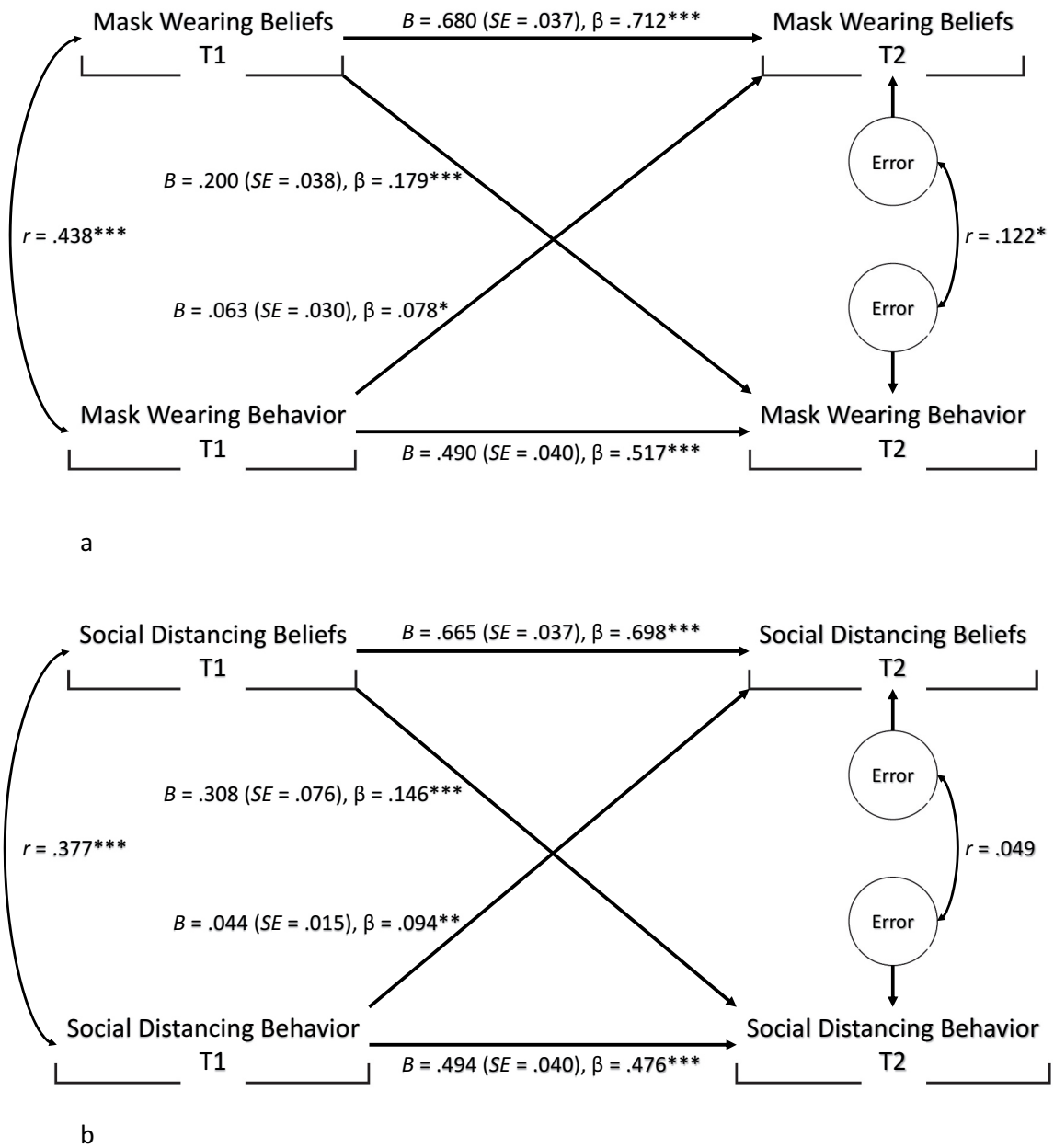

Figure 1. (a) Face Mask Wearing Cross-Lagged Analysis Results. (*Note.* $n = 889$; MLR estimation results after controlling for confounders; missing values were handled using FIML) (b) Social-Distancing Cross-Lagged Analysis Results. (*Note.* $n = 889$; MLR estimation results after controlling for confounders; missing values were handled using FIML).

collection six weeks apart permitted replication of the results with both cross-sectional and longitudinal analyses. The potential weaknesses are shared with any survey-based observational study: reliance on self-reported behaviors, concerns about unmeasured confounders not completely dealt with by the longitudinal design, and possible biases of the sampling procedures producing an analytic sample imperfectly representing the population.

Implications for health communication

Causal claims from observational data, even longitudinal observational data, are necessarily uncertain. Nonetheless, these results do bear on thinking about what beliefs ought to be the target of public communication campaigns. Specifically, they suggest that a communication intervention directly addressing misinformation beliefs is likely to be less promising than one directly addressing the specific behavioral beliefs around the protective behaviors. The results suggest that despite the moderate association of belief in misinformation with behavior, directly targeting such false beliefs may be unnecessary for encouraging protective behaviors.

Addressing such beliefs is unnecessary in the context of health campaigns because any influence they might have on behaviors is accounted for by the direct behavioral beliefs. Focusing on addressing specific behavioral beliefs may also be preferable given the difficulty of effectively correcting misinformation. While some strategies have been found to be effective at correcting misinformation, the effectiveness of different

types of correctives varies greatly (van der Meer & Jin, 2020; Walter & Murphy, 2018), and misinformation about infectious diseases may be particularly difficult to correct (Walter et al., 2020). Moreover, even after correction, misinformation can continue to have negative effects on people's attitudes due to the persistence of a "belief echo" (Thorson, 2016). Further complicating matters, coronavirus-related misinformation has included hundreds if not thousands of discrete rumors (as can be seen from perusing fact-checking websites such as snopes.com), which have emerged across a number of different media platforms and have waxed and waned in their prominence over the course of the pandemic. Thus, identifying which pieces of misinformation need to be corrected and the ideal platforms through which to issue corrective communications would be a great challenge.

In contrast, both theory (i.e. Fishbein & Ajzen, 2010) and the evidence presented here speak to the promise of prioritizing direct behavioral beliefs, regardless of false beliefs. Each of the specific beliefs is a candidate for persuasive interventions. Campaigns would focus on moving people from disagreement or less than strong agreement with these beliefs which are highly associated with behaviors (*you will protect more vulnerable people in our society; you will help the healthcare system so that people who need urgent medical care will receive it; you will slow the spread of the coronavirus; it will prevent you from transmitting coronavirus to others; your family and friends will approve of your decision; you will be less likely to get sick*). While this study cannot establish that a campaign which successfully addressed these beliefs would also influence adoption of behaviors, it does create the beginning of a roadmap for priority focus for such campaigns (Brennan et al., 2017; Hornik et al., 2019).

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Author contributions

RH led and worked on all aspects of the study; LS, KK also did data analysis; all co-authors contributed to the development of the study design, drafting of the questionnaire, as well as writing and reviewing drafts. Authors after RH are listed in random order since all contributed equally.

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