

RESEARCH ARTICLE

Irrational beliefs differentially predict adherence to guidelines and pseudoscientific practices during the COVID-19 pandemic

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[Corrections made on 15 December 2020, after first online publication: ORCID iDs have been added and the Funding information removed in this version.]

Summary

In the coronavirus “infodemic,” people are exposed to official recommendations but also to potentially dangerous pseudoscientific advice claimed to protect against COVID-19. We examined whether irrational beliefs predict adherence to COVID-19 guidelines as well as susceptibility to such misinformation. Irrational beliefs were indexed by belief in COVID-19 conspiracy theories, COVID-19 knowledge overestimation, type I error cognitive biases, and cognitive intuition. Participants ($N = 407$) reported (1) how often they followed guidelines (e.g., handwashing, physical distancing), (2) how often they engaged in pseudoscientific practices (e.g., consuming garlic, colloidal silver), and (3) their intention to receive a COVID-19 vaccine. Conspiratorial beliefs predicted all three outcomes in line with our expectations. Cognitive intuition and knowledge overestimation predicted lesser adherence to guidelines, while cognitive biases predicted greater adherence, but also greater use of pseudoscientific practices. Our results suggest an important relation between irrational beliefs and health behaviors, with conspiracy theories being the most detrimental.

KEYWORDS

cognitive biases, conspiracy theories, COVID-19 health behavior, knowledge overestimation, pseudoscience

With the coronavirus pandemic, societies are forced to introduce new measures to curb the infection rate. This means that ordinary people are asked to adopt enhanced protective health behaviors, such as physical distancing and frequent handwashing. However, along with these official recommendations, people are exposed to pseudoscientific information and unverified content pertaining to COVID-19, which have proliferated rapidly through social media (Depoux et al., 2020; Kouzy et al., 2020; Mian & Khan, 2020; Zarocostas, 2020). In fact, we are “not just fighting an epidemic; we’re fighting an infodemic. Fake news spreads faster and more easily than this virus, and is just as dangerous” (WHO, 2020). Pseudoscientific recommendations such as consuming garlic, drinking ginger tea or rinsing nose with saline to prevent contracting the virus, became so pervasive that the WHO (n.d.) had to officially debunk the claims

about their effectiveness. Certain pseudoscientific practices (PSPs) are extremely dangerous—for example, more than 700 Iranians were reported dead of methanol poisoning falsely believing it was a miracle cure for COVID-19 (Associated Press, 2020). Another “victim” of the infodemic is the COVID-19 vaccine, which is still in development. Even amid the pandemic, the topic of vaccination has provoked an online backlash (e.g., Mooney, 2020). Given the grave consequences of vaccination refusal, such as failure to reach herd immunity, it is important to understand why some people might be reluctant to get immunized.

Both adherence to official public health recommendations and the use of PSPs might be embedded in a set of irrational beliefs. We refer to irrational beliefs as an umbrella term that covers beliefs which lack a solid evidence base or defy principles of normative rationality

(Žeželj & Lazarević, 2019). It encompasses beliefs that differ in content (e.g., paranormal beliefs, conspiracy beliefs or anti-science attitudes) and form, but what they have in common is that they may inhibit reasoning processes (Rizeq et al., 2020). Irrational beliefs have also been referred to as “epistemically-suspect” (Pennycook, Cheyne, et al., 2015; Pennycook, Fugelsang, & Koehler, 2015) or “contaminated mindware” (Rizeq et al., 2020; Stanovich et al., 2016).

In this study, we explored whether people who differ in their predisposition to form irrational beliefs also differ in their tendency to follow appropriate preventive measures for COVID-19. More precisely, whether irrational beliefs such as belief in COVID-19 conspiracy theories, overestimation of one's own COVID-19 knowledge, susceptibility to type I error cognitive biases, and cognitive intuition predict adherence to COVID-19 guidelines, use of PSPs, and intention to receive a COVID-19 vaccine if it were available. In addition to cognitive intuition and cognitive biases that are more general, knowledge overestimation (i.e., a calibration error relating to the discrepancy between actual, objectively measured and subjective, self-estimated knowledge), and belief in conspiracy theories (potential source of false knowledge about a particular subject) are measures that are content-laden and refer to a specific context, event or a class of events. Content laden beliefs, in comparison to cognitive biases and cognitive intuition, may be more or less pertinent for different health behaviors in the current pandemic.

The COVID-19 pandemic is a public health crisis and, as such, a fertile ground for conspiracy theories (Gonçalves-Sá, 2020; van Prooijen & Douglas, 2017). This aspect of the infodemic might be especially dangerous since medical conspiracy theories have been consistently associated with a range of risky health behaviors including less sunscreen use, not getting annual check-ups or vaccinations, less contraceptive use, and HIV medication nonadherence (e.g., Bogart et al., 2010; Jolley & Douglas, 2014; Oliver & Wood, 2014; Setbon & Raude, 2010; Thorburn & Bogart, 2005). However, recent studies examining the relation between belief in COVID-19 conspiracy theories and self-reported adherence to recommended behaviors have produced inconsistent results. While some found a relation with adherence to health guidelines (Imhoff & Lamberty, 2020; see also Swami & Barron, 2020), others did not (Čavojová et al., 2020; see also Plohl & Musil, 2020). Furthermore, conspiracy theories might be predictive of some, but not other types of recommended protective behaviors—for example, believing in COVID-19 conspiracy theories was related to less social-distancing but unrelated to personal-hygiene behaviors (Pummerer & Sassenberg, 2020). As for pseudoscientific practices, it was shown that people more prone to conspiratorial thinking were more likely to endorse claims related to the effectiveness of complementary and alternative medical treatments in general (Lamberty & Imhoff, 2018; Lobato et al., 2014; Pennycook, Cheyne, et al., 2015) and that they reported greater use of PSPs to prevent contracting coronavirus (Čavojová et al., 2020; Pummerer & Sassenberg, 2020; see also Imhoff & Lamberty, 2020). A possible mechanism through which conspiracy theories may influence health behaviors is by amplifying distrust toward institutions, which makes people less willing to follow official

COVID-19 recommendations (Pavela Banai et al., 2020). In order to stay healthy, some people may then turn to PSPs, which are not recommended by authorities due to absence of evidence for their effectiveness. Thus, although there is converging evidence suggesting that conspiracy theories are predictive of PSPs, more studies are needed to explore their influence on adherence to COVID-19 guidelines. We expected that stronger beliefs in COVID-19 conspiracy theories would predict lesser adherence to COVID-19 guidelines (H1a), greater use of PSPs (H1b), and a weaker intention to get vaccinated (H1c).

Knowledge overestimation is typically calculated as a difference between self-assessed and objectively assessed knowledge on a certain subject (Ackerman et al., 2002; Harvey, 1997; Kleitman & Stankov, 2001; Kruger & Dunning, 1999; Stankov, 2000). Pennycook et al. (2017) showed that intuitive individuals tended to be more overconfident on the cognitive reflection test, rating themselves as relatively reflective, despite their test scores showing otherwise. Thus, it is possible that some people would overestimate their COVID-19 related knowledge because their nonreflexivity prevents them from recognizing their ignorance (see also Dunning, 2011; Kruger & Dunning, 1999), which would in turn make them less likely to engage in preventive behaviors during the pandemic. In fact, knowledge overestimation has been widely documented in the health domain (see Dunning et al., 2004). The inability to recognize one's lack of skill or knowledge (Kruger & Dunning, 1999) can, in this context, prevent people from familiarizing themselves enough with the official guidelines. In this study, we expected that higher levels of COVID-19 related knowledge overestimation would predict lesser adherence to COVID-19 guidelines (H2a), greater use of PSPs (H2b), and weaker intention to get vaccinated (H2c).

Cognitive biases, as systematic departures from what is normatively defined rational behavior, can be viewed as a relatively broad category of irrational beliefs. Taking into account that the cognitive biases space is considerably heterogeneous (see, for example, Kahneman & Frederick, 2005; Pohl, 2004; Stanovich, 2009; Teovanović et al., 2015), we focused on a subset which concerns a general tendency to make a type I error. Such a choice was motivated by Haselton and Buss' (2000) notion on cost asymmetry between two types of errors (type I and type II) that can occur when judgments are made under uncertainty. More precisely, as the probability of making either type of error cannot be simultaneously minimized, people tend to decrease the likelihood of making the costlier one (Haselton et al., 2009). Since the consequences of type II errors (i.e., false-negatives) refer to failures to notice actual relations between phenomena, they are usually considered as costlier. Thus, people are typically biased toward type I errors (i.e., false-positives) which refers to making incorrect conclusions about the existence of relations between unrelated phenomena. In our study, biases that are based on making a type I error were represented by the illusory correlation detection (Smedslund, 1963), base-rate neglect (Tversky & Kahneman, 1974), gambler's fallacy (Tversky & Kahneman, 1974), and hot-hand fallacy (Gilovich et al., 1985) bias. Although cognitive biases have shown to be predictive of some paranormal (Bressan, 2002; Pennycook et al., 2012; Šrol, 2020; van Prooijen et al., 2017) and pseudoscientific

beliefs (Pennycook, Cheyne, et al., 2015; Redelmeier & Tversky, 1996; Šrol, 2020), they remain underexplored in the domain of both PSPs and adherence to public health guidelines. Starting from the general hypothesis about relation between irrational beliefs and health behaviors, we expected that a higher susceptibility to such cognitive biases would predict lesser adherence to COVID-19 guidelines (H3a), greater use of PSPs (H3b), and weaker intention to get vaccinated (H3c).

Cognitive intuition is often assessed with the cognitive reflection test (CRT; Frederick, 2005), which consists of three items that lead most people to answer quickly and incorrectly. While cognitive biases are related to specific types of predictable errors on heuristics-and-biases tasks, cognitive intuition refers to an inability to “resist reporting the response that first comes to mind” (Frederick, 2005, p. 27). Previous research has shown that misleading intuitions predict paranormal beliefs (Pennycook et al., 2012; Ståhl & van Prooijen, 2018) as well as religious beliefs (Pennycook, Fugelsang, & Koehler, 2015; Shenhav et al., 2012). In the health domain, cognitive intuition was related to beliefs about the effectiveness and self-reported use of complementary and alternative treatments both before (Browne et al., 2015; McPhetres & Pennycook, 2019; see also Lindeman, 2011) and during the COVID-19 pandemic (Čavojoová et al., 2020; Erceg et al., 2020; Pennycook et al., 2020). However, recent findings on the relation between CRT performance and adherence to official COVID-19 guidelines are mixed – while some found a negative relation (Stanley et al., 2020), others failed to establish any link (Čavojoová et al., 2020; Erceg et al., 2020; Pennycook et al., 2020; cf. Stanley et al., 2020). We expected that higher cognitive intuition would predict lesser adherence to COVID-19 guidelines (H4a), greater use of PSPs (H4b), and weaker intention to get vaccinated against COVID-19 (H4c).

In sum, the present study builds upon emerging research on evidence and nonevidence based COVID-19 related recommendations by examining the predictiveness of different irrational beliefs for COVID-19 related health behaviors in a single design.

1 | METHODS

1.1 | Sample and procedure

We recruited a total of 754 participants via a snowball procedure and through social networks (Facebook and Viber groups), between April 10 and April 22, 2020. The final sample ($N = 407$) included participants who met all of the following criteria: fully completed the questionnaires, accurately responded to all three attention check items, and confirmed that they did not search for information online while completing the questionnaires. The mean age of participants was 34.88 years ($SD = 12.81$). Females were overrepresented in the sample (76.9%), as were participants with higher education: about 0.5% of participants completed elementary school, 42.5% completed high-school, 30.2% completed undergraduate studies, and 26.3% completed graduate studies. The questionnaire was administered in Serbian language.

This study is a part of a larger project (https://osf.io/9njp3/?view_only=f778fab66d8b4a52acbc01bce9bfcc14). The full list of measures is available at https://osf.io/qk9nf/?view_only=f778fab66d8b4a52acbc01bce9bfcc14.

1.2 | Instruments and variables

Belief in COVID-19 conspiracy theories scale was developed for the purpose of this study. It consisted of 13 items representing most popular conspiracy theories circulating in digital media and conversations on social networks (e.g., “5G electromagnetic field exposure played a role in the coronavirus pandemic”). Response options ranged from 1 (Completely Disagree) to 5 (Completely Agree). The scale was highly reliable ($\alpha = .90$). We averaged responses for the 13 items to form a total score.

COVID-19 knowledge overestimation was calculated as a difference between standardized scores of subjectively estimated and objectively assessed knowledge. Subjective estimation of knowledge related to COVID-19 was represented by a single item (“How would you rate your knowledge about the new coronavirus?”), on a scale ranging from 1 (Insufficient) to 5 (Excellent). Objective knowledge was assessed using a previously developed test (Lep et al., 2020), consisting of nine true or false statements related to COVID-19 (e.g., “The coronavirus is transmitted through respiratory droplets”); correct responses were summed to create the overall score. To convert them into a common metric, both subjective and objective scores were transformed to a standard scale; finally, the objective knowledge z-score was subtracted from the subjective knowledge z-score.

Type I error cognitive biases were measured with six heuristics-and-biases tasks which tap into peoples' tendency to erroneously recognize relations between unrelated phenomena. They were represented with two covariation detection problems as measures of illusory correlation (Smedslund, 1963), two base-rate problems (Tversky & Kahneman, 1974), and two probability judgment tasks measuring hot-hand fallacy (Gilovich et al., 1985) and gambler's fallacy (Tversky & Kahneman, 1974). We calculated the total score as the average of biased responses across tasks ($\alpha = .52$).

Cognitive Intuition was assessed via the CRT (Frederick, 2005), consisting of three items which cue a fast but incorrect response.¹ One example of an item is the following question: “A racket and a ball cost 1100 RSD [Serbian currency] in total. The racket costs 1000 RSD more than the ball. How much does the ball cost?.” Although the correct answer is “50 RSD” approximately 40% of participants answered “100 RSD”. A total score was calculated as a mean of intuitive responses (range 0–1; $\alpha = .63$).

Adherence to COVID-19 guidelines was measured with 12 items based on the official WHO and the Serbian Ministry of Health COVID-19 guidelines ($\alpha = .69$). Five items related to newly introduced (e.g., physical distancing) or enhanced (e.g., thorough handwashing) health behaviors, in the previous 2 weeks, rated on a scale ranging from 1 (Never) to 5 (Very Often). Additional seven items referred to behaviors recommended to be avoided during the outbreak (e.g., visiting other households or attending social gatherings).

Participants rated the frequency of these behaviors in the previous 2 weeks by entering a number. These seven items were multiplied by -1 so that higher scores would always correspond to greater adherence to COVID-19 guidelines. To convert into a common metric, all item scores were standardized. To handle outliers, z values above 3.29 were winsorized. A total score was calculated as an average of all 12 items.

Use of PSPs related to COVID-19 was assessed via a 12-item scale created for the purpose of this study ($\alpha = .73$). Five items were based on the list of common myths indicated on the WHO website (WHO, n.d.), while the remaining seven were based on PSPs against COVID-19 commonly reported in digital media outlets. Participants rated how often they used PSPs in the previous 2 weeks as a means

to protect themselves against COVID-19 on a scale ranging from 1 (Never) to 5 (Very Often). We averaged the participants' responses for all 12 items to create a total score.

Vaccination intention was assessed by asking participants to rate their willingness to receive a COVID-19 vaccine if it were available at that time. The scale ranged from 1 (Definitely would not) to 5 (Definitely would).

2 | RESULTS

Table 1 shows frequencies for each health related behavior during the pandemic, indicating that participants reported high adherence to the

TABLE 1 Frequencies of adherence to COVID-19 guidelines (prevention and risk avoidance) and pseudoscientific practices

Adherence to COVID-19 guidelines (prevention)					
In the last 2 weeks, how often have you done the following to protect yourself from COVID-19?	Never	Rarely	Sometimes	Often	Very often
Washed/disinfected your hands after coughing or sneezing	12.3% (50)	8.1% (33)	14.7% (60)	29.2% (119)	35.6% (145)
Avoided touching your face	4.9% (20)	11.3% (46)	23.3% (95)	38.3% (156)	22.1% (90)
Cleaned and disinfected frequently used surfaces	9.3% (38)	8.4% (34)	26.5% (108)	34.4% (140)	21.4% (87)
Washed your hands with soap and water for at least 20 s	2.2% (9)	2.2% (9)	11.5% (47)	29.0% (118)	55.0% (224)
Kept at least 1 m distance from people outside your household	5.4% (22)	5.7% (23)	5.7% (23)	23.8% (97)	59.5% (242)
Adherence to COVID-19 Guidelines (risk avoidance)					
In the last two weeks, how often have you...	Never	Once	Twice	Three times	> Three times
Had direct physical contact (hugging, kissing, handshaking) with someone outside of your household	72.0% (293)	7.6% (31)	8.6% (35)	3.2% (13)	8.6% (35)
Visited someone	71.3% (290)	12.3% (50)	9.1% (37)	3.9% (16)	3.4% (14)
Had someone visit your place	64.1% (261)	16.5% (67)	9.1% (37)	6.1% (25)	4.2% (17)
Attended a public gathering (e.g. a party)	93.9% (382)	2.9% (12)	2.0% (8)	0.5% (2)	0.7% (3)
Had contact with people outside of your household	60.0% (244)	14.5% (59)	10.8% (44)	4.9% (20)	9.8% (40)
Left your house for no essential reason	59.7% (243)	9.6% (39)	6.1% (25)	3.4% (14)	21.1% (86)
Visited a park or a picnic area for a reason other than walking your dog	79.1% (322)	7.1% (29)	3.4% (14)	2.2% (9)	8.1% (33)
Pseudoscientific practices					
In the last 2 weeks, how often have you engaged in the following behaviors with the aim of preventing to contract coronavirus	Never	Rarely	Sometimes	Often	Very often
Drank water every 15 min	51.6% (210)	21.1% (86)	14.7% (60)	9.3% (38)	3.2% (13)
Consumed garlic	44.0% (179)	23.8% (97)	18.9% (77)	9.8% (40)	3.4% (14)
Drank alcoholic beverages	53.3% (217)	16.5% (67)	20.1% (82)	6.9% (28)	3.2% (13)
Drank ginger tea, baking soda with lemon, or similar drinks	46.7% (190)	17.7% (72)	17.9% (73)	11.5% (47)	6.1% (25)
Used essential oils	83.0% (338)	7.6% (31)	6.4% (26)	2.0% (8)	1.0% (4)
Used colloidal silver	95.8% (390)	1.0% (4)	1.5% (6)	1.7% (7)	0.0% (0)
Followed special diet	53.3% (217)	19.9% (81)	16.5% (67)	7.4% (30)	2.9% (12)
Inhaled saline solution	90.4% (368)	5.9% (24)	2.0% (8)	1.5% (6)	0.2% (1)
Consulted an astrologer	95.6% (389)	2.5% (10)	1.5% (6)	0.2% (1)	0.2% (1)
Consumed honey or similar products	34.4% (140)	19.2% (78)	20.9% (85)	17.9% (73)	7.6% (31)
Taken large amounts of vitamin C	16.2% (66)	18.7% (76)	27.5% (112)	25.1% (102)	12.5% (51)
Disinfected surfaces with natural products (e.g. vinegar, baking soda)	51.6% (210)	14.0% (57)	15.5% (63)	11.1% (45)	7.9% (32)

official recommendations. When the frequencies regarding adherence to COVID-19 guidelines were aggregated, they indicated that 76.7% ($n = 312$) of the participants reported adhering to at least three out of five newly introduced or enhanced health behaviors often or very often. As for behaviors that were recommended to be avoided by the guidelines (e.g., visiting other households), as much as 27.8% ($n = 113$) of participants reported always avoiding all of them. In terms of using PSPs, responses were more diverse. While 67.6% ($n = 275$) of participants reported having used at least one PSP often or very often, 11.3% ($n = 46$) had rarely or never used any of the listed PSPs. Finally, although 49.1% ($n = 200$) of participants reported they would definitely or probably receive a COVID-19 vaccine, a significant percentage (26.8%; $n = 109$) of participants stated they definitely or probably would not.

Descriptive statistics and bivariate correlations between all measured variables are presented in Table 2. Overall, participants showed a low to moderate susceptibility to intuitive reasoning on the CRT and type I error cognitive biases. As for content-laden measures of

irrational beliefs, participants moderately endorsed COVID-19 conspiracy theories and only modestly overestimated their knowledge about COVID-19.² Eight out of 12 zero order correlation coefficients between four types of irrational beliefs and the three health behaviors were statistically significant ($ps < .05$), all in the expected direction.

To discern the predictive power of a single variable in the set while controlling for effects of the other variables in the model, we ran three multiple regression models with adherence, PSPs, and vaccination intention as outcome variables. Cognitive intuition, susceptibility to type I error cognitive biases, overestimation of COVID-19 knowledge, and belief in COVID-19 conspiracy theories served as predictors (see Table 3).

The regression model predicting adherence to COVID-19 guidelines had relatively low explanatory power ($F[4402] = 7.78$, $R^2 = .07$, $p < .001$). As expected, belief in COVID-19 conspiracy theories, overestimation of COVID-19 related knowledge, and cognitive intuition negatively predicted adherence to COVID-19 guidelines (H1a, H2a, and H4a respectively). Contrary to our hypothesis (H3a), susceptibility

TABLE 2 Descriptive statistics and correlations

	Min	Max	M	SD	Skewness	Kurtosis	1	2	3	4	5	6
1. Cognitive intuition (0–1)	.00	1.00	.32	.35	.65	−.92						
2. Type 1 error cognitive biases (0–1)	.00	.83	.24	.22	.70	−.41	.39***					
3. COVID-19 conspiracy beliefs (1–5)	1.00	4.38	2.25	.79	.28	−.87	.28***	.33***				
4. COVID-19 knowledge overestimation	−3.27	6.03	.00	1.37	.37	.89	.04	.05	.08			
5. Adherence to COVID-19 guidelines	−1.47	.62	.02	.40	−1.11	1.52	−.14**	.05	−.17*	−.12*		
6. PSP (1–5)	1.00	3.42	1.83	0.52	0.53	−0.20	.20***	.28***	.31**	−.07	.14**	
7. COVID-19 vaccine (1–5)	1.00	5.00	3.34	1.29	−0.32	−0.96	−.11*	−.09	−.53*	−.07	.33***	−.07

Note: $SE_{Skewness} = .12$; $SE_{Kurtosis} = .24$.

* $p < .05$.

** $p < .01$. *** $p < .001$.

TABLE 3 Multiple regression analysis for adherence to COVID-19 guidelines, PSP, and intentions to vaccinate against COVID-19

	Adherence to COVID-19 guidelines					PSP					COVID-19 vaccine				
	b	SE	95% CI		p	b	SE	95% CI		p	b	SE	95% CI		p
			LL	UL				LL	UL				LL	UL	
Cognitive intuition	−.18	.06	−.30	−.06	.003	.10	.08	−.05	.25	.192	.04	.17	−.30	.37	.826
Type 1 error cognitive biases	.32	.10	.13	.52	.001	.42	.12	.18	.66	.001	.56	.28	.02	1.10	.042
COVID-19 conspiracy beliefs	−.09	.03	−.14	−.04	.001	.16	.03	.10	.22	<.001	−.92	.07	−1.07	−.78	<.001
COVID-19 knowledge overestimation	−.03	.01	−.06	.00	.028	−.04	.02	−.07	.00	.037	−.03	.04	−.11	.04	.390
R^2	.07					.14					.29				
R^2 adjusted	.06					.14					.29				

Abbreviations: CI, confidence interval; LL, lower limit; UL, upper limit.

to type I error cognitive biases positively predicted adherence to COVID-19 guidelines.

When it comes to the use of PSPs, belief in COVID-19 conspiracy theories, COVID-19 knowledge overestimation and susceptibility to type I error cognitive biases significantly contributed to the model, explaining 14% of the variance ($F[4402] = 16.89$, $R^2 = .14$, $p < .001$). This suggested that those with stronger beliefs in COVID-19 conspiracy theories, less COVID-19 knowledge overestimation and greater susceptibility to type 1 cognitive biases were more likely to follow pseudoscientific advice, which is in line with H1b, and H2b, but not with H3b.

Regarding vaccination intentions, the model explained a substantial amount of the variance, that is, 29% ($F[4402] = 41.89$, $R^2 = .29$, $p < .001$). In line with H1c, belief in COVID-19 conspiracy theories negatively predicted COVID-19 vaccination intentions, suggesting that those endorsing COVID-19 conspiracy theories may be less likely to get vaccinated when a vaccine becomes available. Contrary to our expectations (H3c), we observed that susceptibility to type I error cognitive biases positively contributed to the model, suggesting that those that were more prone to cognitive biases may be more likely to get vaccinated against the virus. To make sure that the inclusion of a vaccine-related conspiracy question (i.e., “One should be careful when a vaccine against coronavirus is developed because no one knows what they will inject in us”) in the conspiracy beliefs measure did not artificially increase the predictivity of the model, we conducted a sensitivity analysis and re ran the regression omitting this question. This model accounted for 26% of the variance ($F[4402] = 35.2$, $p < .001$), corroborating the robustness of the relation between beliefs in COVID-19 conspiracy theories and COVID-19 vaccination intentions.

Across all regression models, belief in COVID-19 conspiracies and type I error cognitive biases were the most consistent predictors of health behaviors related to COVID-19.

To gain more insight about the relations between the outcome variables, and to make sure that the significant regression models were not the result of p value inflation due to multiple comparisons (Gordi & Khamis, 2004), we conducted a canonical correlation analysis, a multivariate type of the general linear model (Thompson, 2005). The results are presented in Table 4, suggesting that two out of three canonical correlations were significant.

The first canonical function reflects the relations between beliefs in COVID-19 conspiracy theories and, marginally, susceptibility to type I error cognitive biases and cognitive intuition, on the one hand, and weaker COVID-19 vaccination intentions and greater use of PSPs, on the other (Table 5). These results indicate that vaccination hesitancy and use of PSPs have relations with belief in conspiracy theories and to some extent, intuitive and biased thinking. This component explained more than 10% of the variance across the two sets of variables. Moreover, the proportions of explained variance support the examination of irrational beliefs as predictors of health behaviors.

The second canonical function reflects the relations between a greater susceptibility to type I error cognitive biases and lesser COVID-19 knowledge overestimation, on the one hand, and a higher rate of acceptance of all three available preventive practices, on the other. This suggests that following all types of health practices is related to a greater susceptibility to type I error cognitive biases and lesser COVID-19 knowledge overestimation. However, since this component explained only 3% of the variance across the variable sets, this finding should be interpreted with caution.

TABLE 4 Canonical correlation analysis

Canonical function	<i>R</i>	Wilk's Λ	<i>F</i>	<i>p</i>
1	.60	.58	20.38	<.001
2	.25	.91	6.85	<.001
3	.18	.97		

TABLE 5 Canonical loadings

		Canonical function 1	Canonical function 2
Set 1	Cognitive intuition	-.33	.23
	Type 1 error cognitive biases	-.34	.81
	COVID-19 conspiracy beliefs	-1.00	-.01
	COVID-19 knowledge overestimation	-.06	-.49
Set 2	Adherence to COVID-19 guidelines	.28	.63
	PSP	-.53	.80
	COVID-19 vaccine	.88	.40
R^2	Set 1 by Set 1	.31	.24
	Set 1 by Set 2	.11	.02
	Set 2 by Set 2	.38	.40
	Set 2 by Set 1	.14	.03

3 | DISCUSSION

We found that health behaviors related to COVID-19—adherence to COVID-19 guidelines, use of PSPs, and intentions to get vaccinated against COVID-19—were all predicted by irrational beliefs to some degree.

Belief in COVID-19 conspiracy theories was the most consistent predictor of each type of health behavior. This is in line with previous findings showing positive relations between conspiratorial thinking and use of PSPs (Čavojská et al., 2020; Oliver & Wood, 2014), non-adherence to medical or public health recommendations (Imhoff & Lamberty, 2020; Oliver & Wood, 2014), and unwillingness to get vaccinated (e.g., Setbon & Raude, 2010). It further strengthens the view of conspiratorial beliefs as a part of contaminated mindware (Rizeq et al., 2020; Stanovich et al., 2016) or unwarranted beliefs detrimental to one's rational thought process, which may influence decisions that lead to unfavorable health outcomes. In our study, the relation between conspiratorial beliefs and unwillingness to get vaccinated against COVID-19 was particularly strong. Importantly, this result remained even when the overall conspiracy theory measure excluded the vaccination conspiracy theory item, and was based on theories about the origin of the virus and political abuse of the health crisis which should not necessarily affect vaccination intention. For example, one may assume that a person believes that the virus was fabricated in a laboratory, but still considers it dangerous and is willing to protect themselves with a vaccine. Our data, however, suggest that even beliefs relating to the origin of the virus are related to a weaker vaccination intention. This could be due to a more general assumption common to both phenomena: that key information, such as the truth about the harmfulness of vaccines or about the source of pandemic, is hidden from the general public and not included in the official narrative about it (Lukić et al., 2019; Wood et al., 2012).

Other irrational beliefs were also somewhat predictive of COVID-19 health behaviors. Those who overestimated their COVID-19 knowledge reported lesser adherence to COVID-19 guidelines, but were also somewhat less prone to using PSPs. We have initially assumed that knowledge overestimation may be predictive of greater use of PSPs, however it seems plausible that it operates in a similar fashion for both types of health behaviors. For example, overconfidence in one's knowledge may decrease interest in learning about preventive behaviors, regardless of whether these are evidence-based or not. We also found that those that rely on cognitive intuition and follow their "gut feelings" may be more relaxed when it comes to adhering to behaviors recommended by COVID-19 guidelines. Although there was some indication of a trend for cognitive intuition being related to greater use of PSPs, this result was marginal and we will not interpret it further.

Type I error cognitive biases were directly related (zero order correlation) only to PSPs, however after controlling for other irrational beliefs in the regression analyzes they positively predicted all three health behaviors. This finding may be due to the cost asymmetry between false-positive and false-negative errors (Haselton & Buss, 2000) particularly in critical situations such as a global pandemic. More precisely, the cost of a type II error—not following any preventive practice which may result in an avoidable COVID-19 infection—could be perceived as higher than the cost of a type I error—following all proposed practices, including those with no evidence of effectiveness. Thus, the susceptibility toward type I error cognitive biases, despite the lower reliability of the measure, was consistently

positively associated with uncritical pursuit of any health recommendation. This pattern of results of cognitive biases predicting greater engagement in both pseudoscientific and recommended health behaviors by COVID-19 guidelines and cognitive intuition predicting lesser engagement in health behaviors is in line with the conceptual distinction between type I error cognitive biases and cognitive intuition. Namely, the opposite pattern of results is suggestive of type 1 cognitive biases being related to greater compliance, and intuition to lesser compliance with any kind of health advice.

Of note, adherence to COVID-19 guidelines was the most weakly predicted health behavior. A relatively modest predictive power of irrational beliefs on adherence to COVID-19 guidelines might be due to ceiling effects that have likely resulted from lockdown policies and campaigns (e.g., #StayAtHome) that were in effect both world-wide and locally at the time of the study. This has left people with fewer behavioral choices, particularly with regards to physical distancing. On the other hand, engaging in PSPs was optional and, at the time of data collection, there was no vaccine developed against COVID-19 (no vaccination policies were in place). Therefore, vaccination was assessed as an intention, as opposed to retrospective self-reporting. All this may have permitted a greater influence of intrinsic dispositions such as irrational beliefs on these health behaviors.

3.1 | Strengths, limitations, and suggestions for future work

Our study adds to the existing literature in several ways. First, we have examined a comprehensive set of irrational beliefs in relation to COVID-19 health behaviors, which allowed us to compare their predictive power. Second, we examined different types of health behaviors pertaining to evidence-based and pseudoscientific recommendations related to the COVID-19 pandemic. In addition, the instruments we developed for their assessment proved to be reliable. Third, the fact that the data were collected during the peak of the pandemic (Serbia Coronavirus, n.d.) testifies to their validity.

Several limitations of the study merit comment. We have included preventive behaviors included in the official COVID-19 guidelines at the time when the study was conducted, which precluded other preventive behaviors that were not included in these guidelines such as wearing masks or gloves. Importantly, at the time of the study, the guidelines were supported by lockdown policies, which may have reduced the variability and influence of irrational beliefs on these behaviors. In addition, the health behaviors were self-reported. Future studies could examine observed behaviors (e.g., assessing physical distancing using location-tracking apps) to increase the confidence attached to the current findings.

There was relatively low reliability of composite scores derived from different cognitive biases tasks (Toplak et al., 2011; West et al., 2008) as well as the summary score derived from the three CRT items (Frederick, 2005; Thomson & Oppenheimer, 2016), however, these are typical findings within the field. As a direct consequence of this, their relations with other measures are attenuated (see, for

example, John & Benet-Martínez, 2000). In that sense, the reported coefficients of correlation can be seen as conservative estimates of strength of the association between type I cognitive biases, cognitive intuition, and health-related behaviors. Another possible limitation is that the current study did not control for cognitive ability when exploring the effects of cognitive intuition. We did not include measures of cognitive ability in the design since the current study focuses on irrationality, which is conceptually and theoretically distinct from measures of intelligence (e.g., Frederick, 2005; Stanovich, 2009). However, previous studies reported a moderate correlation between cognitive reflection and measures of intelligence (e.g., Shenhav et al., 2012; Toplak et al., 2011). Therefore, it is unclear whether the relations observed between CRT and health-related behaviors reflect solely the inability to resist intuitive responses or more general limitations in cognitive capacity. Future studies should address this question.

Finally, as we pointed out in the results, scores on the COVID-19 knowledge test were negatively skewed, indicating that the test was easy for the participants. This was likely due to heavy media coverage of COVID-19 at the time of the study and that people were continuously learning about the virus. In addition, although we tried to reach as a diverse sample of participants as possible by seeding the links to different social media groups, a probability sample representative of the population would certainly provide a greater variance in the objective knowledge measure; further, results obtained via snowballing recruitment are typically less generalizable than those obtained via probability recruitment (King et al., 2014). Nonetheless, despite these limitations, knowledge overestimation and other assessments included in our study revealed meaningful relations between irrational beliefs, namely conspiratorial thinking, and relevant health behaviors during the COVID-19 pandemic.

Future research should explore factors contributing to conspiracy beliefs. We believe that distrust in official institutions and related constructs such as political cynicism are the most promising candidates (see e.g., Brotherton et al., 2013; Swami et al., 2010, 2011); there is already evidence that such constructs could be important for COVID-19 related conspiracy theories (Pavela Banai et al., 2020). Importantly, the rapid proliferation of pandemic misinformation through social media (Depoux et al., 2020; Kouzy et al., 2020; Mian & Khan, 2020; Zarocostas, 2020) may also have the potential to substantially impact health outcomes. Some of the promising interventions to counter science misinformation and conspiracy theories include presenting people with factual corrections (e.g., Porter et al., 2018; Porter et al., 2019), combining factual corrections with personal/social narratives (Lazić & Žeželj, 2020), “inoculating” them by presenting anti-conspiracy information prior to conspiracy theories (e.g., Jolley & Douglas, 2017), and exposing misleading argumentation techniques (e.g., Roozenbeek & van der Linden, 2019).

4 | CONCLUSION

A starting point for social and behavioral sciences to mitigate the effects of global pandemics (Van Bavel et al., 2020) is to understand the psychological underpinnings of health behaviors during the course

of the crisis. Our study highlights that people prone to a particular set of irrational beliefs are less likely to follow official COVID-19 guidelines, more likely to engage in PSPs and have weaker intentions to vaccinate. Once again, and strongly corroborating our hypotheses, conspiracy theories have shown to pose a serious threat to public health—one that demands future attention to prevent unfavorable health outcomes and spread of diseases. The pattern of results for cognitive intuition and COVID-19 knowledge overestimation was less robust, but mostly in line with initial expectations predicting lesser adherence to COVID-19 guidelines. Somewhat unexpectedly, susceptibility to type I error cognitive biases predisposed people to engage in any type of preventive behavior, whether evidence-based or pseudoscientific. Together, the findings show that irrational beliefs are an important factor to consider when tailoring behavioral health policies, especially in a global health crisis.

ACKNOWLEDGEMENT

The study design and data collection were approved by the Institutional Review Board of the Department of Psychology, University of Belgrade (Protocol no. #2020-018).

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest concerning the authorship or the publication of this article.

AUTHOR CONTRIBUTIONS

Predrag Teovanović, Petar Lukić, and Zorana Zupan designed the study. Iris Žeželj, Aleksandra Lazić, Zorana Zupan, Milica Ninković, Petar Lukić, and Predrag Teovanović drafted the manuscript. Milica Ninković, Predrag Teovanović, and Petar Lukić conducted the analyzes. All authors revised and approved the manuscript.

DATA AVAILABILITY STATEMENT

The full dataset and analysis code for this paper are available at the (https://osf.io/cpe5t/?view_only=f778fab66d8b4a52acbc01bce9bfcc14).

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ENDNOTES

¹ We have initially included three additional items to examine if an extended version of instrument would provide a more reliable measure. However, their inclusion decreased internal consistency to $\alpha = .58$; thus, we decided to proceed with the original 3-item version.

² Since scores on all variables had a non-normal distribution, we re-ran all the analyzes on normalized scores using Blom's transformation. Results of the analyzes on normalized scores are detailed at https://osf.io/wfr5a/?view_only=455508f470e94cd0bade1fd6d4386061.

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How to cite this article: Teovanović P, Lukić P, Zupan Z, Lazić A, Ninković M, Žeželj I. Irrational beliefs differentially predict adherence to guidelines and pseudoscientific practices during the COVID-19 pandemic. *Appl Cognit Psychol*. 2021;35:486–496. <https://doi.org/10.1002/acp.3770>