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Correcting Misperceptions about the MMR Vaccine: Using Psychological Risk Factors to Inform Targeted Communication Strategies

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Abstract

Many Americans endorse misinformation about vaccine safety. This is problematic because those who do are more likely to resist evidence-based policies, such as mandatory vaccination for school attendance. Although many have attempted to correct misinformation about vaccines, few attempts have been successful. This study uses psychological correlates of vaccine misinformation acceptance to develop a novel misinformation correction strategy by tailoring provaccine messages to appeal to these psychological traits. For example, people with higher moral purity levels are more likely to view vaccines as contaminating the body, but messages highlighting disease via under-vaccination can use their higher moral purity to push them toward vaccine support. Using a large survey experiment ($N = 7{,}019$) and a smaller replication experiment ($N = 825$) of American adults, we demonstrate that interventions designed to appeal to people high in moral purity and needle sensitivity—two relatively understudied correlates of vaccine misinformation support—can also be targeted to effectively reduce vaccine misinformation endorsement. This study provides a better understanding of the psychological origins of misinformed political and policy attitudes, and it suggests a strategy for combating policy-related misinformation more generally, ultimately boosting support for evidence-based policies.

Keywords

misinformation, moral purity, needle sensitivity, need for cognitive closure, science communication, policy attitudes

Vaccines safely and effectively prevent the outbreak of diseases that used to be prevalent across the globe. Yet many people throughout the world believe misinformation that vaccines are unsafe and cause significant side effects such as autism, despite overwhelming scientific evidence to the contrary. These beliefs can lead to the pursuit of alternative vaccination schedules, opposition to policies designed to protect public health like mandatory school vaccination, and even skipping vaccinations altogether, all of which can create windows for nearly eradicated diseases to return and spread (Joslyn and Sylvester 2017).

This phenomenon is part of a larger trend related to antiscience attitudes and the rejection of scientific facts. Science often becomes politicized when actors motivated to reject it exploit its inherent uncertainty (e.g., Nisbet and Mooney 2007). In addition, the advent of online social media has enabled these actors to easily create and disseminate information (e.g., Kata 2010). Should certain members of the public accept this misinformation, it is difficult to change due to motivated reasoning (Druckman 2017).

How can we effectively correct misinformed vaccine beliefs, particularly if they are so difficult to change? Research indicates that scientists and science communicators are generally more likely to change minds when they *recognize and validate* skeptics' concerns (Kahan 2010), including their political opinions, values, and psychological dispositions. In this paper, we develop and test a novel, psychologically informed communications strategy, to correct misinformation about vaccines. In a large, nationally diverse opt-in survey of American adults, and a smaller replication survey, we first test whether several theoretically important (but understudied) psychological

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dispositions—needle/blood sensitivity (NS), the need for cognitive closure (NCC), and the purity/degradation moral foundation (moral purity [MP])—are associated with individuals endorsing the notion that vaccines cause autism.

We then test the efficacy of a psychologically driven communication strategy by which vaccine misinformation might be corrected. In a novel experiment embedded in our survey, we designed several misinformation correction communication strategies designed to alleviate psychological discomfort for those scoring highly in each of the aforementioned traits. We find that exposure to psychologically tailored science communication decreased misinformation endorsement among respondents high in NS and MP. In other words, by creating messages targeted at precisely the people *most likely to endorse misinformation*, we were able to reduce their misinformed attitudes.

Misinformation and Why It Matters

Many Americans hold beliefs about the MMR vaccine that are at odds with scientific consensus—including the possibility that they can cause children to develop autism (Oliver and Wood 2018). Misinformation prevalence is important, because those that accept it are more likely to oppose vaccination policies, aimed at mitigating the spread of infectious disease (Motta, Callaghan, and Sylvester 2018).

Research on the psychology of misinformation can help explain the prevalence of these attitudes. Individuals are motivated to retain information congruent with their prior beliefs (Kuklinski et al. 2000; Taber and Lodge 2007). Consequently, if misinformed people are confronted with new incongruent (but correct) information, the tendency is to generate counterarguments against this new information or to question the information's validity (Taber and Lodge 2007). Correspondingly, misperceptions can distort policy preferences, public opinion, political debate, and health behavior (Gilens 2001; Nyhan 2010).

Given the normative implications of a misinformed public, it is imperative to devise strategies to correct these beliefs. Some scholars have employed principles from behavioral economics to encourage people to vaccinate (Betsch, Bohm, and Chapman. 2015; Bohm, Betsch, and Korn 2016). However, some of these studies find that providing economic incentives to vaccinate, such as vouchers, are not enough to assuage vaccine skepticism, showing that strong prior attitudes can override decision-making (Buttenheim et al. 2016; Fazio and Olson 2014).

Therefore, correcting misinformation can be difficult, as misinformation is "sticky" once it has been accepted. Corrections inconsistent with prior beliefs are less easily processed because doing so requires people to expend additional cognitive resources in service of reaching accurate beliefs (Kuklinski et al. 2000; Lewandowsky et al. 2012; Taber and Lodge 2007). Simply stating that a misinformed attitude is based on incorrect information sometimes changes attitudes, though some studies find this strategy ineffective, and can even make false beliefs stronger due a backfire effect (Berinsky 2015; Flynn, Nyhan, and Reifler 2017; Kuklinski et al. 2000; Nyhan 2010; Nyhan and Reifler 2015). That said, these backfire effects may be overestimated (Guess and Coppock 2018; Haglin 2017; Wood and Porter 2019). Backfire effects might also be stronger for certain subgroups with strongly held beliefs or less science literacy (Oliver and Wood 2018).

Although it is somewhat unclear when factual correction messages are effective, several studies have identified promising strategies to reduce vaccine misinformation specifically. For example, Nyhan, Reifler, and colleagues experimentally show that vaccine safety information from the Center for Disease Control (CDC) reduced MMR vaccine misinformation and potential flu hazards (Nyhan and Reifler 2015; Nyhan et al. 2014). This was especially true if participants were given treatment articles that convey a threat or danger narrative, thereby appealing to emotional concerns. Other studies have found that emphasizing medical consensus (van der Linden, Clarke, and Maibach 2015) and exposing misleading argumentation (Cook, Lewandowsky, and Ecker 2017) reduce vaccine misinformation.

Although factual corrections have produced some positive but mixed results, we argue that appealing to people at a more personal level may motivate them to expend the cognitive resources necessary to correct misinformed beliefs. Few studies develop tailored vaccine misinformation correction appeals for population subgroups—such as Dixon, Hmielowski, and Ma (2017), who used target value–based appeals to sway climate change skeptics—and none to our knowledge appeal to vaccine skeptics' psychological traits to address misinformation. This strategy has a built-in appeal; we can leverage the very psychological reasons why someone might endorse misinformation to frame vaccines positively.

Three Psychological Correlates of Misinformation about Vaccines

While existing scholarship has identified several political, social, and demographic correlates of endorsing misinformation about the vaccine-autism link (Carpiano and Fitz 2017; Joslyn and Sylvester 2018; Motta, Callaghan, and Sylvester 2018), less work has considered the effects of *abstract* psychological factors (Callaghan et al. 2019). We aim to remedy this notable omission, as previous research suggests that dispositions like MP, NS, and NCC may play an important role in leading people to accept false claims about vaccines.

Needle and Blood Sensitivity

Individuals high in NS are those who report high levels of discomfort and anxiety with needles, blood, and hospitals. Several studies cite NS as the primary reason for immunization noncompliance, while others find that the anticipation of pain or discomfort from receiving injections is the number one reason parents avoid vaccinating children (Gowda et al. 2012; Kennedy, Basket, and Sheedy 2011; Taddio et al. 2012). Misperceptions about vaccine safety, efficacy, and trust are also associated with higher levels of needle and blood sensitivity, both in the population (Hornsey, Harris, and Fielding 2018) and in parental subsamples (Callaghan et al. 2019).

We argue that people high in NS are more likely to endorse vaccine misinformation due to certain cognitive biases. Cognitive dissonance is one of these, where people are uncomfortable with information that is incongruent with previous evaluations (Kunda 1990; Taber and Lodge 2007). Being exposed to information incongruent with these prior expectations leads to cognitive dissonance, which is something people try to avoid. To eliminate cognitive dissonance, people high in NS will adopt misinformation that reconciles the conflict between the feeling that needles are dangerous and/or fear-inducing, and the predominant societal view that vaccines (which are typically administered via needles) are safe and effective. Furthermore, people also experience confirmation bias—they selectively remember information that comports with previous expectations, and for high NS people, this means they could be more likely to remember and integrate information confirming that needles and vaccines are bad. Therefore, people who already are uncomfortable with needles may be more likely to accept vaccine misinformation because it comports with previously held beliefs and supports their fears (i.e., that needles are dangerous or scary).

Moral Purity

Moral Foundations Theory posits that people use five different dimensions to make moral, ethical, and political judgments, and that individuals vary in how much each of these dimensions is relevant in decision-making (Haidt, McCauley, and Rozin 1994). One of these dimensions—purity/sanctity—is shaped by feelings of disgust and driven by an evolutionary mechanism to avoid disease and contamination (Haidt and Graham 2007; Horberg et al. 2009). People high in MP therefore exercise caution around things such as sex, interpersonal contact, certain types of foods, and other perceived violations of the body (Haidt, McCauley, and Rozin 1994). Previous research finds that MP is associated with negative views toward vaccines (Clifford and Wendell 2016; Rossen et al. 2019), as well as vaccine hesitancy (Amin et al. 2017). A related concept, disgust sensitivity, has also been found to predict endorsement of vaccine misinformation (Clay 2017).

Consequently, we expect higher levels of MP to be associated with vaccine misinformation. This link likely occurs because individuals who are high in MP have a predisposition to avoid contamination. Anything that may cause contamination (such as vaccines) would be viewed negatively and should therefore be avoided. As is the case with NS, we expect that any information confirming that vaccines are dangerous or unsafe will be more easily adopted because it comports with prior beliefs and expectations (Kunda 1990; Taber and Lodge 2007). However, despite higher levels of MP being found to consistently correlate with higher skepticism of vaccines, we nevertheless recognize that MP could be manipulated to promote vaccine support, as those high in MP should also be particularly sensitive to behaviors that have been shown to prevent disease if appropriately framed.

Need for Cognitive Closure

Finally, although the link has not been tested previously, belief that vaccines cause autism could be related to the NCC. NCC is the desire for answers to unanswered questions, and an intolerance toward ambiguity and confusion (Webster and Kruglanski 1994). For those high in NCC, any answer is preferable to no answer. For phenomena that have a large degree of uncertainty involved, those higher in NCC will want to latch onto an explanation and strive to uphold this explanation, even if the veracity of that explanation has yet to be proven or has been questioned.

For example, people high in NCC may be more likely to endorse conspiracy theories and other forms of misinformation (Marchlewska, Cichocka, and Kossowska 2018). Because vaccine safety has been linked to mistrust in medical institutions and the pharmaceutical industry (Freed et al. 2010), this uncertainty creates conditions ripe for misinformation adoption. Moreover, the exact causes of autism are uncertain (Ratajczak 2011), so vaccines as the cause of autism presents a seemingly simple answer to a complex question. Therefore, high NCC individuals may be more likely to endorse antivaccine misinformation because both vaccine safety and the causes of autism are uncertain. Consequently, we think that people high in NCC may be more likely to adopt vaccine misinformation, as it provides clear and definite—if incorrect—answers.

Although we think it is more likely that individuals high in NCC will accept misinformation, they could also be more likely to *resist* new sources of information, including misinformation, and steadfastly assume the medical community already knows the causes of autism. Individuals under NCC-inducing conditions have been found to be less persuadable (Kruglanski, Webster, and Klem 1993). This would result in high NCC people being less likely to adopt attitudes and beliefs driven by misinformation if they have already adopted the explanation rooted in fact. In any case, we treat the effects of NCC and belief in the vaccine-autism link as an open question.

Expectations

Our discussion suggests a potential link between higher individual scores on NS and/or MP and the endorsement of vaccine misinformation. We therefore posit that these psychological predispositions correlate with individuals who are skeptical of vaccines, and who link vaccines to autism:

> **Hypothesis 1a:** Individuals high in MP will be more likely to endorse vaccine misinformation.
> **Hypothesis 1b:** Individuals high in NS will be more likely to endorse vaccine misinformation.

We propose two directional hypotheses based on findings in the existing literature that, in the U.S. population, high MP and high NS individuals are more likely to endorse vaccine misinformation, compared with those low in these traits. Although we believe MP and NS could potentially correlate with provaccine information, antivaccine misinformation in broader societal context has more successfully appealed to these groups. However, we believe this can be reversed if such individuals are presented with provaccine information that appeals to their underlying motivations.

In addition, while there is some evidence to suggest that vaccine misinformation endorsement should positively correlate with NCC, the relationship is somewhat unclear. For this reason, we propose the following research question:

> **Research Question (RQ1):** Are individuals high in NCC more or less likely to endorse vaccine misinformation?

After testing for the influence of these psychological predispositions on vaccine misinformation, we then aim to capitalize on their potential ability in vaccine beliefs to correct misinformed attitudes. As outlined above, we suspect that it may be possible to reduce misinformation about childhood vaccines by designing communication strategies that *exploit* the very psychological mechanisms that make people likely to believe vaccine misinformation.

If individuals high in certain psychological traits endorse vaccine misperceptions, then we have reason to believe that these individuals are receptive to messages that *recognize and validate* these concerns. Targeting messages for key audiences is certainly not a new concept; in health communication and beyond, a message is more likely to be accepted if it speaks to an individual's circumstances, life experience, or predisposition (Kreuter and Wray 2003). Similarly, recent work has successfully corrected misinformed climate change beliefs in conservatives by making targeted value-based appeals (Dixon, Hmielowski, and Ma 2017). By extension then, targeting on relevant psychological traits should provide an additional and effective avenue to appeal to those with vaccine-related misperceptions.

In this study, our goal is to present corrective information in a way that is likely to activate the same psychological dispositions that make people more likely to endorse misinformation. For example, by presenting the side effects of *not* inoculating children against MMR (a measles outbreak) as "disgusting" or "impure" through a description of the disease's side effects, we hypothesize that we can convince those who highly value MP to recognize the dangers of antivaccination opinion, and to potentially accept vaccine safety. Similarly, since people high in NS are more likely to endorse vaccine misinformation because they are more apt to accept information justifying what they already feel (that needles are bad), information on the safety and efficacy of nonintravenous inoculation should help assuage this underlying concern.

Finally, due to the uncertain relationship between NCC and the vaccine-autism link endorsement, we decided to cast a wider net on NCC-specific treatments. Specifically, we created two different treatments covering potential underlying uncertainty relating to vaccines. One addresses uncertainty about the causes of autism and the other addresses uncertainty surrounding the safety of vaccines. Assuming higher NCC individuals are more likely to endorse vaccine misinformation, we predict those high in NCC who receive either a list detailing the known contributing factors to autism or a treatment assuring them that vaccines are safe will have lower endorsement of vaccine misinformation.

With this general framework in mind, we propose the following hypotheses:

> **Hypothesis 2:** Individuals high in MP who are given a disgust-inducing article about the dangers of not vaccinating children will decrease their endorsement of vaccine misinformation.

Hypothesis 3: Individuals high in NS who are given an article describing safe and effective needleless immunization methods will decrease their endorsement of vaccine misinformation.

Hypothesis 4: Individuals high in NCC who are given information on the contributing factors to autism, or who are given information saying that vaccines do not cause autism, will decrease their endorsement of vaccine misinformation.

Analytical Strategy

In order to test these expectations, our analyses are structured in two parts. First, we investigate the *psychological origins* of misinformation about vaccines (Hypothesis 1 and RQ1). To do this, we use survey data to model the extent to which survey respondents believe that the vaccines can cause autism as a function of MP, NS, and the NCC. We also control for a wide range of other known correlates of misinformation acceptance, including respondents' sex (Freed et al. 2010), race (Armstrong et al. 2001; Freed et al. 2010), levels of educational attainment (Feiring et al. 2015; Prislin et al. 1998), and partisan identification (Joslyn and Sylvester 2018; Rabinowitz et al. 2016).

Second, we assess the effectiveness of efforts to *correct misinformation* about vaccines (Hypotheses 2–4). To test this, we designed a survey experiment that randomly exposed survey respondents to one of several treatments aimed at correcting misinformation for those scoring highly on each potential psychological correlate. We construct models nearly identical to those used to assess the psychological origins of misinformation. This time, however, we *interact* respondents' experimental condition assignment with their scores on MP, NS, and NCC. This enables us to assess whether the effect of being exposed to each condition—relative to all other conditions and the control—corrects misinformation most strongly for those scoring higher in each trait.

Methods

Data and Procedure

To test these expectations, we fielded a large and demographically diverse survey of U.S. adults ($N = 7{,}019$) in mid-September 2018. Lucid's Fulcrum Academic service invited 9,700 members of its large online opt-in panel to participate in the study, 72 percent of whom ultimately completed the survey. Although the data are not nationally representative, Lucid targeted representativeness on several known demographic benchmarks—including race, age, sex, household income, and Census region. These comparisons can be found in the Supplemental Materials. Recent work shows that demographic and experimental findings on Lucid are similar to U.S. national benchmarks and better representative than traditional convenience samples on several demographic, political, and psychological factors (Coppock and McClellan 2019).

To further account for potential deviations from representativeness, we weighted the data to population benchmarks on race, age, sex, income, and educational attainment. Technical information about how we constructed these weights can be found in the Supplemental Materials. To ensure that any effects we observe are not a consequence of decisions made in constructing the weights, we run all analyses both with and without weights. As these data are not nationally representative, we do not claim that any specific point estimate in our analysis reflects that of the general population. However, since we are examining differences in attitudinal change between article conditions that have been randomly assigned, sample composition should not bias the results (Mutz 2011).

Survey respondents first answered several questions about their attitudes toward a wide range of social, health, and political issues, followed by assessments of their levels of NS, MP, and NCC. After doing that, respondents were randomly assigned to read one of four fictional newspaper articles. The treatments were conceptually informed by Nyhan et al.'s (2014) experimental manipulations designed to influence parents' intent to vaccinate. All articles were attributed to the same source (*The Wall Street Journal*),[1] the same author, and were designed to correct misinformation. These four article conditions are based loosely on existing news stories and the stories all contained factual information. A fifth group was assigned to read a control article about an unrelated subject. The treatment conditions are summarized in Table 1.

We designed two treatments aimed at reaching people high in NCC, recognizing that "closure" in this domain could pertain to *either* information about vaccine effectiveness or information about the origins of autism. Individuals receiving the "vaccines are safe" condition received an article simply correcting misinformation relating to vaccines, stating that vaccines do not cause autism and are generally safe. This condition targeted high NCC individuals, who may take cognitive comfort in receiving scientifically backed answers about the origins of autism. We designed a second treatment to reach individuals high in NCC; which we call "roots of autism" condition. This condition targets high NCC individuals by listing the known contributing factors to autism and highlights how these factors are present before a child is born.

Next, the "measles" condition targets those high in MP by describing a young girl's symptoms of the measles in depth, to trigger thoughts of impurity and uncleanliness.

Table 1. Summary of Experimental Conditions.

Condition	Article title	Key quotation	Targeted trait
1 ("control")	Language development in babies	N/A	None (control condition)
2 ("vaccines are safe")	Yes, vaccines are safe	"The vast majority of scientists, doctors, and vaccine experts agree that vaccines are safe and effective, . . . and that they do not cause autism."	Need for cognitive closure
3 ("roots of autism")	The roots of autism are less mysterious than you think	"However, many researchers do have a good idea of the contributing factors of Autism Spectrum Disorder (ASD)."	Need for cognitive closure
4 ("measles")	Measles infections are real, and they are serious	". . . Jenna examined Sofia's throat and noticed that sickly bluish-white bumps had infiltrated the one-year-old's cheeks."	Moral purity
5 ("no needles")	No needles? No problem	"Medical researchers in recent years have been developing new ways to protect us against dangerous and deadly diseases without the use of needles."	Needle sensitivity

In other words, it aims to combat the violation of MP associated with vaccination by presenting the effects of nonvaccination as being even more in violation of MP. The "no needles" condition targets high NS individuals by highlighting safe methods of vaccination without the use of needles, such as through pills, sprays, and patches. The control condition is an unrelated article about language development in babies. These conditions are listed in full in the Supplemental Materials.

While being shown the treatment article, subjects could not skip to the next screen of the survey until twenty seconds had passed to encourage participants to read the treatment articles.[2] Once respondents finished reading the assigned article, they completed a comprehension check question asking them to identify correct information about the article they read (Kane and Barabas 2018). The respondents then answered a series of questions about their attitudes toward the safety and efficacy of vaccines, as well as support for vaccine-related public policy (e.g., required vaccination for children in public schools).

Two additional procedural elements of our design are worth noting. First, in all analyses, we interact the experimental condition and the relevant psychological trait with an indicator of whether or not respondents passed the basic factual recall question about the subject of the article they just read (a full list of these questions is available in the Supplemental Materials). Assessing our results conditional on treatment comprehension has the major benefit of ensuring that our analyses are comparing the effectiveness of the treatments among respondents who actually *received* them (i.e., by reading and comprehending the articles; Kane and Barabas 2018).

Although this analytical move limits the conclusions, we can draw here to the 66 percent of our sample who passed the comprehension check; these individuals do not appear to differ systematically from those who likely engaged with the task less seriously on any of the psychological traits studied here, or the condition to which they were assigned, although they were somewhat more likely to endorse antivaccine misinformation. These subgroup comparisons can be found in the Supplemental Materials.

Moreover, while estimating treatment effects for about two-thirds of our sample is far from ideal, we nevertheless collected enough data to have sufficient power to detect small effects. Moreover, the levels of disengagement we observe with our treatments are not uncommon in online opt-in panel surveys (e.g., see Paas and Morren 2018).

Still, we recognize that this move poses an important methodological tradeoff. Because the comprehension check item was administered posttreatment, estimating treatment effects conditional on passing the check violates the principle of random assignment and may lead to an inaccurate estimation of treatment effects (Montgomery, Nyhan, and Torres 2018). Consequently, to proxy engagement with the treatments using a less theoretically problematic approach, we reestimate all analyses presented in the main text using a survey-level measure of satisficing (Krosnick 1991), a binary indicator of whether or not respondents completed the survey in less than one half of the study's anticipated completion time (available in the Supplemental Materials). Approximately 9 percent of our sample was scored as satisficers, on this measure.

This indicator provides a general sense of who, in our sample, did not seriously engage with the survey, but we caution that this approach cannot *entirely* eliminate the threat of posttreatment bias. Technically, survey-level metadata is captured both pre- and posttreatment.

"Failure" could therefore be the result of pretreatment, posttreatment, or both pre- *and* posttreatment timing behavior. Nevertheless, because the experimental task was brief, and because we standardized the minimum amount of time respondents had to engage with it, we suspect that respondents scored as satisficers on this measure are very likely to engage less seriously with other tasks in the survey as well (i.e., it is highly unlikely that the experimental task *alone* influences being scored as a satisficer). Although this approach could add random noise to our treatment estimates, by estimating treatment effects among those not receiving the treatment, we find (as we note later on) that our central findings are generally robust to this alternative specification.

Finally, the other design element worth noting is that our vaccine misinformation dependent variable is measured *following* assignment to each of the treatments summarized in Table 1. This means that our measurement of the dependent variable in this analysis might be influenced by engagement with the treatments. Consequently, we control for assignment to each condition when running analyses aimed at exploring the psychological correlates of misinformation. For robustness, we replicate all analyses pertaining to the psychological correlates of vaccine misinformation using *only* the control group. These analyses can be found in the Supplemental Materials.

Measures

To measure vaccine misinformation endorsement, we asked respondents, "Can vaccines administered to children at young ages cause them to become autistic?" The question had four possible response options: "they definitely cannot," "they probably cannot," "they probably can," and "they definitely can." These responses were coded so that higher values indicate greater misinformation endorsement and standardized onto a 0–1 scale. We chose a single item indicator because the treatments we created were specific to this piece of misinformation, which has been one of the most prominent pieces of misinformation not only related to vaccines but also related to health and science misinformation more broadly (Lewandowsky et al. 2012).

To measure NS, we combine five items in our survey taken from the blood-injury-injection phobia diagnostic scale (American Psychiatric Association [APA] 2013), which have been used to measure general discomfort toward blood and needles. The factor loading coefficients of the original twenty-two questions on the APA questionnaire are very high, with most over .80 (Wani, Ara, and Bhat 2014). The response option for each question is a seven-point Likert-type scale of agreement, with higher responses indicating greater NS. Statements included items such as "I feel uncomfortable with needles or sharp objects" or "the larger the needle, the more upset I feel." The five items used in our survey were chosen based on factor loadings and have a Cronbach's alpha of .795. The five items were combined into a single indicator standardized to go from 0 to 1.

We measure MP using the four relevant questions on the twenty-item Moral Foundations (MQ20) purity/sanctity subscale developed by Graham, Haidt, and Nosek (2009). Two of these questions have a six-point Likert scale of relevance to the respondent's thinking as the response option, while the other two have a six-point Likert-type scale of agreement as the response option. Higher numbers on the scale indicate greater MP levels, and we then recoded the combined scale to run from 0 to 1.

Finally, we base our measure of NCC on Roets and Van Hiel (2011), who developed a fifteen-point short form version of the scale. From the short form, we used the six items with a factor loading of .7 or higher. The response option for each question is a zero to five-point Likert-type scale of agreement, with higher numbers on the scale indicating higher individual-level scores of NCC. We then coded the combined scale from 0 to 1.

Results

Psychological Antecedents of Vaccine Misinformation

We begin our analysis by considering the psychological correlates of misinformation about the vaccine. Table 2 presents the results of an ordinal logistic regression model that regresses the four-point vaccine misinformation item on the three psychological factors discussed earlier (MP, NS, and NCC) in addition to key control measures. Because these items were administered posttreatment, we also include experimental condition assignment indicators as control variables and reestimate effects for *just* the control group in the Supplemental Materials.

Table 2 demonstrates that the psychological predispositions significantly predict levels of vaccine misinformation endorsement. Consistent with Hypotheses 1a and 1b, MP ($B = 1.24$, $p < .05$) and NS ($B = 1.88$, $p < .05$) are positively and significantly associated with an increased likelihood of endorsing vaccine misinformation. These findings suggest that individuals with high levels of NS and MP are more likely to endorse the belief that vaccines cause autism. Regarding our NCC research question, we find that NCC is associated with a *decreased* likelihood of endorsing vaccine misinformation ($B = -0.70$, $p < .05$).

The effects of MP and NS are also substantively large. When we convert the ordered logit coefficients in Table 2 into predicted probabilities, we find that moving from the minimum to maximum value of MP is associated with a 9 percent increase in the likelihood of indicating that

Table 2. Baseline Predictors of Antivaccine Misinformation Endorsement for the Original Experiment, Including Treatment Controls.

	Baseline
Needle sensitivity	**1.88** (0.14)**
Need for closure	**−0.70** (0.22)**
Purity	**1.24** (0.17)**
Party ID (Republican = 1)	**0.13** (0.12)**
Sex: female	**0.51** (0.06)**
Black	**0.88** (0.09)**
Hispanic	**0.62** (0.10)**
Education	**−0.01* (0.02)**
T: vax works	**−0.34** (0.09)**
T: measles	−0.09 (0.09)
T: roots	−0.08 (0.09)
T: no needle	0.04 (0.09)
τ_1	**0.81** (0.18)**
τ_2	**2.65** (0.19)**
τ_3	**4.38** (0.19)**
N	6,517

Ordered logistic regression coefficients presented; standard errors in parentheses. Table contains all baseline effects of NS, NCC, and purity, adjusting for experiment assignment. Baseline models restricting analysis to the control group only are available in the Supplemental Materials. For ease of interpretation, statistically significant effects are bolded.
*$p < .10$. **$p < .05$; two-tailed.

vaccines "definitely can" cause autism—those lowest in MP had a predicted probability of .05, while those highest in MP had a predicted probability of .11. For NS, that same shift is associated with a 17 percent increase.[3]

Overall, the controls in Table 2 also align well with conventional wisdom about the correlates of misinformation endorsement. As found in prior work, women, Republicans, black, and Hispanic respondents were all significantly more likely to endorse misinformation about vaccines. All results presented hold when analyses are limited to control group respondents only, though NCC becomes statistically insignificant (see Supplemental Materials).

The results suggest that individuals higher in MP and NS (but not NCC) are more likely to endorse vaccine misinformation. But, can communication efforts be designed that *reduce* misinformation for these groups, and ultimately improve support for provaccine policies among those predisposed toward vaccine misinformation? We take up this question in the following analyses.

Reducing Vaccine Misinformation

The key test of Hypotheses 2–4 is whether the corrective benefits of each intervention appeal most strongly to the psychologically informed groups they were designed to influence. To test this, we interact condition assignment with each psychological correlate of vaccine misinformation and our comprehension check. To avoid introducing excessive collinearity into the models, we present three sets of models (Table 3): column 1 interacts condition assignment with MP, column 2 does this for NS, and column 3 does the same for NCC.

Hypothesis 2 predicted that the "measles" condition would be especially effective for those highest in MP. The results support our expectations, as the interaction between "measles" condition assignment and MP was negative ($B = -3.30$) and statistically significant ($p < .05$). To better interpret these results, we plot the predicted probability of thinking that childhood vaccines "definitely can" cause autism across levels of MP, for those assigned to the "measles" versus the control conditions. The targeted treatment "cancels out" the effect of MP on strongly endorsing vaccine misinformation (the rightmost panel in Figure 1). In the control condition, MP is associated with a large (and, again, virtually exponential) increase in the likelihood of misinformation endorsement from around 5 percent for the lowest MP levels to just shy of 20 percent for the highest MP levels. However, when assigned to read the "measles" condition, the effect of MP on misinformation endorsement is considerably more modest (i.e., it only increases slightly, and monotonically).

If Hypothesis 3 is correct, we should again expect to see a negative and statistically significant interaction between the "no needles" condition and NS, for those who passed the comprehension check. This would indicate that individuals higher in NS exposed to the treatment article held comparatively and significantly lower levels of misinformation than those in the control group. Indeed, we find evidence that this psychologically tailored message decreased misinformation most strongly for those high in NS relative to the control ($B = -2.46$, $p < .05$).

The left-most panel in Figure 1 offers a more tractable interpretation of these effects by plotting the predicted probability that respondents think that childhood vaccines "definitely can" cause autism across levels of NS. Note that these probabilities (bars) are expressed as 95 percent confidence intervals across the control (in green) and "no needles" treatment (in blue) conditions. In the control condition, misinformation endorsement increases dramatically (almost *exponentially*) at high levels of NS. However, for those in the "no needles" condition, the effect of NS on misinformation endorsement is subdued, increasing only modestly (and monotonically) as NS increases. For example, in the control condition those lowest in NS have around a 5 percent probability of endorsing the antivaccine misinformation, and this probability jumps to around 20 percent those highest in NS.

Table 3. Targeted Treatment Effects of NS, NCC, and MP on Antivaccine Misinformation Endorsement for the Original Experiment, Including Interactions with Comprehension Check Pass.

	MP	NS	NCC
Needle sensitivity	**1.69****	**1.50****	**1.68****
	(0.14)	**(0.51)**	**(0.14)**
Need for closure	**−0.69****	**−0.71****	−01.32
	(0.22)	**(0.22)**	(0.93)
Purity	0.09	**1.28****	**1.29****
	(0.65)	**(0.17)**	**(0.17)**
Party ID (Republican = 1)	**0.13****	**0.13****	**0.13****
	(0.01)	**(0.01)**	**(0.01)**
Sex: female	**0.46****	**0.46****	**0.46****
	(0.06)	**(0.06)**	**(0.06)**
Black	**0.80****	**0.810****	**0.80****
	(0.09)	**(0.09)**	**(0.09)**
Hispanic	**0.55****	**0.54****	**0.56****
	(0.10)	**(0.10)**	**(0.10)**
Education	−0.00	−0.01	−0.00
	(0.02)	(0.02)	(0.02)
T: vax works	0.25	**0.87****	0.15
	(0.57)	**(0.44)**	(0.76)
T: measles	−0.47	−0.18	−0.20
	(0.64)	(0.45)	(0.82)
T: roots	−0.05	−0.45	1.22
	(0.82)	(0.07)	(1.04)
T: no needle	0.57	−0.07	0.67
	(0.09)	(0.41)	(0.74)
Works × Needles	—	−0.16	—
		(0.75)	
Measles × Needles	—	**1.51***	—
		(0.84)	
Roots × Needles	—	**2.18****	—
		(0.93)	
No needles × Needles	—	**1.50****	—
		(0.75)	
Works × NCC	—	—	1.01
			(1.24)
Measles × NCC	—	—	1.33
			(1.32)
Roots × NCC	—	—	−0.81
			(1.63)
No needles × NCC	—	—	0.08
			(1.21)
Works × MP	0.81	—	—
	(0.90)		
Measles × MP	**1.70****	—	—
	(0.96)		
Roots × MP	1.15	—	—
	(1.20)		
No needles × MP	0.78	—	—
	(0.90)		
Comprehension check	**−1.41****	0.04	−0.57
	(0.50)	(0.34)	(0.68)
NS × Pass check	—	0.30	—
		(0.65)	
NCC × Pass check	—	—	1.24
			(1.11)
MP × Pass check	**2.50****	—	—
	(0.78)		
Works × Pass check	−0.05	−1.63**	−0.77
	(0.68)	(0.51)	(0.92)
Measles × Pass check	1.08	0.13	0.50
	(0.76)	(0.52)	(0.97)
Roots × Pass check	0.77	0.21	−1.05
	(0.90)	(0.55)	(1.15)
No needles × Pass check	0.11	0.11	−0.63
	(0.72)	(0.49)	(0.91)
Works × NS × Pass check	—	0.22	—
		(0.93)	
Measles × NS × Pass check	—	**−2.31****	—
		(0.99)	
Roots × NS × Pass check	—	**−2.33****	—
		(1.07)	
No needles × NS × Pass check	—	**−2.46****	—
		(0.94)	
Works × NCC × Pass check	—	—	−1.19
			(1.48)
Measles × NCC × Pass check	—	—	−2.49
			(1.55)
Roots × NCC × Pass check	—	—	0.03
			(1.81)
No needles × NCC × Pass check	—	—	−0.76
			(1.49)
Works × MP × Pass check	**−2.25****	—	—
	(1.07)		
Measles × MP × Pass check	**−3.30****	—	—
	(1.14)		
Roots × MP × Pass check	**−2.75****	—	—
	(1.33)		
No needles × MP × Pass check	**−1.89****	—	—
	(1.11)		
τ_1	0.04	**0.67****	0.43
	(0.43)	**(0.32)**	(0.56)
τ_2	**1.95****	**2.57****	**2.33****
	(0.43)	**(0.32)**	**(0.56)**
τ_3	**3.73****	**4.38****	**4.11****
	(0.44)	**(0.33)**	**(0.56)**
N	6,517	6,517	6,517

Ordered logistic regression coefficients presented; standard errors in parentheses. For ease of interpretation, treatments hypothesized to be effective for subgroups high in these factors are bolded, as well as statistically significant effects. NS = needle sensitivity; NCC = need for cognitive closure; MP = moral purity.
$^*p < .10$. $^{**}p < .05$; two-tailed.

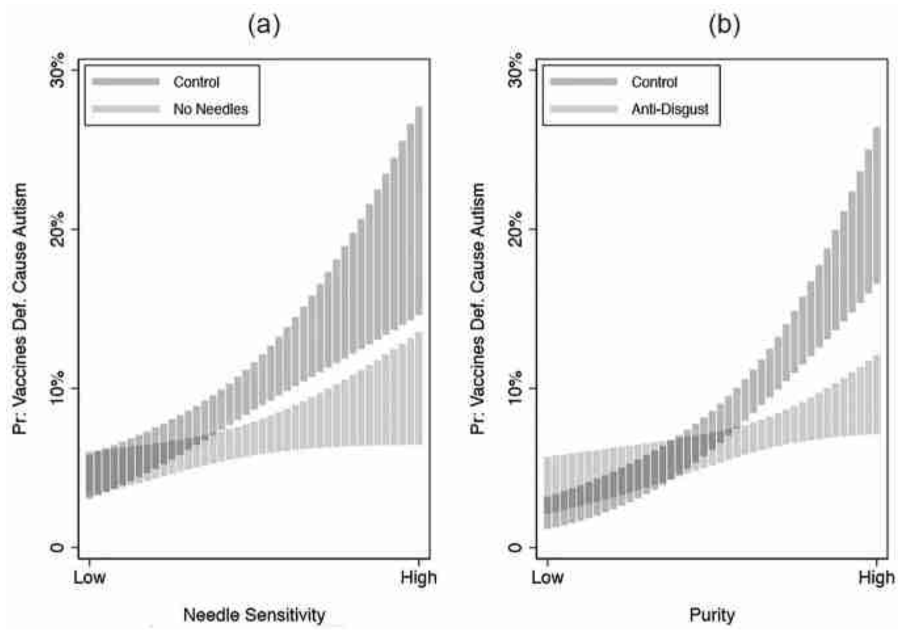

Figure 1. The predicted effects of NS (a) and MP (b) on the probability of strongly endorsing antivaccine misinformation in the original study.
Predicted probabilities are presented as 95% confidence intervals (see Kahan et al. 2017) across the control (darker gray) and targeted treatment (lighter gray) conditions. MP = moral purity; NS = needle sensitivity.

However, in the tailored treatment condition, individuals have around a 5 percent probability of endorsing vaccine misinformation, regardless of their level of NS. The treatment therefore appears to have diminished the effect of NS on vaccine misinformation endorsement.

Unsurprisingly, given the effects of NCC we observed earlier, we find no evidence in support of Hypothesis 4 (column 3). Recall that two conditions ("vaccines are safe" and "roots of autism") were thought to potentially be effective at reducing misinformation among high NCC individuals. Unsurprisingly, because NCC is negatively associated with vaccine misinformation endorsement, neither the "roots of autism" treatment nor the "vaccines are safe" treatment produced significant interactions.

Finally, for the reasons noted earlier (see section "Methods"), we reestimated all interactive effects swapping the posttreatment comprehension check for a survey-level measure of satisficing. As anticipated—that is, because we may be attempting to estimate treatment effects for those not actually treated—this move inflates the size of the standard errors for the interactive coefficients. Despite this imprecision, we recover correctly signed effects for both high NS respondents shown the "no needles" treatment ($B = -3.62$) and high MP respondents shown the "measles" treatment ($B = -0.18$). The former, but not the latter, approached two-tailed levels of significance at the $p < .10$ level. More detailed results can be found in the Supplemental Materials.

Consequently, we caution that the treatment effects observed here may be sensitive to how we operationalize engagement with the experimental protocol. To further probe the replicability of our most robust finding from the above analysis, we readministered the NS treatment to high NS respondents in a second study.

Replication

Data and Procedure

To assess the generalizability our results, we conducted a replication study using a survey of 825 U.S. adults fielded in August 2019. The survey was again conducted using Lucid's Fulcrum Academic service (note that there were no duplicate respondents between our two surveys). The survey demographics again resemble nationally representative benchmarks based on U.S. Census targets (see Supplemental Materials). Our procedure and measures were identical across studies.

However, given timing and space constraints, we only had the opportunity to replicate *one* of the experimental conditions listed in Table 1 (vs. the control). We decided to replicate the NS condition not only to probe the robustness of the strong effects observed in Tables 2 and 3, but because NS has received less attention than MP in the political science literature

Table 4. Treatment Effects of NS on Antivaccine Misinformation Endorsement for the Replication.

	Baseline	NS
Needle sensitivity	**1.91****	**2.92****
	(0.32)	**(0.96)**
Party ID (Republican = 1)	**0.76****	**0.81****
	(0.20)	**(0.20)**
Sex: male	**−0.50****	**−0.38****
	(0.15)	**(0.16)**
Black	**0.67****	**0.55***
	(0.23)	**(0.23)**
Hispanic	**0.59****	**0.43****
	(0.20)	**(0.21)**
Education	−0.30	−0.41
	(0.37)	(0.37)
T: No needles	**−0.61****	**1.72***
	(0.15)	**(0.97)**
No needles × NS	—	**−4.47****
		(1.64)
Pass check	—	−0.82
		(0.57)
NS × Pass check	—	−0.69
		(1.10)
No needles × NS × Pass check	—	**3.54****
τ_1	0.30	0.14
	(0.39)	(0.59)
τ_2	**1.86****	**1.77****
	(0.39)	**(0.58)**
τ_3	**3.52****	**3.53****
	(0.41)	**(0.61)**
N	790	790

Ordered logistic regression coefficients presented; standard errors in parentheses. NS = needle sensitivity. For ease of interpretation, statistically significant effects are bolded.
*$p < .10$. **$p < .05$; two-tailed.

Again, we interact an indicator of whether or not respondents passed the basic factual recall question in a similar way to the original experiment results above. However, the results were fairly similar when analyzed with and without the failed comprehension check respondents. We present the results without the failed comprehension check respondents in the following section, and the results for all respondents are included in the Supplemental Materials.

Results

Table 4 displays the results of the ordered logistic regression models predicting vaccine misinformation endorsement. The model includes NS, the experimental treatment condition, and the interaction between the two; as well as the same control variables from the models in the original experiment.

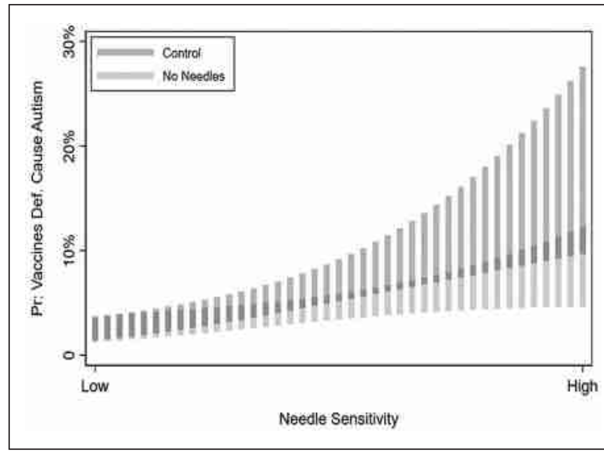

Figure 2. The predicted effects of NS on the probability of strongly endorsing antivaccine misinformation in the replication study.
Predicted probabilities are presented as 95% confidence intervals (see Kahan et al. 2017) across the control (darker gray) and targeted treatment (lighter gray) conditions. This displays results for only those who pass the comprehension check, though similar results occur for the entire sample. Two-way interaction between NS and "no needles" and three-way interaction between NS, "no needles," and comprehension check are both significant at $p < .05$. NS = needle sensitivity.

Consistent with Hypothesis 1b, NS is once again associated with higher levels of vaccine misinformation endorsement. Critically, the interaction between NS and the treatment condition yielded a statistically significant and negative interaction, which supports Hypothesis 3. This three-way interaction is statistically significant both with and without respondents who passed the comprehension check. Like in the original experiment, we find evidence that this psychologically tailored message decreased misinformation for those high in NS relative to the control (Figure 2); high-NS respondents in the control group were more likely to endorse misinformation about vaccines, while those in the treatment group were much less likely to do so. This is true with and without survey weights, with and without the satisficing measure, and when the outcome measure is converted into a binary measure and analyzed using a logit model (see Supplemental Materials for more information).

Discussion

This study provides new insight into how we can reduce vaccine misinformation. As expected, our research shows that people who are high in NS and MP are more susceptible to accepting the idea that vaccines cause autism, but that this tendency is diminished when exposed to targeted appeals. It is also unsurprising that NS's effect sizes are higher than those for MP; the former more directly relates to vaccination—vaccines are typically administered using needles—while the latter is less directly related to vaccines and is a more general contamination-related trait. We also find evidence that those highest in NCC are less likely to endorse vaccine misinformation, and that subsequent attempts to correct misinformation were not necessary. As previously discussed, it could be that individuals high in NCC accepted the safety of vaccines before misinformation became more visible in recent years.

More importantly, our findings emphasize that a "one-size-fits-all" may not be the most effective means of reducing vaccine misinformation, or misinformation more broadly. Our work suggests that a psychologically driven, audience-focused approach to science communication is especially good at reducing misinformation acceptance among those who are *most likely* to accept it. This is something more generalized communication efforts have struggled to do in previous research. Future research could not only create messaging that targets other psychological factors correlated with antivaccine attitudes—such as conspiratorial thinking, individualistic worldview, and reactance, among others (Callaghan et al. 2019; Hornsey, Harris, and Fielding 2018)—but also broaden this approach from vaccine misinformation correction to other types of policy-relevant misinformation corrections.

How communicators might then attempt to *present* these messages to misinformed individuals, however, introduces an additional set of challenges that researchers must consider in future work. Psychographic microtargeting—that is, efforts to reach subpopulations with messages tailored to appeal to opinions and psychological dispositions they might hold (Resnick 2018; see also Hall Jamieson 2013)—could provide a potential answer to this challenge.

To do this, communicators must first identify who in the American public falls into their subpopulation or "audience" of interest. While self-reports from public opinion surveys could help identify audiences directly, it is impractical to administer surveys like ours to all U.S. adults. Instead, communicators can *predict* the likelihood that adults fall into their audience based on more easily observable factors; for example, by figuring out whether vaccine skeptics who hold certain psychological traits tend to hold certain demographic traits, or the different types of products they buy (see Franz 2013 for a review). Communicators can then air their messages on channels (e.g., social media outlets like Facebook) that enable them to filter who sees their messages based on publicly available (or otherwise properly obtained) demographics, consumption patterns, and other potential correlates of their audience.

It is critical to note that psychographic microtargeting has received substantial backlash in recent years in part due to Cambridge Analytica's improper acquisition of personal information from nearly one hundred million Facebook users (Prokop 2018). In addition, microtargeting may prove ineffective if adults become aware that they are being microtargeted, or if they are *mis*-targeted (Hersh and Schaffner 2013). Although we think that microtargeting has the potential to be effective at decreasing misinformation, we urge researchers to consider not just the mechanics of how this procedure might work, but the ethics of and potential public resistance to these messages.

As important as this research is to our understanding of vaccine misinformation and efforts to correct it, there are several limitations to this study that are important to note. First, our research is unable to account for individuals' prior exposure to vaccine information, misinformation, and attempts to correct it. Individuals may be more or less susceptible to our frames based on their prior experiences. Future studies should consider running similar treatments in longitudinal studies, which can track respondents' exposure to and acceptance of antivaccine information prior to being administered interventions like ours.

In addition, our study only uses data from a sample of U.S. respondents, despite the prevalence of vaccine misinformation and antivaccine movements outside the United States. The endorsement of the belief that vaccines cause autism is also high in other countries not studied here and prominent antivax movements exist in other countries (Hornsey, Harris, and Fielding 2018; Jolley and Douglas 2014). We leave it to future research to test our misinformation correction strategy outside the U.S. context.

Finally, our research is limited in its focus on a single item indicator of vaccine misinformation as our outcome measure. While reducing misinformation about vaccines causing autism is certainly at the heart of developing effective vaccination messages, future research should see whether our messaging strategy is effective not only at reducing other dimensions of vaccine misinformation but also in altering vaccination behavior. This would provide a broader understanding of when targeting psychological factors is most effective.

Even with these limitations, our research provides a significant contribution to correcting vaccine misinformation and suggests a future avenue for combating the politicization of science more broadly. We emphasize the importance of psychological predispositions to believing that vaccines cause autism and highlight the added benefit of targeting these psychological predispositions in efforts to correct this misperception.

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Data Availability Policy

Any data on which the article's conclusions are based are available upon request by the corresponding author, Kristin Lunz Trujillo (lunzx007@umn.edu).

Notes

1. The authors chose *The Wall Street Journal* for treatments because it was found to be Americans' most trusted news source out of thirty-eight news organizations in a 2018 survey by MRI-Simmons (Millman 2018). In addition, this source has not been linked with misinformation or a specific pro versus anti-vaccine "side" since the source normally deals with economic issues. Although the source leans conservative, it is still mostly center and maintains high journalistic standards.
2. We note that, since we forced subjects to stay on the treatment screen for at least twenty seconds, we may be over-estimating the size of our treatment effects. Although this is no guarantee of compliance, we address the possibility of effect size over-estimation when discussing the limitations of our methodological approach below.
3. Although Tables 2 and 3, and Figure 1 predict the probably of the respondent saying that vaccines definitely cause autism, in the Supplemental Materials we collapse our outcome measure into a binary one and get similar results.

Supplemental Material

Supplemental material for this article is available with the manuscript on the *Political Research Quarterly* (PRQ) website.

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