Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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How threat perceptions relate to learning and conspiracy beliefs about COVID-19: Evidence from a panel study

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ABSTRACT

According to appraisal theory, individuals cope with perceived threats in different ways. If engaging in problem-focused coping, for example, they may seek information useful for eliminating the root cause of the threat. However, during crises such as the COVID-19 pandemic, people tend to navigate complex information environments marked by high levels of uncertainty. In such contexts, individuals may adopt maladaptive behaviours—for instance, avoiding information or switching to pseudo-epistemic coping—in which they engage with non-scientific explanations. As a consequence, they may learn less from their information environment and become susceptible to conspiracy theories. Against that background, we investigated how threat perceptions relate to learning, believing in conspiracy claims and conspiracy thinking in context of the COVID-19 pandemic. Drawing from two-wave panel data, we found that threat perceptions were associated with a decrease in knowledge and an increase in believing conspiracy claims. Taken together, our findings indicate that high levels of threat perceptions in uncertain information environments may impede societal learning and encourage conspiracy beliefs. Thus, although provoking general anxiety may support short-term political goals, including adherence to policy during crises, accumulated threat perceptions may adversely affect citizens' motivation to cooperate in the long term.

1. Introduction

Anxiety is an important emotion that has helped humankind to survive. Perhaps above all, because anxiety arises in contexts of uncertainty—that is, amid an imminent threat perceived to be beyond control—feelings of anxiety help people to make careful decisions when confronting environmental threats (Spielberger & Reheiser, 2009). Although anxiety's important evolutionary role remains undisputed, questions about whether high levels of anxiety stimulate or impede learning processes in today's societies and how those dynamics affect phenomena in mass communication, including the spread of misinformation, continue to go unanswered (Georgiou et al., 2020; Green & Douglas, 2018). However, considering those questions is especially important during crises such as the COVID-19 pandemic, when strong fears of economic and social consequences prevail and individual behaviour becomes vital to counteracting critical threats (Van Bavel et al., 2020).

In literature on the topic, one strand of research has shown that anxiety can stimulate learning by incentivising people to scan their information environments for threat-reducing clues (Gardarian & Albertson, 2013; Marcus & MacKuen, 1993; Valentino et al., 2008). A second strand, however, has demonstrated that anxiety and the experience of stress may also impede problem-focused coping when information is scarce, inaccessible or overly complex (Green & Douglas, 2018; Grzesiak-Feldman, 2013; Swami et al., 2016). Following that second strand, our study focused on how anxiety has related to learning and conspiracy beliefs during the COVID-19 pandemic's parallel crisis: the COVID-19 *infodemic*, defined as "an overabundance of information and the rapid spread of misleading or fabricated news, images, and videos" (World Health Organization, 2020).

1.1. Coping with anxiety

If humans identify threats and consequently experience anxiety, then they engage in cognitive appraisal processes, understood to involve "categorizing an encounter, and its various facets, with respect to its significance for well-being" (Lazarus & Folkman, 1984, p. 31). In one type of appraisal, known as primary appraisal, individuals evaluate

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whether they are in danger and how they could benefit from their current situations. By contrast, in secondary appraisal, individuals evaluate how they can manage those situations—in a word, *cope* (Lazarus & Folkman, 1984; Smith & Kirby, 2011). By extension, individuals also engage in reappraisal processes, in which they evaluate and re-evaluate how actions taken or initiated have affected threats posed by their situations (Lazarus & Folkman, 1984; Smith & Kirby, 2011).

Depending upon individual environment and predispositions, people engage in different types of coping strategies (Folkman et al., 1986; Lazarus, 1991; Park & Folkman, 1997; Smith & Kirby, 2011). For one, individuals may adopt a *problem-focused coping* approach, in which they seek problem-related information as a means to overcome a threat by getting to the root of the problem. Indeed, that approach may facilitate understanding and ultimately help to resolve the problem at hand. For another, individuals may engage in *meaning* or *epistemic coping*, in which they seek to determine why an event has occurred. In the process, they may encounter scientific facts that similarly facilitate understanding and aid in resolving the problem. However, in the absence of accessible, accurate information, they may also formulate transcendent or pseudo-scientific explanations and, in turn, engage in a third coping strategy, which we call *pseudo-epistemic coping* (also see Douglas et al., 2017; Park & Folkman, 1997).

Of course, individual predispositions can readily determine how individuals cope with anxiety and stress. For example, problem-focused coping requires certain personal skills (e.g. cognitive abilities and information literacy); however, if individuals lack those skills, then they may resort to other, less effort-intensive coping strategies (Carver & Connor-Smith, 2010; Park & Folkman, 1997). Added to that, environmental factors can also determine how individuals cope. One's environment may enable effective problem-focused coping, for instance, by providing access to the necessary information and thus opportunities to solve the problem. However, some environments prevent such problem-solving, as Park and Folkman (1997) have pointed out: "Some of the most persistent stressors … are impervious to problem solving, [and result in] discouraging active ameliorative coping efforts." (p. 124). In such cases, individuals may stumble across alternative explanations and solutions that may uphold their pre-existing belief systems, or what Park and Folkman (1997) have termed *global meaning*. After all, as cognitive dissonance theory maintains, individuals are liable to skew facts from their environments in order to confirm their beliefs and promote their goals (Leman & Cinnirella, 2013).

1.2. Anxiety and learning

In research on learning effects, Marcus and MacKuen (1993) found that anxiety induced during electoral campaigns can contribute to political learning—that "when politics makes people anxious, people sharpen their eyes and pay careful attention" (p. 681). Valentino et al. (2008) also observed that experimentally induced threat perceptions increased information seeking and learning via feelings of anxiety. However, in both of those studies, information was highly accessible to the participants. For example, Valentino et al. (2008, p. 264) measured learning with questions addressing the content of information provided ex post the threat-inducing stimulus.

At the same time, other findings suggest that higher levels of anxiety may impede learning in more complex information environments. Early during the COVID-19 pandemic, for instance, as scientific evidence about a new, threatening virus was emerging by the day, individuals may have struggled to meet their epistemic needs with accessible, evidence-based information (Rutter et al., 2020). In such contexts, individuals who perceive high levels of threat may be unable to gain new information that allows them to better understand and manage the perceived threat. If so, then they may resort to maladaptive coping strategies, including pseudo-epistemic coping (Swami et al., 2016), or even avoid information about the threat (Grant et al., 2013), which only further impedes learning processes. Turning to pseudo-epistemic coping, for instance, reduces opportunities for evidence-based learning. To the same effect, experiencing stress while engaging with information about the threat discourages further encounters with such information. In those cases, individuals can engage only in shallow information processing, which by definition impedes deep learning (Carpenter, 2020; Moneta et al., 2007).

Extending all of the above to the context of the COVID-19 infodemic, we developed a research question to guide our study:

RQ1. How do threat perceptions concerning COVID-19 relate to (a) knowledge about COVID-19 and (b) changes in such knowledge across time?

1.3. Anxiety and conspiracy beliefs

Individuals have an innate need to understand and explain unexpected or negative events (Douglas et al., 2017; Park & Folkman, 1997). After all, such events are liable to induce anxiety, which intensifies the need to make sense of the environment and develop explanations for the events. Among those types of explanations, conspiracy theories provide simple answers to complex events and are a vital source for pseudo-epistemic coping. Put differently, "A conspiracy theory helps people to make sense of the world by specifying the causes of important events, which further helps them predict, and anticipate, the future" (Van Prooijen & Douglas, 2017, p. 327). As such, conspiracy theories can aid people in coping with acute anxiety or stress by granting them a sense of control and a channel for processing negative emotions (Swami et al., 2016).

However, higher levels of uncertainty do not necessarily lead to *conspiracy beliefs*, which we use as an umbrella term for beliefs in specific conspiracy claims, such as that Bill Gates would be responsible for the spread of COVID-19 (Bensley et al., 2020), or more general conspiracy thinking, for example that some secret organisations heavily influence political decision-making (Bruder et al., 2013). A recent meta-analysis suggests that, on the whole, studies have found mixed and inconclusive evidence of uncertainty's effects on conspiracy beliefs (Stojanov & Halberstadt, 2020), possibly because individuals engage in different strategies in their efforts to cope with uncertainty. In fact, individuals may prefer to cope with uncertainty by eliminating the root causes of perceived threats and resort to conspiracy claims only when their environments impede such problem-focused coping. In our study's context, due to the scarcity of scientific evidence, the COVID-19 pandemic has bred high levels of uncertainty. Such information environments may indeed impede problem-focused coping and create the need for alternative explanations. Thus, Hypothesis 1 (H1) and Hypothesis 2 (H2) were that:

H1. Threat perceptions about COVID-19 positively relate to (a) believing conspiracy claims and (b) increased beliefs in such claims across time.

H2. Threat perceptions about COVID-19 positively relate to (a) conspiracy thinking and (b) increases in such thinking across time.

Last, we also wanted to investigate the role of psychological traits, represented by the big five personality traits—extraversion, agreeableness, openness, conscientiousness and neuroticism—as control variables, in variations in learning and conspiracy thinking (Goreis & Voracek, 2019; Komarraju et al., 2011). Neuroticism may be especially confounded with threat perceptions, because individuals who experience negative emotions and stress on a more general, stable level may also be more likely to experience anxiety in stressful situations (Hollander, 2018; Horikawa & Yagi, 2012; Lobato et al., 2014). Thus, we accounted for personality traits in our models by asking:

RQ2. How do the big five personality traits relate to learning and conspiracy beliefs, and how do they influence their relationship with threat perceptions?

1.4. Context of the study

To investigate the effect of threat perceptions when the COVID-19 pandemic peaked in Austria, we relied on national two-wave panel data collected in early April 2020, the peak of the first COVID-19 pandemic wave in Austria, and again at the end of the national lockdown in early June. This panel-based approach allowed us to examine how threat perceptions at the peak of the crisis related to changes in knowledge and conspiracy beliefs till the end of the lockdown.

After the first COVID-19 cases in Austria were detected in February 2020, the spread of the virus increased rapidly throughout March. In view of developments in Bergamo, Italy, the Austrian government implemented a nationwide lockdown in early April that paralyzed public life for weeks but also significantly lowered the rate of infection (Pollak et al., 2020). Although the measures taken proved effective, the ways in which they were implemented received considerable criticism. Among others, some observers accused the federal government's lockdown-related decision-making of lacking transparency and scientific support (Tóth, 2020). Such criticism gained momentum when the minutes from a March meeting of the Coronavirus Task Force leaked in late April to reveal the government's anxiety-based strategy to managing the crisis. Critics were particularly concerned by statements of Chancellor Sebastian Kurz warning that "everyone will soon know someone who has died of Corona" and similarly terrifying descriptions of 100,000 deaths related to COVID-19 (Tóth, 2020). Against that background, we investigated the potential consequences of fear-based politics on societal learning and conspiracy beliefs.

2. Method

2.1. Sample

After receiving ethical approval from our university's Ethical Review Board, a two-wave panel survey was conducted. Data collection was performed by Dynata, a private market research company that selects respondents from an online panel according to predefined quotas (i.e. defined based on population data retrieved from the Austrian statistical office, Statistik Austria). Dynata provides financial incentives to their panel members. After reading an informed consent, the participants could either agree to participate or opt out of participation. The final composition of the sample represented the population structure of Austria. During Wave 1, conducted between 1 and 7 April 2020 at the peak of the COVID-19 epidemic in Austria, the survey received 1800 clicks, and 1725 individuals started the survey. Of them, 33 did not provide their informed consent to participate, 555 were screened out due to full quotas, and 113 did not complete the survey for other reasons. Thus, 1024 individuals completed the survey (i.e. 57% of those who clicked on the survey link). For Wave 2, conducted between 2 and 10 June 2020 when the number of infections had been greatly reduced and regulations loosened, invitations were sent to participants from Wave 1 only. At that time, the survey received 769 clicks, and 632 individuals completed the survey: 320 women and 312 men, with an average age of 49.30 years ($SD = 17.53$, min. = 18, max. = 87). Whereas 105 had only completed compulsory schooling as their highest level of education, 305 had completed vocational school, 115 had earned high school diplomas, and 104 had earned a college degree.

2.2. Measures

2.2.1. Threat perceptions about COVID-19

To measure anxiety over COVID-19, we asked participants whether they were anxious about different threat scenarios on a 5-point scale, ranging from 1 (*disagree*) to 5 (*agree*). Although we referred to published approaches to measuring anxiety (e.g. Green & Douglas, 2018), we tailored our items specifically to COVID-19. Thus, the items included (a) "I am anxious that the virus will spread further in an uncontrollable way", (b) "I am anxious that our healthcare system will become overwhelmed", (c) "I am anxious that the freedom of the citizens will be further restricted", (d) "I am anxious that the grocery supply will run short", (e) "I am anxious that I will be confronted with financial problems", (f) "I am anxious that I will not see my family or relatives anymore" and (g) "I am anxious that the government measures will lead to an economic collapse". All items were combined on a mean scale ($\alpha = 0.79$, $M = 3.14$, $SD = 0.90$).

2.2.2. Knowledge about COVID-19

To measure knowledge about COVID-19, we asked participants six quiz questions (e.g., about the meaning of "incubation period" or recommended behaviour in response to signs of infection). Each question came with three response options (of which one was correct) and an additional "I don't know" option. For each correct answer, participants received 1 point; for incorrect answers, they received 0. We totalled the correct answers as a formative scale ($M = 5.03$, $SD = 1.35$). We debriefed the participants by informing them about the correct answers at the end of the survey.

For Wave 2, we changed the questions addressing knowledge about COVID-19 for two reasons. First, for ethical reasons, we had debriefed participants in Wave 1, which made it infeasible to ask the same questions again in Wave 2. Second, the information environment about COVID-19 had changed in the 2 months since Wave 1, with various aspects waxing and waning in importance. Thus, following past research (e.g., Andersen & Hopmann, 2018), we updated the knowledge-related items for Wave 2. All items appear in the Supplemental material (Tables S2 and S3). We followed the same procedure as with items in Wave 1 and created a formative scale ($M_{(W2)} = 4.48$, $SD_{(W2)} = 1.70$). All items appear in the Supplemental material (Tables S1 and S2).

2.2.3. Belief in conspiracy claims

In line with existing approaches (e.g. Bensley et al., 2020), we assessed the extent to which participants believed certain conspiracy claims by having them rate three widespread claims circulating in Austria during the COVID-19 epidemic on a 5-point scale, ranging from 1 (*not credible*) to 5 (*credible*). The three claims were (a) "The coronavirus was bred in a lab in China and systematically disseminated", (b) "The coronavirus was spread to counter population ageing" and (c) "The coronavirus was created by financial companies to reduce cash payments" ($\alpha = 0.85$, $M = 0.96$, $SD = 0.56$; $\alpha_{(W2)} = 0.84$; $M_{(W2)} = 0.98$, $SD_{(W2)} = 0.55$).

2.2.4. Conspiracy thinking

To assess conspiracy thinking, we relied on Bruder et al.'s (2013) Conspiracy Thinking Scale, which contains five items to which participants responded on a 5-point scale, ranging from 1 (*disagree*) to 5 (*agree*). Participants were asked, "Regarding the coronavirus pandemic, do you agree that (a) several very important things are happening in the world that the public is never informed about; (b) politicians usually do not tell citizens the true motives behind their decisions; (c) government agencies closely monitor all citizens; (d) events that seem to lack connection on the surface are often the result of secret activities; and (e) secret organisations greatly influence political decisions" ($\alpha = 0.87$, $M = 2.99$, $SD = 1.05$; $\alpha_{(W2)} = 0.88$, $M_{(W2)} = 3.08$, $SD_{(W2)} = 1.05$).

2.2.5. Big five personality traits

To measure the big five personality traits, we used a 15-item inventory (Danner et al., 2019; Lang et al., 2011) during Wave 2. The measurement yielded an acceptable fit, as indicated by a confirmatory factor analysis of the items (Table S3).

2.2.6. Control variables

We controlled for participants' age, gender, level of education and overall news consumption. Age was measured as a continuous variable, gender as a binary variable (50.63% women) and level of education as

whether individuals had earned a college degree (16.93%), a high school diploma (18.20%) or less. We asked participants how many days per week they accessed general news about the coronavirus ($M = 6.29$, $SD = 1.63$) and how often they accessed news about the coronavirus from public TV channels ($M = 3.93$, $SD = 1.39$), private TV channels ($M = 3.21$, $SD = 1.46$), newspapers ($M = 3.17$, $SD = 1.57$), the Internet ($M = 3.35$, $SD = 1.42$) and social media ($M = 2.51$, $SD = 1.50$).

3. Results

3.1. Statistical analysis

Using the statistical program R for all statistical analyses, we ran OLS multiple linear regressions. Because we measured the dependent variables at two points in time, we could predict changes in them between Wave 1 and Wave 2. In these panel models, we also included the baseline scores (Wave 1) as covariates, because changes in the dependent variable are often associated with baseline scores (see Dalecki & Willits, 1991). Such panel models afford multiple advantages over mere cross-sectional analysis. Above all, it reduces problems associated with sample bias and eliminates reversed causation. To reduce omitted variable bias, we included potential confounding variables—most importantly, demographic variables and news consumption. The distributions of the key independent and dependent variables appear in Fig. S1, and a correlation table appears in Table S4 (Supplementary material).

Following Zhang and Mai (2018), we also ran a post hoc power analysis in the R package "WebPower". The results indicated that, given our sample size, we could detect effect sizes equal to or greater than $f^2 = 0.03$ ($\alpha = 0.05$, power = 0.80) in the most complex models (i.e. with 18 predictors) that we ran.

3.2. Cross-sectional models

Shown in Table 1, the results of the regression analyses revealed that threat perceptions constituted a negative predictor of knowledge ($b = -0.13$, $p < 0.05$). Moreover, that effect remained significant when news-related variables (i.e., general news use and news-related use of public TV, private TV, newspapers, internet, and social media) were omitted from the model, which thus foreclosed upon the possibility that threat perceptions positively relate to knowledge via increased information-seeking. Table 1 also indicates that threat perceptions were positively associated with believing conspiracy claims ($b = 0.16$, $p < 0.001$) and conspiracy thinking ($b = 0.41$, $p < 0.001$).

As shown in Table S5 (Supplementary material), we ran the same regressions but controlled for the big five personality traits. Among our results, all coefficients of threat perceptions remained significant, and extraversion was positively associated with believing conspiracy claims ($b = 0.16$, $p < 0.001$).

Table 1
Cross-sectional models.

	Covid-19 knowledge	Believing conspiracy claims	Conspiracy thinking
	b (*SE*)	*b* (*SE*)	*b* (*SE*)
Age	**0.01***** (0.003)	−0.001 (0.001)	0.002 (0.002)
Male	**−0.28**** (0.10)	−0.06 (0.04)	0.03 (0.07)
College[a]	**0.52***** (0.14)	−0.10^{+} (0.05)	**−0.32**** (0.10)
High school[a]	**0.44**** (0.14)	**−0.19***** (0.05)	**−0.29**** (0.10)
News use	**0.13***** (0.03)	**−0.03*** (0.01)	**−0.08**** (0.02)
Internet news	0.05 (0.04)	**−0.03*** (0.02)	−0.02 (0.03)
SM news	**−0.08*** (0.04)	**0.07***** (0.01)	**0.12***** (0.03)
Private TV	−0.05 (0.04)	0.003 (0.01)	0.004 (0.03)
Public TV	**0.09*** (0.04)	**−0.05**** (0.02)	**−0.12***** (0.03)
Newspaper	−0.01 (0.03)	**−0.03*** (0.01)	**−0.07**** (0.02)
Knowledge		**−0.07***** (0.02)	−0.01 (0.03)
Threat perceptions	**−0.13*** (0.06)	**0.16***** (0.02)	**0.41***** (0.04)
Constant	**4.14***** (0.37)	**1.45***** (0.15)	**2.60***** (0.29)
Observations	632	632	632
Adjusted R^2	0.13	0.27	0.26

Bold coefficients are statistically significant ($p < 0.05$).
[a] Vocational school is the reference category.
$^{+}$ $p < 0.1$.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

As shown in Table S6 (Supplementary material), we ran the same regressions but controlled for the big five personality traits. The regression coefficients of threat perceptions in the models which predicted change in knowledge and change in believing conspiracy claims remained robust. However, the effect size of threat perceptions in the model for conspiracy thinking weakened slightly. The coefficient of neuroticism was statistically significant ($b = 0.09$, $p < 0.01$), which may explain the reduced influence of threat perceptions. In addition, extraversion was a significant negative predictor of change in knowledge ($b = -0.15$, $p < 0.05$).

3.3. Panel models

In the next step, we ran panel models in which we controlled for the baseline scores (i.e. Wave 1 scores) of the dependent variables (i.e. the change score). All independent variables were measured at Wave 1, the dependent variables represent changes from Wave 1 to Wave 2. The results, detailed in Table 2, indicated that threat perceptions represented a negative predictor of change in knowledge from Wave 1 to Wave 2 ($b = -0.14$, $p < 0.05$). Results in Table 2 also indicate that threat perceptions predicted an increase in believing conspiracy claims ($b = 0.05$, $p < 0.001$). The relationship of threat perceptions and changes in conspiracy thinking had only marginal significance, however ($b = 0.07$, $p < 0.10$). Fig. 1 visualises the relationship between threat perceptions and changes in knowledge and believing conspiracy claims.

Table 2
Panel models.

	Change in Covid-19 knowledge	Change in believing conspiracy claims	Change in conspiracy thinking
	b (*SE*)	*b* (*SE*)	*b* (*SE*)
Conspiracy claims[b]		**−0.36***** (0.03)	
Conspiracy thinking[b]			**−0.36***** (0.03)
Age	0.005 (0.004)	−0.002^{+} (0.001)	−0.002 (0.002)
Male	0.05 (0.11)	−0.01 (0.03)	0.02 (0.06)
College[a]	0.21 (0.16)	−0.06 (0.04)	−0.02 (0.09)
High school[a]	**0.46**** (0.15)	0.02 (0.04)	−0.03 (0.08)
News use	**0.10*** (0.04)	−0.01 (0.01)	−0.02 (0.02)
Internet news	0.04 (0.04)	−0.005 (0.01)	−0.03 (0.02)
SM news	**−0.14***** (0.04)	0.01 (0.01)	0.01 (0.02)
Private TV	−0.05 (0.04)	0.01 (0.01)	0.03 (0.02)
Public TV	**0.13**** (0.04)	**−0.03*** (0.01)	−0.02 (0.02)
Newspaper	−0.06 (0.04)	−0.01 (0.01)	−0.03 (0.02)
Knowledge[b]	**−0.45***** (0.04)	−0.02 (0.01)	0.01 (0.02)
Threat perceptions	**−0.14*** (0.07)	**0.05**** (0.02)	0.07^{+} (0.04)
Constant	**1.13*** (0.45)	**0.57***** (0.12)	**1.26***** (0.25)
Observations	632	632	632
Adjusted R^2	0.15	0.19	0.16

Bold coefficients are statistically significant ($p < 0.05$).
[a] Vocational school is the reference category.
[b] These variables represent baseline scores of the dependent variables (change scores) at Wave 1. Knowledge represents the baseline score of change in knowledge in model 1.
$^{+}$ $p < 0.1$.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

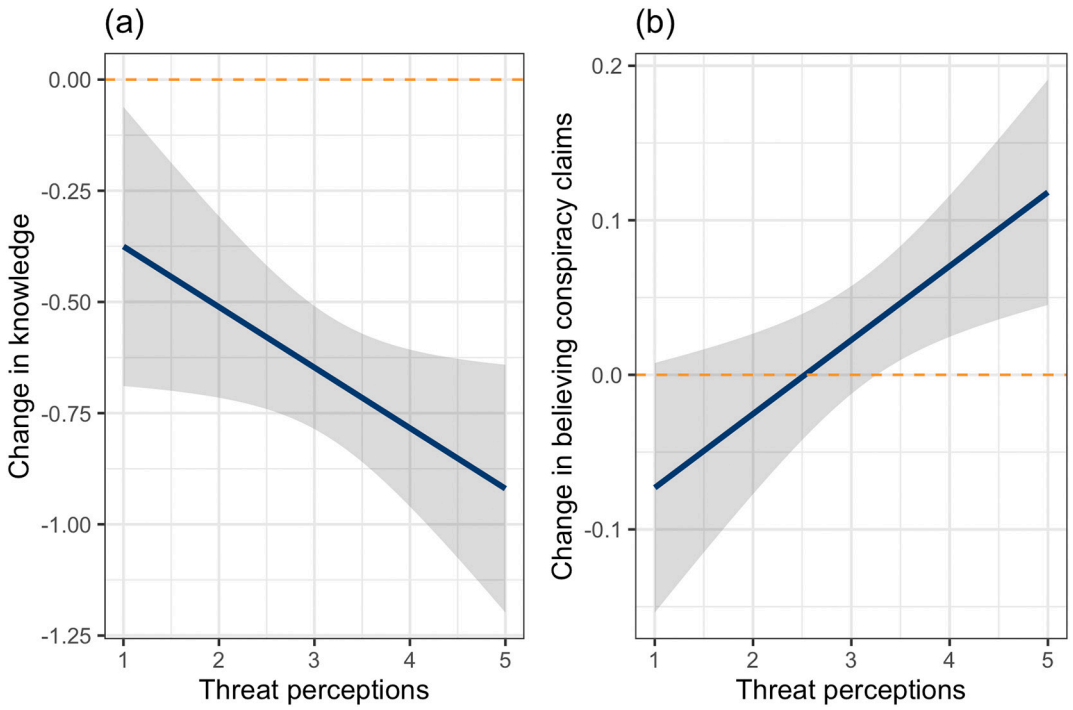

Fig. 1. Lines show the predicted values based on ordinary least square regressions shown in Table 2. Panel (a) corresponds to model 1 (changes in knowledge) and panel (b) corresponds to model 2 (changes in believing conspiracy claims). All covariates in the models are set to mean values. Shaded regions indicate 95% confidence intervals, while the y-axis indicates changes in the dependent variables from Wave 1 to Wave 2. The dashed orange line represents no change whatsoever.

4. Discussion

The literature contains conflicting evidence about the role of threat perceptions in affecting learning and conspiracy beliefs, especially during times of crisis. One reason for such discrepancies may be that environmental factors moderate the influence of threat perceptions. According to appraisal theory, individuals scan their environments in search of information to understand and, in turn, eliminate the root cause of threats therein. However, in cases of novel pandemics, information is not always accessible (Rutter et al., 2020). In such contexts, individuals may switch from problem-focused to maladaptive coping mechanisms, including the avoidance of threat-related information or pseudo-epistemic coping (Moneta et al., 2007; Park & Folkman, 1997; Swami et al., 2016).

In support of those theoretical accounts, our findings suggest that high levels of threat perceptions may impede societal learning and facilitate beliefs in conspiracy claims. In turn, they imply that the so-called "intelligence effect" of anxiety, found in low-risk environments with highly accessible information (Marcus & MacKuen, 1993), may not apply in critical situations marked by high levels of information uncertainty. Thus, although other research has indicated that threat perceptions can incentivise political adherence in the short term (Witte & Allen, 2000), high levels of anxiety may also have unintended effects in the long run. Worried citizens who are unable to gain knowledge and develop conspiracy beliefs instead may convey their views to others—for instance, on social media—and may further fuel climates of uncertainty (Heiss, 2020a). As a result, citizens may lose trust in science and the government more broadly, which may adversely affect efforts promoting vaccination and other preventive behaviours (Romer & Jamieson, 2020).

We also tested whether the influence of threat perceptions occurs independently of the big five personality traits. Including those traits did not largely affect the coefficients of threat perceptions, except for changes in conspiracy thinking, which were better explained by neuroticism. A possible explanation for that finding is that neuroticism may not be directly linked to conspiracy thinking under normal circumstances. However, because neurotic individuals react more strongly to external stress factors (Grzesiak-Feldman, 2013; Horikawa & Yagi, 2012), the experience of being in lockdown may have heightened their susceptibility to conspiracy claims. Along similar lines, others studies have revealed positive correlations between neuroticism and conspiracy beliefs (Hollander, 2018; Lobato et al., 2014).

We additionally found that extraversion was positively correlated with believing conspiracy claims in the cross-sectional model and that extraverted individuals were less likely to gain knowledge over the study period. Both findings corroborate prior research suggesting that extraverted individuals are prone to impulsive decision-making and less cognitive engagement with societal issues (Heiss & Matthes, 2017; Mondak & Halperin, 2008). However, the role of personality traits may be context-specific and studies overall provide a mixed picture (Goreis & Voracek, 2019). Thus, more longitudinal studies are therefore needed to clarify how neuroticism and extraversion in particular may affect learning and conspiracy beliefs, especially in times of crisis.

4.1. Limitations

As all studies, ours involved some limitations. First, despite using panel data, we also relied on self-report observational data. Although such data offer insights into the real-world situations experienced by participants, they also tend to suffer from the bias of omitted variables and confounding effects. Second, to elucidate the causal links between threat perceptions, learning and conspiracy beliefs, experimental studies are needed. Third, our study was conducted in only one country and replications in other countries are needed. Last, while our findings on conspiracy beliefs echo the results of past studies, the relationship between threat perceptions and learning needs to be further explored. To be sure, learning is a complex phenomenon to measure. For example, we used different knowledge-related questions during both Waves 1 and 2, which came with the risk of additional unobserved heterogeneity. Thus, replication, especially in experimental contexts, may offer additional evidence about the relationship between anxiety and gains in knowledge.

5. Conclusions

Our key finding—that high levels of threat perceptions may inhibit societal learning and strengthen conspiracy beliefs—should guide policymakers towards curbing high levels of threat perceptions. Although the spread of fear may support adherence to policy in the short run, lower levels of learning and higher levels of conspiracy beliefs may dampen citizens' motivation to cooperate in the long run, including with using contract tracing apps and receiving vaccinations (Romer & Jamieson, 2020). Thus, it may be important to engage citizens in common problem-solving processes and empower them to navigate and understand health information in infodemics (Heiss, 2020b). To that end, political decision-makers need to support citizens and increase the accessibility of facts. For example, they could initiate public campaigns and new innovative educational programs to increase citizens' health literacy, political literacy and new media literacy. At the same time, our findings encourage researchers to further investigate that complex relationship. On top of that, they call for using experimental designs that manipulate the level of information uncertainty as a moderating factor of the relationship between threat perceptions, learning and conspiracy beliefs.

CRediT authorship contribution statement

Raffael Heiss: Term, Conceptualization, Methodology, Formal analysis, Visualization, Writing - Original draft preparation, Funding acquisition,
Sascha Gell: Writing - Support, Methodology.
Esther Röthlingshöfer: Writing - Support, Project administration.
Claudia Zoller: Writing - Support, Second-Reading.

Appendix A. Supplementary material

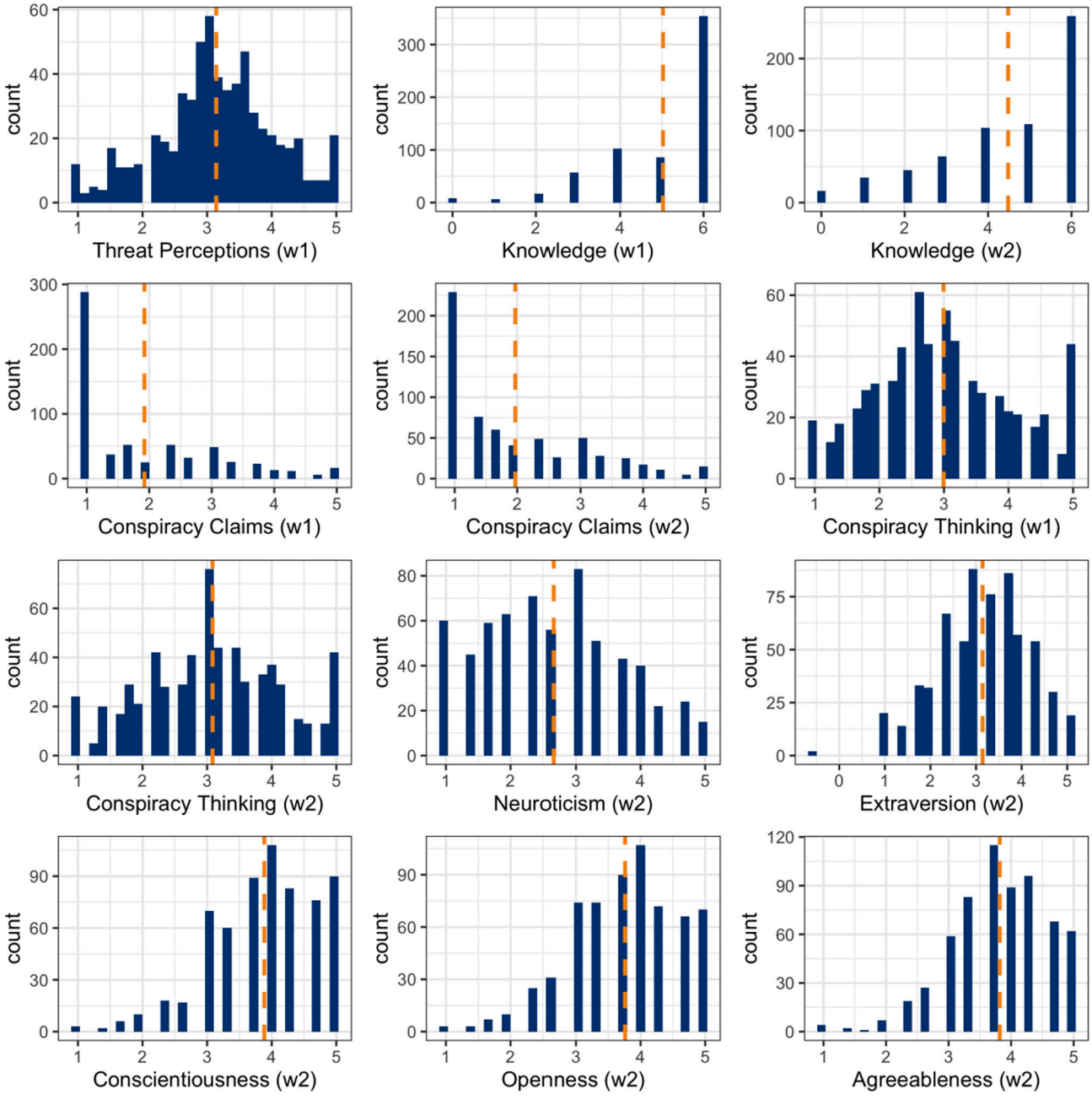

Figure S1. Distributions of key independent and dependent variables in Wave 1 (w1) and Wave 2 (w2). Dotted lines represent mean values.

Table S1
Knowledge items at Wave 1

What does the term "incubation period" mean?
- The duration of lockdown restrictions
- The period between infection and the appearance of symptoms
- The period when an infected person is contagious
- I don't know.
What does "flattening the curve" mean in discussions about COVID-19?
- The rapid immunisation of the population
- A slowdown in new infections
- An increase in new infections
- I don't know.
What does the term "herd immunity" mean in discussions of COVID-19?
- When a large part of the population is immunised against the coronavirus due to having already overcome infection
- When part of the population can resist the coronavirus for genetic reasons
- When a large group isolates itself and protects itself from the coronavirus
- I don't know.
What does the term "social distancing" mean?
- Keeping a distance of 1 to 2 metres between yourself and anyone not in your household who is coughing or sneezing
- Keeping a distance of 1 to 2 metres between yourself and everyone outside your household
- Not shaking hands with strangers
- I don't know.
Which people are at risk of COVID-19?
- All people 40 years old or older
- People with severe pre-existing conditions (e.g. heart disease or diabetes) or advanced age
- People who have recently had a cold
- Idon't know.
How should you react if you suspected that you had COVID-19?
- I should stay at home and call 1450 (i.e. the health hotline).
- I should visit my family doctor.
- I should go to the emergency room.
- I don't know.

Table S2
Knowledge items at Wave 2

How is the coronavirus mainly transmitted?
- By droplets and aerosols
- By contact transmission (e.g. shaking hands and touching contaminated door handles)
- By contaminated wastewater
- I don't know.
What does the term "reproductive rate" (i.e. R value) mean?
- The R value indicates how many people each infected person infects on average.
- The R value indicates how quickly the virus reproduces itself in the body.
- The R value indicates how quickly the virus spreads from country to country.
- I don't know.
What is the purpose of a so-called "antibody test"?
- To check whether an immune reaction has occurred and, in turn, whether immunity against COVID-19 exists
- To determine whether the body contains viral material and is infected with COVID- 19
- To test whether COVID-19 infection has spread to the lungs
- I don't know.
Which role do children play in transmitting the coronavirus?
- Despite experiencing only minor symptoms, children can infect others.
- Children do not contribute to the occurrence of infection.
- Children are immune against COVID-19.
- I don't know.
What is the effect of covering one's mouth and nose with a facemask in relation to COVID- 19?
- Facemasks primarily protect me from possibly infecting others.
- Facemasks primarily protect me from being infected.
- Because all viruses are filtered by facemasks, facemasks eliminate the danger of infection.
- I don't know.
What is the purpose of the Stopp Corona app from the Red Cross?
- To facilitate contact tracing by notifying people who have had contact with an infected person
- To record the infection status of individuals via e-cards
- To rapidly communicate medical information in the case of infection
- I don't know.

Table S3
Items addressing the big five personality traits measured at Wave 2
Intro: The following statements are about your personal character. How much do you agree with the statements in relation to yourself?

• I worry a lot. (Neuroticism)	α = .80
• I get nervous easily.	$M = 2.66$, $SD = 1.07$
• I get sad and depressed easily.	
• I am talkative. (Extraversion)	α = .75
• I am outgoing and sociable.	$M = 3.89$, $SD = 0.82$
• I am rather loud and talk a lot.	
• I am original and come up with new ideas. (Openness)	α = .72
• I am interested in many different things.	$M = 3.76$, $SD = 0.83$
• I have an active imagination.	
• I am empathetic and warm-hearted. (Agreeableness)	α = .64
• I have a forgiving nature.	$M = 3.82$, $SD = 0.77$
• I am considerate and kind to almost everyone.	
• I work on tasks until they are done. (Conscientiousness)	α = .78
• I make plans and execute them.	$M = 3.89$, $SD = 0.82$
• I do things quickly and efficiently.	

Note. We also ran a confirmatory factor analysis to test the 5-factor structure. These were the results: Fit measures: x^2 (80) = 256.951 ' $p < .001$; comparative fix index = .941, root mean square error of approximation = .059; standardised root mean residual = 0.055 Standardised item loadings: neuroticism (0.72, 0.75, 0.81), extraversion (0.73, 0.84, 0.43), openness (0.67, 0.69, 0.68), agreeableness (0.76, 0.42, 0.72), conscientiousness (0.72, 0.73, 0.77)

Table S4
Correlations between independent and dependent variables.

	1	2	3	4	5	6	7	8
1. Threat perceptions (W1)	1							
2. Knowledge (W1)	-0.13***	1						
3. Conspiracy claims (W1)	0.32***	-0.31***	1					
4. Conspiracy thinking (W1)	0.39***	-0.61***	0.54***	1				
5. Neurticism (W2)	0.32***	-0.07	0.15***	0.17***	1			
6. Extraversion (W2)	0.05	0.02	0.12**	0.08*	-0.15***	1		
7. Conscientiousness (W2)	0.00	0.18***	-0.05	-0.04	-0.23***	0.31***	1	
8. Openness (W2)	0.00	0.17***	-0.04	0.03	-0.15***	0.43***	0.51***	1
9. Agreeableness (W2)	-0.02	0.17***	-0.04	-0.03	-0.06	0.24***	0.44***	0.40***

Note. Extraversion has two missing cases, which were omitted for correlations with extraversion. * p<0.05; ** p<0.01; *** p<0.001

Table S5
Cross-sectional models with big five personality traits

	Covid-19 Knowledge *b (SE)*	Believing Conspiracy Claims *b (SE)*	Conspiracy Thinking *b (SE)*
Age	**0.01**** (0.003)	-0.003 (0.003)	0.002 (0.002)
Male	-0.19+ (0.11)	-0.13 (0.08)	0.04 (0.08)
College[a]	**0.48***** (0.14)	-0.15 (0.11)	**-0.33**** (0.10)
High school[a]	**0.47***** (0.14)	**-0.36***** (0.10)	**-0.28**** (0.10)
News use	**0.12***** (0.03)	**-0.06*** (0.03)	**-0.08**** (0.02)
Internet news	0.04 (0.04)	**-0.08*** (0.03)	-0.02 (0.03)
SM news	**-0.08*** (0.04)	**0.13***** (0.03)	**0.12***** (0.03)
Private TV	-0.05 (0.04)	-0.0002 (0.03)	-0.001 (0.03)
Public TV	**0.08*** (0.04)	**-0.10***** (0.03)	**-0.12***** (0.03)
Newspaper	-0.01 (0.03)	**-0.07*** (0.03)	**-0.07*** (0.03)
Knowledge		**-0.15***** (0.03)	-0.01 (0.03)
Threat perceptions	**-0.14*** (0.06)	**0.31***** (0.05)	**0.41***** (0.05)
Neuroticism	0.05 (0.05)	0.002 (0.04)	0.02 (0.04)
Extraversion	-0.04 (0.06)	**0.16***** (0.05)	0.06 (0.04)
Conscientiousness	0.15+ (0.08)	0.0003 (0.06)	-0.04 (0.06)
Openness	0.13 (0.08)	-0.04 (0.06)	0.09+ (0.06)
Agreeableness	0.11 (0.08)	-0.02 (0.06)	-0.04 (0.06)
Constant	**2.79***** (0.51)	**2.75***** (0.40)	**2.38***** (0.38)
Observations	630	630	630
Adjusted R^2	0.17	0.30	0.29

Note. [a]Vocational school is the reference category +p<0.1; * p<0.05; ** p<0.01; *** p<0.001

Table S6
Panel model with big five personality traits

	Change in Covid-19 Knowledge *b (SE)*	Change in Believing Conspiracy Claims[b] *b (SE)*	Change in Conspiracy Thinking *b (SE)*
Conspiracy claims[b]		**-0.36***** (0.03)	
Conspiracy thinking[b]			**-0.36***** (0.03)
Age	0.004 (0.004)	-0.003+ (0.002)	-0.001 (0.002)
Male	0.09 (0.12)	-0.03 (0.06)	0.05 (0.06)
College[a]	0.15 (0.16)	-0.11 (0.08)	-0.02 (0.09)
High school[a]	**0.44**** (0.15)	0.06 (0.08)	-0.03 (0.08)
News use	**0.09*** (0.04)	-0.02 (0.02)	-0.02 (0.02)
Internet news	0.05 (0.04)	-0.01 (0.02)	-0.04 (0.02)
SM news	**-0.13**** (0.04)	0.02 (0.02)	0.01 (0.02)
Private TV	-0.04 (0.04)	0.02 (0.02)	0.03 (0.02)
Public TV	**0.13**** (0.04)	**-0.06**** (0.02)	-0.02 (0.02)
Newspaper	-0.05 (0.04)	-0.03 (0.02)	-0.03 (0.02)
Knowledge[b]	**-0.46***** (0.04)	-0.03 (0.02)	0.002 (0.02)
Threat perceptions	**-0.14*** (0.07)	**0.10**** (0.04)	0.05 (0.04)
Neuroticism	0.01 (0.06)	-0.005 (0.03)	**0.09**** (0.03)
Extraversion	**-0.15*** (0.07)	0.06+ (0.03)	0.05 (0.04)
Conscientiousness	0.01 (0.09)	-0.03 (0.04)	0.02 (0.05)
Openness	0.15+ (0.08)	0.01 (0.04)	0.02 (0.05)
Agreeableness	0.05 (0.08)	0.02 (0.04)	-0.01 (0.05)
Constant	0.81 (0.58)	**1.05***** (0.30)	**0.85**** (0.32)
Observations	630	630	630
Adjusted R^2	0.16	0.19	0.17

Note. [a]Vocational school is the reference category $^{+}p<0.1$; * $p<0.05$; ** $p<0.01$; *** $p<0.001$
[b]These variables represent baseline scores of the dependent variables (change scores) at Wave 1. Knowledge represents the baseline score of change in knowledge in model 1

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