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## Searching for the cognitive basis of anti-vaccination attitudes

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### ABSTRACT

Research on the reasons for vaccine hesitancy has largely focused on factors directly related to vaccines. In contrast, the present study focused on cognitive factors that are not conceptually related to vaccines but that have been linked to other epistemically suspect beliefs such as conspiracy theories and belief in fake news. This survey was conducted before the Covid-19 pandemic (N = 356). The results showed that anti-vaccination attitudes decreased slightly with cognitive abilities and analytic thinking styles, and strongly with scientific literacy. In addition, anti-vaccination attitudes increased slightly with teleological bias and strongly with an intuitive thinking style, ontological biases, and religious and paranormal beliefs. The results suggest that the same cognitive mechanisms that predispose to other epistemically suspect beliefs may predispose to anti-vaccination attitudes as well. The findings also indicate that pro-vaccination communication should focus on early prevention and that interventions against vaccine hesitancy should strive to be intuitively appealing.

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In recent years, Western countries have witnessed increasing outbreaks of diseases that could be prevented by vaccinations. Cases of measles have increased mostly because people have intentionally decided not to vaccinate (ECDC, 2019), and a few years ago, a large number of Italian families requested “asylum” in Austria over a new law making vaccinations obligatory for

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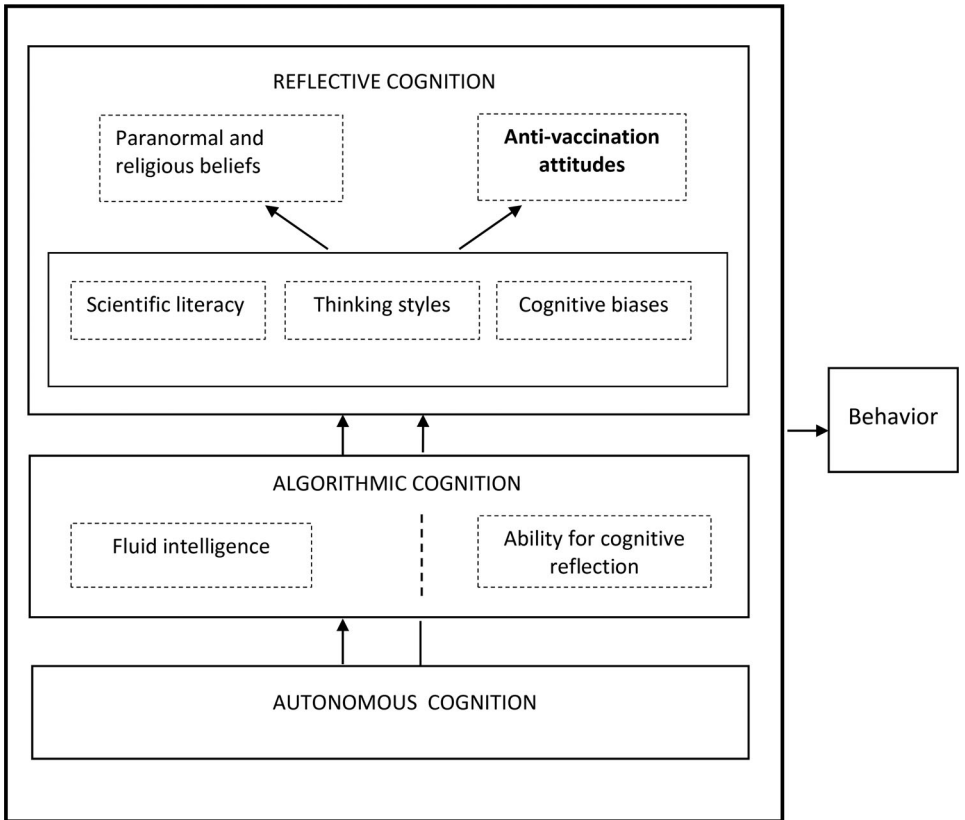
admission to Italian schools, stating as reason that they did not want to poison their children. As negative attitudes are rising, researchers have been urged to help the world to address this worrying trend (Editorial, 2020, November 24).

The World Health Organization's Strategic Advisory Group of Experts (SAGE) defines vaccine hesitancy behaviorally: "Vaccine hesitancy refers to delay in acceptance or refusal of vaccination despite availability of vaccination services" (MacDonald & the SAGE Working Group on Vaccine Hesitancy, 2015, p. 4163). We will here bring focus to the broader concept of attitudes towards vaccinations. Attitudes are psychological constructs that are based on beliefs of a target (e.g., vaccination), and they may or may not lead to behavioral responses. As we form beliefs about an attitude target, evaluations arise spontaneously and inevitably (Ajzen, 2001), ranging on a positive–negative continuum (e.g., good–bad, beneficial–harmful). Our focus in the present study is on anti-vaccination attitudes (a.k.a. vaccine skepticism) which refer to the negative side of the evaluative continuum.

The bulk of the research on the determinants of vaccine hesitancy has focused on factors closely linked to vaccines or vaccination, for example on people's knowledge about vaccines and vaccination, and their trust in health authorities. We agree with scholars who have argued that this research should be accompanied by more comprehensive viewpoints (Hornsey et al., 2018; Poland & Brunson, 2015). To this end, we propose that anti-vaccination attitudes represent what are known as epistemically suspect beliefs. Epistemically suspect beliefs are not founded on reliable reasoning or evidence and they can conflict with common naturalistic conceptions of the world (Lobato et al., 2014; Pennycook et al., 2015a). Previous findings show that people who endorse one type of epistemically suspect belief also tend to endorse other epistemically suspect beliefs. For instance, beliefs that vaccines are unsafe cluster together with beliefs in blood type diet and beliefs that the earth is flat (Fasce & Picó, 2019), and people who believe in paranormal phenomena also tend to believe that people can choose to be homosexual or heterosexual (Lobato et al., 2014). These findings have led researchers to suggest that the same background factors lead both to a general susceptibility towards anti-scientific and other unwarranted beliefs (Piejka & Okruszek, 2020; Rizeq et al., 2021; Ståhl & Van Prooijen, 2018). Whether these same factors also predict anti-vaccination attitudes has not been studied. In this study, we therefore focus on ten variables that are conceptually unrelated to vaccines and health but which in prior studies have been associated with various epistemically suspect beliefs and that may thus relate to anti-vaccination attitudes as well.

## Cognitive determinants of vaccine hesitancy

Earlier work that has focused on anti-vaccination attitudes has shown that anti-vaccination attitudes are affected by ideological issues, such as social



**Figure 1** . Theoretical rationale of the study. *Note.* The figure is modified after Stanovich (2011). Dashed lined boxes include the predictors and correlates of anti-vaccination attitudes examined in this study. Note that despite the similar terminology, in this figure “reflective cognition” refers to beliefs, attitudes, knowledge and habitual thinking styles. “Cognitive reflection ability,” in contrast, refers to a type of algorithmic ability.

identity and nonconformity (Hornsey, 2020). Because terms such as doubt, knowledge, beliefs, perception, confidence, misconception, and misinformation are often employed in studies on vaccine hesitancy, it is possible that anti-vaccination attitudes could also be explained by factors that are cognitive in nature. Although some studies have addressed these factors, the research is limited and theoretically fragmented, and consequently, we do not know how cognition shapes vaccination attitudes and which factors are more important than others.

The theoretical framework of this study (Figure 1) is based on Stanovich’s tripartite theory of the mind, which is a comprehensive specification of the widely accepted dual-process theory of thinking and reasoning (Evans & Stanovich, 2013). The theory postulates three different types of

cognitive processes: reflective, algorithmic, and autonomous, that together shape how we think (Stanovich, 2011). Our main focus is on reflective cognition, the enabler of good thinking, which embodies beliefs and attitudes, knowledge, and habitual thinking styles (approximating the concept of crystallized intelligence).<sup>1</sup> Algorithmic cognition, which refers to cognitive abilities and the efficiency with which we are able to carry out mental operations, is examined but only briefly, because cognitive abilities are not good indicators of decision making and they do not alone protect from thinking biases (Stanovich, 2011). Autonomous cognition is not directly addressed because it involves mostly unconscious, nonverbal, automatic and intuitive processes that cannot be accessed using a survey. However, although autonomous processes are unconscious, their output can pop into the reflective mind resulting in intuitions, a way of thinking or believing something instinctively, but not knowing why (Epstein, 2010; Evans & Stanovich, 2013).

### ***Cognitive abilities: fluid intelligence and ability for cognitive reflection***

Studies on the relationship between cognitive abilities and vaccination attitudes are scarce. The few available studies have focused on cognitive reflection ability, which refers to the ability to inhibit potentially incorrect intuitions, and to consider solutions which could lead to the correct decision. A typical task for assessing this ability is: “A bat and a ball cost \$1.10 in total. The bat costs \$1.00 more than the ball. How much does the ball cost?” The results are inconsistent: some studies have shown that lower reflection ability is more common among unvaccinated than among vaccinated people (Scherer et al., 2018) but other studies have not found such associations (Browne et al., 2015).

A general susceptibility to epistemically suspect beliefs, in turn, decreases with higher cognitive reflection ability and with general cognitive ability (Čavojevová et al., 2020; Ståhl & Van Prooijen, 2018). Because of these findings, and because fluid intelligence, which entails the ability to solve novel problems, is a necessary precondition for rational thinking (Stanovich, 2011), we will investigate whether cognitive reflection ability and fluid intelligence are related to anti-vaccination attitudes. We do not expect these relationships to be strong because to think rationally, people must also

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<sup>1</sup>As noted by an astute reviewer, reflective cognition includes both optimal processes that support rational thinking, such as cognitive decoupling, and more error-prone ways of thinking, such as rationalization, which can be used to support biases. For the present purposes, we focus on a set of reflective processes that seem relevant for predicting anti-vaccination attitudes. For more in-depth discussions of forms of reflective cognition, we refer the reader to Pennycook et al. (2015c) and Stanovich (2009).

value epistemically sound beliefs and to be motivated to use their abilities in pursuit of the truth (Evans & Stanovich, 2013; Ståhl & Van Prooijen, 2018). We now turn to these dispositional factors, i.e., the overall style how a person does things, how a person typically thinks, how he or she usually feels about things in general (McAdams & Pals, 2006).

### *Thinking styles: intuitive and analytic*

Because thinking styles reflect how one approaches knowledge and one's views on how information can and should be obtained, it is reasonable to assume that these styles also predict vaccine attitudes. In this study, we investigate the two most studied styles, intuitive and analytic styles. Intuitive thinkers like to trust their initial feelings and first impressions, they place trust in personal experiences, and prefer to go by their instincts even for important decisions (Norris & Epstein, 2011). People with an analytic style, in turn, can have a high need for cognition and thus engage in and enjoy effortful cognitive activity (Norris & Epstein, 2011). They can also endorse actively open-minded thinking, which means that they like to consider various points of view before drawing conclusions, and their confidence in their opinions tends to depend on the amount of supporting evidence (Stanovich, 2011).

Intuitive and analytic styles predict thinking on many real-life topics, such as human-caused global warming, evolution, conspiracy theories, alternative medicine, religiosity and paranormal beliefs, usually so that intuitive style increases and analytic style decreases epistemically unjustified beliefs (Fasce & Picó, 2019; Pennycook et al., 2015b; Trémolière & Djeriouat, 2021). However, only a few studies have examined how thinking styles are related to vaccine attitudes. The results have been mixed and the observed effects small: In one study, on young adult Americans, neither need for cognition nor faith in intuition predicted vaccination intentions (Scherer et al., 2018), in one study conducted in Croatia faith in intuition increased vaccine refusal and vaccine conspiracy beliefs but need for cognition had no effect (Tomljenovic et al., 2020), and in one study, on US adults, people's vaccination attitudes became less favorable with increasing faith in intuition (Schindler et al., 2021). Despite these inconclusive results, we hypothesize that negative vaccination attitudes decrease with higher analytic thinking style and that they increase together with higher faith in intuition.

### *Cognitive biases and scientific literacy*

Preliminary evidence indicates that vaccine hesitant people may hold some cognitive biases. One example comes from studies which have found that vaccine hesitant people believe in conspiracy theories, such as those

surrounding the death of Princess Diana and the 9/11 terrorist attacks in the United States (Bertin et al., 2020; Hornsey et al., 2018). In addition, anti-vaccination attitudes themselves can manifest as conspiracy beliefs that involve themes such as immunization, vaccination and its side effects, and pharmaceutical companies (Jolley & Douglas, 2017; Tomljenovic et al., 2020). Hence it is worth investigating whether vaccine skeptics share the same cognitive biases that have been found among conspiracy believers.

Conspiracy theories include the assumption that a group of actors have secretly planned and executed an event with a malicious goal (van Prooijen & Van Vugt, 2018). Because this assumption is most often unfounded, research has tested the hypothesis that conspiracy believers more generally detect intentionality and agents even where there are none. The findings support this hypothesis. For example, more than others, conspiracy believers attribute intentionality to dots on a computer screen (Douglas et al., 2016), and they see purpose in random events such as a stone falling from a scaffold, leading to injury (van Der Tempel & Alcock, 2015). In the present study, we test whether vaccine skeptics endorse this teleological bias, in which natural phenomena are explained by incorrectly referring to their intentional design, purpose, or believing that something exists “in order to” (Järnefelt et al., 2015). Finding that vaccine skeptics possess the teleological bias would also help us understand why vaccine hesitancy increases with religiosity (Rutjens et al., 2018; Schindler et al., 2021), as the teleological bias is one of the major explanations for religiosity in the cognitive science of religion (Barrett, 2000; Kelemen et al., 2013).

Both teleological bias and conspiracy beliefs indicate seeing intentionality where there is none. In addition, there are more fundamental ontological confusions that misattribute properties of one type of thing to another, and which together with the teleological bias are proposed to be side-effects of human mental design, which may retain their intuitive power throughout life (Guthrie, 1993; Hood, 2009; Kelemen, 2004; Lindeman, 2018). These biases may typify vaccine skeptics. Ontological confusions of core knowledge reflect a mix-up between the key properties that differentiate mental, biological, and physical phenomena, and they especially characterize supernatural beliefs (Fasce & Picó, 2019; Lindeman & Svedholm, 2012; Rizeq et al., 2021). For example, supernatural beliefs in healing energy, thoughts that can move physical objects, and spirits that can live without a biological body include ontological confusions of core knowledge. Finding that vaccine skeptics hold these types of confusions would explain the findings that vaccine skeptics also endorse supernatural beliefs that do not involve any agents or intentionality. There is evidence that negative vaccination attitudes increase with beliefs in unlucky numbers and other superstitions (Lu et al., 2019), with endorsement of spirituality as a source of knowledge (Browne et al., 2015; Rutjens & van der Lee,

2020), and with magical health beliefs, such as “Colors change the organism’s energy vibration in a direction that is beneficial to health” (Bryden et al., 2018). These findings have been difficult to explain because vaccines or vaccinations do not include any supernatural elements (i.e., paranormal, magic, spirituality, superstitions; Lindeman & Svedholm, 2012). In sum, given that vaccine skeptics feel drawn to supernatural beliefs, and that ontological confusions increase together with supernatural beliefs (Fasce & Picó, 2019; Lindeman et al., 2015; Rizeq et al., 2021), we expect that vaccine skeptics show ontological confusions.

Even though cognitive biases are incorporated into the reflective mind of adults, they are assumed to derive from autonomous cognition. Scholars agree that the biases are rooted in early childhood thinking when understanding of the distinctions between mental, physical and biological phenomena is not yet fully developed, and that the biases can remain as lifelong biases (Kelemen et al., 2013; Lindeman et al., 2015; Shtulman & Valcarcel, 2012).

Finally, if vaccine skeptics endorse ontological confusions and the teleological bias, it can be expected that their scientific literacy is limited. Preliminary evidence supports this hypothesis, as scientific literacy about issues such as radioactivity, lasers, electrons, and antibiotics is negatively related to vaccine skepticism (Rutjens et al., 2018) and to susceptibility to pseudoscientific claims, regardless of their content (Piejka & Okruszek, 2020).

## The present study

We extend the scope of previous research by investigating how cognitive factors which are not directly linked to vaccines or vaccination predict anti-vaccination attitudes. The cognitive factors that we study have previously been found to be associated with other epistemically suspect beliefs, but their possible relationships to anti-vaccination attitudes have not previously been studied. The factors addressed are (Figure 1): cognitive reflection ability, fluid intelligence, intuitive thinking style, two analytic thinking styles (need for cognition and actively open-minded thinking), scientific literacy, and two cognitive biases (teleological bias and ontological confusions). We hypothesize that negative vaccination attitudes are associated with higher faith in intuition, lower analytic thinking style, more teleological bias, more ontological confusions, and poorer scientific literacy. We also aim to replicate the findings that negative vaccination attitudes increase together with religious and paranormal beliefs.

## Materials and methods

### Participants and procedure

Three hundred and fifty-six Finnish participants (62.1% females) with a mean age of 31.8 years ( $SD = 9.90$ , range 18–65) took part in the study. This

sample size is sufficient to detect correlations  $r \geq .15$  (with  $\alpha = .05$ , and 80% statistical power). The material was collected with an online questionnaire as part of a larger, two-stage study before the Covid-19 pandemic (Lindeman & Svedholm-Häkkinen, 2016). The participants were recruited via several open internet discussion forums and student mailing lists. Of them, 37.1% were working, 43.4% were students, and 16.8% were employed in activities other than those above; 2.2% had grammar school education, 41.7% had vocational or upper secondary school education, 53.1% had polytechnic or university education. Religious affiliations were none (60.1%), Lutheranism (35.2%), other (1.6%), and information was missing from 2.4%.

Following Finnish law and the guidelines of the Finnish Advisory Board on Research Integrity (<http://www.tenk.fi/en/tenk-guidelines>), the Ethical Committee of the University of Helsinki approves studies that (1) do not fall within the category of medical research as defined in the Act on Medical Research, and (2) do fulfill specific requirements, without a separate ethical review. Psychological studies, which focus on the general healthy adult population, include no intervention for the participants, obtain informed consent and impose no physical or mental harm or security risk for the participants, fulfill these requirements. Therefore approval for the study has been granted without review.

## Measures

### *Anti-vaccination attitudes*

The attitudes were measured with a 15-item scale, developed for the present study (see the Appendix). We formulated statements (1 = *Strongly disagree*, 5 = *Strongly agree*) based on findings concerning the reasons that people state for refusing to vaccinate, and they were related to ideas that vaccinations are not safe, that vaccinations are impure or unnatural, and to conspiracy ideas regarding vaccinations. Because vaccine hesitancy has been characterized as multidimensional (Dubé & MacDonald, 2018), explorative factor analyses with orthogonal and oblique rotations were performed. However, the analyses did not reveal conceptually meaningful and psychometrically distinct dimensions. As the internal consistency of a composite score calculated as the average of all of our items was high (Cronbach's  $\alpha = .91$ ), we therefore used this composite score in further analyses.

### *Fluid intelligence*

We used Baddeley's Grammatical Reasoning Task (Baddeley, 1968), because it is quick to administer and because it has been shown to be a reliable and valid measure of the fluid intelligence component of general cognitive

ability (Kyllonen & Christal, 1990). In the task, the participants were shown a combination of the letters A and B and a statement about their relation, and asked to indicate as quickly as possible whether the statement was true or false (e.g., “A does not precede B: AB”). Responses were given using a response box. The task ran for 3 min and the number of correct responses given in this time made up the score.

### *Cognitive reflection*

We also used the Cognitive Reflection Test (CRT; Frederick, 2005). The CRT consists of three mathematical questions that cue incorrect heuristic answers that must be inhibited in order to give the correct answers. The number of correct responses made up the CRT score.

### *Thinking styles*

Analytic style was measured with two scales. The Need for Cognition subscale ( $\alpha = .87$ ) of the Rational/Experiential Multimodal Inventory (Norris & Epstein, 2011) assesses engagement in and enjoyment of effortful cognitive activity. The scale includes 12 items, for example “I enjoy problems that require hard thinking” (1 = *Strongly disagree*, 4 = *Strongly agree*). The Actively Open-minded Thinking scale (Sá et al., 1999) focuses on reflective thinking, collecting information before making up one’s mind, and seeking various points of view before drawing conclusions. The scale includes 41 items (1 = *Disagree strongly*, 6 = *Agree strongly*), for example “People should always take into consideration evidence that goes against their beliefs.” The reliability ( $\alpha$ ) of the scale was .94.

The Faith in Intuition subscale of the Rational/Experiential Multimodal Inventory (Norris & Epstein, 2011) was used to measure intuitive thinking style ( $\alpha = .78$ ). The four-point scale (1 = *Strongly disagree*, 4 = *Strongly agree*) includes 10 items, for example “I like to rely on my intuitive impressions.”

### *Teleological bias*

Six teleology statements ( $\alpha = .75$ ) were derived from the studies of Kelemen and her colleagues (see Table 1 in Kelemen et al., 2013). In the instructions, we told the participants that we will describe some natural phenomena and explanations for them. The participants’ task was to judge whether the explanations were bad (scored 1) or good (2). The more statements a participant evaluated as good explanations, the higher that person’s teleological bias. Example statements are “Earthworms tunnel underground to aerate the soil” and “Mosses form around rocks to stop soil erosion.” The scale also included three filler items (e.g., “Soda fizzes because carbon dioxide gas is released”).

**Table 1.** Descriptive statistics of the variables, and correlations between studied variables.

	M (SD)	1	2	3	4	5	6	7	8	9	10
1. Anti-vaccination attitudes <sup>a</sup>	.25 (.14) [.00–.68]										
2. Fluid intelligence	43.52 (11.14) [0.00–64.00]	–.14									
3. Cognitive reflection ability	1.87 (1.09) [.00–3.00]	–.29	.12								
4. Need for cognition	3.05 (.48) [1–4]	–.32	.09	.39							
5. Actively open-minded thinking	4.60 (.42) [1–6]	–.29	.02	.15	.26						
6. Faith in intuition	2.58 (.44) [1–4]	.43	–.07	–.32	–.39	–.29					
7. Teleological bias	7.79 (1.78) [6–12]	.37	–.16	–.32	–.28	–.33	.38				
8. Ontological confusions <sup>b</sup>	.00 (.86) [–1.35–2.99]	.49	–.17	–.35	–.36	–.31	.44	.43			
9. Scientific literacy	12.32 (1.94) [6–16]	–.38	.26	.38	.24	.21	–.28	–.30	–.39		
10. Paranormal beliefs <sup>a</sup>	.20 (.18) [.00–.69]	.55	–.11	–.30	–.33	–.33	.50	.44	.69	–.33	
11. Religious beliefs <sup>a</sup>	.23 (.21) [.00–.70]	.40	–.06	–.23	–.28	–.33	.43	.41	.52	–.28	.78

Note.  $r$ 's > .21:  $p < .001$ ,  $r$ 's > .16:  $p < .01$ ,  $r$ 's > .12:  $p < .05$ .

<sup>a</sup>Log10 scores.

<sup>b</sup>z-scores.

### *Ontological confusions*

Z-scores of participants' responses to items in two scales were averaged to create the ontological confusion variable ( $\alpha = .91$ ). First, we used the 14-item Core Knowledge Confusions scale (Lindeman et al., 2015). Example statements are "Earth wants water" and "A house knows its history." Metaphorical ("Friends are the salt of life") and literal statements ("Sibelius was a composer") were used as practice items. Then in the task, the participants were asked to rate on a 5-point scale whether the statements were fully metaphorical (1) or fully literal (5). Because mentalizing biases are underrepresented in this scale, we supplemented it with items from the Over-Mentalizing Scale (Lindeman & Svedholm-Häkkinen, 2016). The participants were asked to rate 23 words on the extent to which they can be characterized as denoting something mental or nonmental (1 = *Not at all mental*, 4 = *Mental*). The instructions stipulated that "by mental we mean anything that has some kind of spirit, or something which itself is mental. For example, thoughts are mental phenomena and human beings are mental beings. Many people also consider God to be a mental being. A pen or a car, by contrast, is generally considered non-mental." The stimulus words denoted physical processes, lifeless matter, artificial objects, or living but inanimate phenomena (e.g., electricity, water, paper, moss, and other things lacking consciousness). Both scales, available in the Appendix, also included filler items to hide the purpose of the study.

### *Scientific literacy*

Sixteen items (see the Appendix) were used to assess scientific literacy (Lindeman & Svedholm-Häkkinen, 2016). To prevent participants from looking up the answers, we limited answering time to 10–12 seconds per item. Because the length of the statements ranged from 29 to 157 characters, the answering time was 10 seconds for shorter statements and 12 seconds for longer statements. Participants answered whether each of 16 statements was true or not, and the number of correct responses was calculated.

### *Religious and paranormal beliefs*

We used eight items from the Supernatural Belief Scale ( $\alpha = .94$ ) (Jong et al., 2013) to measure religious beliefs (e.g., "There exists an all-powerful, all-knowing, loving God"). Paranormal beliefs were assessed with 15 items from the Revised Paranormal Belief Scale, which assesses beliefs in astrology, telepathy, and precognition, witchcraft, superstition, spiritualism, and psychokinesis (RPBS,  $\alpha = .94$ ; Tobacyk, 2004). To avoid item overlap, two items were excluded from the original 10-item SBS, and five items were excluded from the original 26-item RPBS. Following the suggestions of Lindeman and Svedholm (2012), an additional six items were removed from

**Table 2.** Hierarchical regression analysis predicting anti-vaccination attitudes.

	R <sup>2</sup>	Adj R <sup>2</sup>	β	t	p
STEP 1	.36	.34			
Fluid intelligence			−.02	−.43	.668
Cognitive reflection			.03	.43	.665
Need for cognition			−.05	−.94	.347
Actively open-minded thinking			−.11	−2.00	.047
Faith in intuition			.19	3.06	.002
Teleological bias			.09	1.55	.122
Ontological confusions			.27	4.29	<.001
Scientific literacy			−.20	−3.41	<.001
STEP 2	.37	.34			
Fluid intelligence			−.03	−.49	.627
Cognitive reflection			.02	.38	.703
Need for cognition			−.05	−.92	.356
Actively open-minded thinking			−.10	−1.80	.073
Faith in intuition			.17	2.73	.007
Teleological bias			.08	1.35	.180
Ontological confusions			.24	3.74	<.001
Scientific literacy			−.19	−3.36	<.001
Religious beliefs			.07	1.05	.294

the RPBS because they were too culture-specific (e.g., belief in the Loch Ness Monster) or dated (e.g., a black cat crossing brings bad luck). The participants indicated their opinion about the statements on a 5-point scale (1 = *Strongly disagree*, 5 = *Strongly agree*). Both scales can be found in the Appendix.

## Results

Because scores for anti-vaccination attitudes ( $M = 2.20$ ,  $SD = 0.47$ ), supernatural beliefs ( $M = 1.72$ ,  $SD = 0.84$ ), and religious beliefs ( $M = 1.93$ ,  $SD = 1.04$ ) were negatively skewed ( $>1$ ), we transformed these variables by taking the common logarithm ( $\log_{10}$ ). Although the results for all analyses remained roughly the same when the original variables were used, the following results are based on the transformed variables.

Descriptive statistics for the variables and correlations are presented in Table 1. The results show that all cognitive factors were associated with anti-vaccination attitudes as hypothesized. The strongest connections with anti-vaccination attitudes were found for (poor) scientific literacy, intuitive thinking, religious and non-religious supernatural beliefs, and ontological confusions. All cognitive factors also correlated with each other, some of them very strongly.

To test how the cognitive factors predict anti-vaccination attitudes, a hierarchical multiple regression analysis was conducted (Table 2). Multicollinearity statistics were acceptable between the predictors and anti-vaccination attitudes (tolerance  $> .85$ ). The eight cognitive factors were entered in the first block, and religious beliefs were entered in the second

block (see Discussion for justification of this model). The cognitive factors explained 36.2% of the variance in negative attitudes towards vaccination,  $F(8,246) = 17.47$ ,  $p < .001$ . Significant and positive beta coefficients were found for faith in intuition and ontological confusions, and significant but negative coefficients were found for actively open-minded thinking and scientific literacy. Religious beliefs explained an additional 0.3% of the variance,  $R^2$  change was not significant,  $F(1,245) = 1.11$ ,  $p = .294$ . In the second step, actively open-minded thinking lost its significance, otherwise the results remained unchanged. The overall model explained 36.5% of the variation in anti-vaccination attitudes.

## Discussion

This study showed that factors which are non-specific to vaccines or health play an important role in vaccine skepticism, supporting all our hypotheses. The vast majority of previous work on vaccine hesitancy has focused on beliefs about vaccines, mistrust in health authorities, and other vaccine and health specific views. Although the need for a broader research focus has been acknowledged (Amin et al., 2017; Hornsey et al., 2018; Poland & Brunson, 2015), research addressing this need has been limited. The present results extend earlier work on the ideological roots of anti-vaccination attitudes (Hornsey, 2020) and broaden the research agenda in several important ways.

Of course, promoting vaccinations requires many types of actions. Many unvaccinated people are unvaccinated for mundane reasons, such as lack of time for or access to vaccination appointments. To promote vaccination among these groups, practical approaches such as monetary rewards, may be most functional (Campos-Mercade et al., 2021). However, the focus of the present discussion is on factors that may help to counter anti-vaccination attitudes among people with a disposition to adopt epistemically suspect beliefs. These approaches need to be wholly different, as will be discussed next.

### *Vaccine skepticism is not a distinct belief*

Factors that refer to the reflective mind were highly correlated with anti-vaccination attitudes. The strongest correlations were found with stronger paranormal and religious beliefs, stronger reliance on one's intuitions, poorer scientific literacy, and more ontological confusions between physical, biological and mental phenomena. Anti-vaccination attitudes also correlated with stronger teleological bias, lower need for cognition, less actively open-minded thinking, and lower cognitive ability to reflect on

one's intuitions. We may note that people with negative vaccination attitudes also had lower fluid intelligence than others, but this association was weak.

Furthermore, anti-vaccination attitudes correlated strongly with beliefs in telepathy, astrology, magic spells, and other supernatural phenomena. Earlier studies have also shown that vaccine skepticism increases with paranormal beliefs, religiosity, and spirituality but the explanations that scholars have given to their findings have remained elusive. It has been argued, for example, that the common link between negative superstitions and vaccine refusal is a belief that negative things will happen (Lu et al., 2019) whereas others have admitted that the reasons for the associations between magical food and health beliefs and vaccine skepticism are not clear (Bryden et al., 2018). The present results provide further evidence for the proposals that vaccine hesitancy, paranormal beliefs and spirituality reflect a radically different epistemology than that of science, an epistemology which is based on intuitions, personal experiences and disregard of evidence and truth (Browne et al., 2015; Rutjens & van der Lee, 2020).

A regression analysis was conducted to expand on the above findings. Besides the other cognitive factors, we also entered religious beliefs as a predictor because the largest under-vaccinated groups in the EU are religious groups (De Figueiredo et al., 2020; Fournet et al., 2018) and because the World Health Organization's SAGE group has defined religiosity as a determinant of vaccine hesitancy (MacDonald & the SAGE Working Group on Vaccine Hesitancy, 2015). Religious beliefs were included in a separate block because including religiosity in the model is not necessarily theoretically coherent. Although belief in god or gods (i.e., cognition) is the key characteristic that differentiates religiosity from all other world views, religiosity—unlike the other predictors—is also a strongly social phenomenon. More importantly, religiosity may not be comparable to the other cognitive predictors in the model because the main tenet of cognitive science of religion is that religiosity should be seen *as a consequence* of the cognitive predictors that we included in Block 1 (Gervais, 2013; Lindeman et al., 2019 (Table 4); Pennycook et al., 2012; Shenhav et al., 2012). The same is true for paranormal beliefs (Lindeman, 2018; Lobato et al., 2014; Pennycook et al., 2012; Rizeq et al., 2021) which is why it was not included in the regression analysis.

The results showed that faith in intuition, low scientific literacy, and ontological confusions predicted vaccine skepticism over and above the other cognitive factors. Although cognitive abilities and analytic thinking styles correlated negatively with vaccine skepticism, and the teleological bias and religious beliefs correlated positively with vaccine skepticism, their associations were suppressed because they overlapped with those

cognitive dispositions that had unique contributions to vaccine skepticism (Table 1). In total, a model taking into account all these cognitive factors, as well as religious beliefs, explained as much as 36.5% of the variation in anti-vaccination attitudes. This is a substantial share in light of the fact that the items in these measures make no mention of vaccines.

Together the results show that the correlates and predictors of vaccine skepticism were the same as the correlates of other epistemically suspect beliefs. Although most earlier studies have included fewer predictor variables, the same cognitive factors that were here associated with vaccine skepticism have predicted belief in fake news (Bronstein et al., 2019), belief in alternative medicine (Galbraith et al., 2018), skepticism about genetic modification (Rutjens et al., 2018) and climate change (Trémolière & Djeriouat, 2021), paranormal and conspiracy beliefs (Rizeq et al., 2021), creationism (Sinatra et al., 2003), the tendency to rate meaningless statements as profound (Pennycook et al., 2015a), and a general tendency to endorse pseudoscientific and other unwarranted beliefs (Čavojská et al., 2020; Fiasce & Picó, 2019; Piejka & Okruszek, 2020).

The relative importance of thinking styles and cognitive ability in this study was also identical to that in previous studies about other epistemically suspect beliefs. These beliefs have been shown to be more strongly related to intuitive thinking style than to analytic thinking style and while cognitive ability has been associated with weaker suspect beliefs, the association has been moderate at best (for references, see Čavojská et al., 2020). This is what we found for vaccine correlates as well. These observations may explain why the few available findings about the relevance of need for cognition and cognitive reflection in vaccine skepticism have been inconsistent (Browne et al., 2015; Scherer et al., 2018; Tomljenovic et al., 2020). In turn, the stronger association between intuitive thinking and vaccine skepticism is in line with the arguments that attitudes towards vaccines can be rooted in intuitions (Amin et al., 2017; Miton & Mercier, 2015) and with the empirical evidence that when faith in intuition increases, people's vaccination attitudes become less favorable (Schindler et al., 2021; Tomljenovic et al., 2020). Overall, the results have important implications for future studies and strategies attempting to promote positive views of vaccination.

### ***Implications and applications***

Several scholars have concluded that most interventions to promote vaccination and to counter people's anti-vaccination decisions have not been successful (Horne et al., 2015; Hornsey et al., 2018; Miton & Mercier, 2015). The strong role that intuitive thinking style played in negative vaccination attitudes may partly explain why. Logical arguments, statistics, probabilities,

risk ratios, and other scientific and abstract information, are not effective for individuals who habitually rely on their intuitions (Epstein, 2010; Phillips et al., 2016). Instead, intuitive thinkers are receptive to the type of information provided by the advocates of anti-vaccination and other pseudoscientific campaigns. This information is concrete, pictorial, and emotional, and it includes narratives, metaphors, and in particular, personal experiences and testimonies. In light of the present results, it would be useful to use this kind of intuitively appealing communication also in pro-vaccination communication because it has the potential to outperform scientific communication about vaccines as has already been observed (Horne et al., 2015).

Two important things about intuitive thinking should be noted. First, because intuitive information processing is the default mode for everybody in most situations (Evans & Stanovich, 2013), we are all receptive to the same kind of concrete and vivid information unless we are not motivated or able to scrutinize the information analytically. Second, and relatedly, many cognitive biases which were not addressed here are common particularly when processing information in an intuitive mode. Because all cognitive biases can be described as improperly overweighting of some aspects of the information and underweighting others (Morewedge & Kahneman, 2010), they are inherently relevant in vaccine hesitancy. To name a few examples, confirmation bias (focusing on information that supports one's beliefs) and availability bias (relying on the most easily accessible information) are easy to succumb to because of the algorithms and the echo chamber nature of social media. To prevent anti-vaccination attitudes, it would be useful for everyone to be familiarized with these well documented intuitively appealing biases, and with ways how to guard against them. This should start from as early as school age, because many reasoning biases grow from childhood to early adolescence when intuition-based reasoning develops (Reyna, 2012). For example, the basic education syllabus could incorporate information about cognitive biases, such as that presented in popularized form by Kahneman (2011).

In good agreement with previous findings (Piejka & Okruszek, 2020; Rutjens et al., 2018), vaccine skepticism was strongly predicted by poor scientific literacy. This is unsurprising, because scientific literacy certainly helps understand how vaccines work, and because anti-vaccination attitudes are typically based on misbeliefs such as thinking that vaccines overload the immune system, that vaccines are unnatural and contain toxins, and that vaccines cause diseases. Because established beliefs do not change easily, teaching should focus on prevention of such misinformation already at school age. Nevertheless, scientific literacy or knowledge alone are insufficient, as our results demonstrate.

Importantly, teaching should also focus more clearly on how physical, biological and mental phenomena differ. The more the participants attributed mentality (intentions, thoughts and feelings) and life (e.g., the ability

to see and hear) to physical processes and inanimate objects such as the moon, flowers, water, or electricity, the more negative their attitudes towards vaccinations were. In earlier studies, ontological confusions have predicted a range of epistemically suspect beliefs, from supernatural beliefs (Fasce & Picó, 2019; Lindeman et al., 2015; Rizeq et al., 2021) to anti-science attitudes and conspiracy beliefs (Fasce & Picó, 2019; Rizeq et al., 2021), and even to what the literature has eloquently termed “receptivity to pseudo-profound bullshit” (Pennycook et al., 2015a). For this reason, explicating the basic differences between ontological categories as part of school teaching might support the development of scientific literacy and counter the adoption of all types of epistemically suspect beliefs.

### **Limitations**

The first limitation is the cross-sectional and survey-based design with a small sample size from internet message boards, so any sampling biases remain unidentified. In addition, the data was gathered only in Finland, where anti-vaccination attitudes are not common and where trust in health authorities is high. Future studies should therefore replicate these findings in different countries and with bigger samples.

Furthermore, the anti-vaccination attitude scale and the scientific literacy scale have not been thoroughly validated. It is therefore important to replicate the present findings using other scales of vaccine attitudes which are nowadays available (De Figueiredo et al., 2020; Shapiro et al., 2018). The scientific literacy scale was in many respects similar to the widely used Civic Scientific Literacy Scale (Miller, 1998). However, the presentation format limited response times to 10 or 12 seconds. Even though this did not force responses to be particularly fast, it precluded more elaborate reasoning about the items. Thus, it is possible that the presentation format limited Type 2 processing to some extent and that responses reflect Type 1 processing more than they would if response time was unlimited. Future studies should put more emphasis on ensuring that all assessment measures are theoretically justified, comprehensive, and psychometrically sound.

One particular challenge concerns the CRT, which has gained large spread among the public and whose items may therefore have been familiar to some of the participants (but see Bialek & Pennycook, 2018 for evidence that the test may be robust to repetition). Moreover, criticism of the test has increased recently, and it is possible that scoring high on the test does not accurately reflect the capacity to inhibit potentially incorrect intuitions (e.g., Raelison et al., 2020).

Finally, because no vaccine-specific predictors were included, a comparison between the relative importance of cognitive and vaccine-specific factors remains for future studies.

## Concluding remarks

The present study provides an initial demonstration that vaccine skepticism may share a common cognitive root with other epistemically suspect beliefs, that is, “a generalized tendency to fall for unwarranted claims” (Piejka & Okruszek, 2020, p. 1073). Browne et al. (2015) and Rutjens and van der Lee (2020) have described that vaccine skeptics hold a radically different epistemology than that of science. The present study complemented and expanded on this view by indicating that this common cognitive profile can be characterized as a strong confidence in gut feelings, emotional testimonies, intuitively appealing socially circulating narratives, and cognitive biases typical of intuitive thinking. This habitual way of thinking can thus contribute to biases in the ways in which individuals seek out and evaluate scientific information, and to downplaying analytic thinking and objective evidence, and to predispose individuals towards decreased science knowledge and diverse unfounded beliefs that may at the outset concern widely different issues. Future studies should aim at increasing our knowledge about this cognitive profile and its relative importance with respect to other important predictors of vaccine skepticism, like vaccine and health specific attitudes, emotions towards vaccination (Amin et al., 2017; Hornsey, 2020; Miton & Mercier, 2015; Rutjens et al., 2018), as well as the cause-and-effect relationships of these factors.

If replicated, our findings have profound implications for interventions addressing vaccine hesitancy because they make clear that simply providing information on the benefits of vaccinating and the disadvantages of not vaccinating are not enough at all. Above all, early-onset prevention is needed, focusing on fostering positive attitudes towards science from early childhood, and later in early adolescence, increasing general knowledge about biological, physical, and mental phenomena, their crucial differences, the characteristics of reliable and unreliable information, and the reasons why intuition and personal experiences are easily misleading in matters belonging to the scope of science. Like enacting changes in vaccine institutes to make them more trustworthy in countries where trust in the institutions is low (Miton & Mercier, 2015), these projects need large political investments, because the projects are much broader than fighting vaccine hesitancy alone. Understanding and targeting these extensive factors are important because negative vaccine attitudes may lead to serious consequences regarding health choices, life, and death.

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## Data availability statement

The data that support the findings of this study are openly available at [https://services.fsd.tuni.fi/catalogue/FSD3260?study\\_language=en&lang=en](https://services.fsd.tuni.fi/catalogue/FSD3260?study_language=en&lang=en). Variable names in English are provided upon request.

## Disclosure statement

No potential conflict of interest was reported by the authors.

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## Appendix

For all instructions, see Measures

### ***The items used to measure anti-vaccination attitudes (R = reversed)***

1. In general, vaccines are useful (R)
2. I would vaccinate/I have vaccinated my child in accordance with the recommendations (R)
3. Vaccines can contaminate the body
4. Vaccines are a way for pharmaceutical companies to extort money from people
5. I oppose vaccination because vaccines are not natural ways to treat diseases
6. Vaccination is safe (R)
7. The public is not told everything about the contents of vaccines
8. The disadvantages of vaccines are not openly reported
9. I could participate in a new vaccine development study (R)
10. I have refused vaccination
11. Vaccines are impure
12. Vaccines often result in serious illness
13. Vaccines put too much strain on the innate immune system
14. Vaccines can be used to benefit governments or other actors and against ordinary people
15. We are being told that vaccines are useful, but in reality they are used against people

### ***Ontological confusions***

#### ***The items used to measure core knowledge confusions***

Items 2, 5, 6, 11, 15 and 18 are fillers, not to be included in the sum variable

1. A rock lives long
2. A good memory is a mine
3. Force lives in the universe
4. Force aims to influence
5. The howling wind is a flute
6. A distressed person is a prisoner
7. Earth wants water
8. Planets know things
9. The sky hears the thunder.
10. Flowers want light
11. Rainless weather is dry
12. Plants know the seasons
13. A home knows its residents
14. Furniture wants a home
15. Flowing water is liquid

16. A house knows its history
17. A mind touches another
18. A bad drawing is a scribble
19. A plan lives in nature
20. Fear poisons a person.

### *The items used to measure over-mentalization*

Items 3, 6, 10, 16, 19 and 23 are fillers, not to be included in the sum variable

1. Wind
2. Metal
3. Justice
4. Room
5. Force
6. Fish
7. Clock
8. Goal
9. Light
10. Purpose
11. Clothes
12. Stone
13. Water
14. Flower
15. Algae
16. Worm
17. Paper
18. Tree
19. Race
20. Moss
21. Air
22. Electricity
23. Freedom

### *The items used to measure scientific literacy*

1. Earth, wind, water and fire belong to the most important (chemical) elements.
2. Increased genetic variability makes a population more resistant to extinction \*
3. The universe stays still but the tectonic plates can move
4. The globe is approximately 4 to 5 million years old
5. Ultimately, everything in the universe consists of some kind of matter
6. Energy can appear out of nowhere
7. Natural selection is a random process
8. Brightness is a property that objects can have
9. Heat is something that one can touch.
10. Living organisms differ from lifeless objects in that they have a special energy or matter (so called life force) that chemistry or physics cannot explain

11. Many diseases are based on an imbalance of bodily fluids
12. The sun is a star that the Earth orbits \*
13. Oxygen is a gas in the atmosphere that is crucial for life \*
14. Evolution means progression towards perfection
15. In a chemical reaction, a matter can transform into another matter \*
16. Cold cannot exist independently; it is only the absence of heat \*

Note. Statements 2, 12, 13, 15, and 16 marked with an asterisk are correct, others are wrong.

### ***The items used to measure paranormal beliefs***

For original items, see Tobacyk (2004), for suggestions for modifications, see Lindeman and Svedholm (2012). Item 12 is reverse coded.

1. Some individuals are able to levitate (lift) objects through mental forces
2. Black magic really exists
3. Your mind or soul can leave your body and travel (astral projection)
4. Astrology is a way to accurately predict the future
5. Psychokinesis, the movement of objects through psychic powers, does exist
6. Witches who have supernatural powers exist
7. During altered states, such as sleep or trances, the spirit can leave the body
8. A person's thoughts can influence the movement of a physical object
9. Through the use of formulas and incantations, it is possible to cast spells on persons
10. Reincarnation does occur
11. Some psychics can accurately predict the future
12. Telepathic mind reading is not possible (R)
13. There are actual cases of witchcraft.
14. Dead people can send messages to their loved ones
15. Some people have an unexplained ability to predict the future.

### ***The items used to measure religious beliefs***

The original scale includes 10 items; see Jong et al. (2013)

1. There exists an all-powerful, all-knowing, loving God.
2. There exist good personal spiritual beings, whom we might call angels.
3. There exist evil, personal spiritual beings, whom we might call demons.
4. Human beings have immaterial, immortal souls.
5. There is a spiritual realm besides the physical one.
6. Some people will go to Heaven when they die.
7. Some people will go to Hell when they die.
8. Miracles—divinely caused events that have no natural explanation—can and do happen.