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Using a mental model approach to undercut the effects of exposure to mRNA vaccination misconceptions: Two randomized trials

Kathleen Hall Jamieson[a,b,1], Laura A. Gibson[a], Patrick E. Jamieson[a], and Shawn Patterson Jr.[a]

Affiliations are included on p. 10.

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Although messenger RNA (mRNA) technology revolutionized vaccine creation, its use is threatened by unwarranted fear that DNA left over from the vaccine manufacturing process could integrate into recipients' DNA, increasing cancer and heritable risks. Drawing on the mental model theory of reasoning, our two preregistered interventions undercut these problematic conclusions. They do so by testing the effectiveness of two mental model-based interventions juxtaposing problematic claims with visualized or verbally explained models of basic biological and vaccination systems. Study 1: a) graphically modeled how mRNA COVID-19 vaccination works (Model 1); b) verbally modeled ways in which cells protect themselves from foreign DNA (Model 2); and c) provided ancillary material designed to bolster perceptions of mRNA vaccination safety. Study 2 deployed an animation of the cell-protection model (Model 2), alone, and in combination with Study 1's messaging. Neither the mRNA vaccine nor the DNA protection model explicitly acknowledged the problematic DNA-integration claim. Both preemptive (before) and rebuttal (after) positioning of the models were effective. Within-person analyses suggested that preemptive positioning may be somewhat more effective than rebuttal positioning. Some positive effects of exposure to the modeled knowledge messaging condition in Study 1 persisted 2 mo after exposure.

debunking | mRNA misinformation and misconceptions | mental models | bypassing | foreclosing

Significance

Misconceptions can continue to influence their recipients despite correction. Correcting before, with inoculation, or after, with fact-checking, risks increasing audience familiarity with targeted misconceptions. Including forewarnings also risks heightening distrust in accurate information. Moreover, outside experimental settings, individuals reached by misconceptions are not necessarily the ones exposed to corrections. Our preregistered experiments address these concerns by using a mental model approach that, without mentioning the misconception that messenger RNA (mRNA) vaccination changes recipients' DNA, preempts or reactively corrects it and associated unwarranted inferences. The modeled messaging shows how mRNA vaccination works and/or how cells protect themselves from foreign DNA. Such models can be introduced in a live debate or in educational, clinical, or public health settings long before misconception exposure.

Use of messenger RNA (mRNA) technology revolutionized vaccine creation by allowing for the formulation of a vaccine as soon as a virus is sequenced. This method of accelerating the pace helps explain why, although then-National Institute of Allergy and Infectious Diseases Director Anthony Fauci forecast in March 2020 that creating a usable COVID-19 vaccine would take 1 to 1.5 y (1), the Moderna and Pfizer-BioNTech mRNA lipid nanoparticle vaccines, the most frequently used in the United States and the European Union (2), were available in December 2020. mRNA technology has life-saving implications. On the horizon are mRNA-based vaccines against melanoma (3), pancreatic cancer (4), the 20 known subtypes of influenza virus (5), respiratory syncytial virus (6), HIV (7), the avian influenza H5N1 virus (8), dengue virus (9), Lyme disease (10), the gastrointestinal infection *Clostridium difficile* (11), and a combination vaccine against influenza and COVID-19 (12).

Unwarranted Claims and Inferences about the mRNA Vaccines. However, funding and acceptance of these mRNA vaccine advances are threatened by unwarranted fear about the possibility that mRNA vaccination may change the recipient's DNA. Believing that COVID-19 vaccination has this effect negatively predicts both self-reported COVID-19 vaccination and willingness to vaccinate a child against the disease (13). In July 2024, 15% of an empaneled U.S. national probability sample reported believing that the COVID-19 vaccines change the recipient's DNA, a seven-percentage point increase from April 2021 (14).

Although worry that vaccines will change the recipient's DNA preceded mRNA vaccines (15), and the amount of DNA that survives the manufacturing process is within U.S. Food and Drug Administration (FDA) (16) and European Union (17) scientific standards, the advent of mRNA vaccines generated new claims, debunked by fact-checkers (18, 19) and the U.S. Centers for Disease Control and Prevention (CDC) (20), that these vaccines could change their recipients' genetic makeup and cause cancer (21, 22). Calls to restrict use of the mRNA vaccines emerged. In a January 2024 Florida Health Department press release and subsequent podcasts (23) and news appearances (24), Joseph Ladapo, State Surgeon

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[1]To whom correspondence may be addressed. Email: kathleen.jamieson@asc.upenn.edu.

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General of Florida, called for a halt in the use of mRNA COVID-19 vaccines in that state, alleging that DNA fragments found in them may be an "efficient vehicle for delivering contaminant DNA into human cells" (25).

In the release, Ladapo contended that "DNA integration poses a unique and elevated risk to human health and to the integrity of the human genome, including the risk that DNA integrated into sperm or egg gametes could be passed onto offspring of mRNA COVID-19 vaccine recipients" (25). When asked whether he thinks "it's likely happening that humanity itself is being changed forever by this round of mRNA vaccines," Ladapo told former Fox News host Tucker Carlson, "[y]es, I do" (26).

Notably, like some other claims of concern in the health field (27), this one about existence of small amounts of residual DNA in mRNA vaccines is literally accurate but is harnessed to implausible inferences. When messengers such as Carlson and Ladapo state that foreign DNA exists in mRNA vaccines, they are correct. But their subsequent inferences—that these DNA fragments change recipients' DNA and by so doing change humanity forever (26)—are unsupported by the best currently available scientific evidence.

Ladapo was not alone in trying to circumscribe use of the new vaccination technology. Concerned that ingesting mRNA-vaccinated food would change consumers' DNA, in 2024, Tennessee legislators expanded the Tennessee Food, Drug and Cosmetic Act's definition of "drug" to include "food that contains a vaccine or vaccine material" (28). "You eat a bunch of this lettuce, take a bunch of these mRNA vaccines, and you go back and get your DNA tested again… it's not going to be the same as it was that you were born with…." (29) alleged Frank Niceley, a Tennessee Republican state senator. Legislation mischaracterizing the mRNA vaccines as gene-based (30) or as gene therapy (31) is under consideration in a number of states (32). A Minnesota bill would designate "mRNA injections and products as weapons of mass destruction" and prohibit "mRNA injections and products." The same bill criminalizes knowingly manufacturing, acquiring, possessing, or making "readily accessible to another [sic] mRNA injections and products" (33). Although he did not cite potential effects on DNA as a factor in his decision, in August 2025 Health and Human Services Secretary Robert F. Kennedy, Jr. canceled 500 million dollars in mRNA vaccine research on the grounds that "mRNA technology poses more risks than benefits" when dealing with viruses such as COVID-19 or the flu (34).

Scientific Response. Experts such as then-FDA Center for Biologics Evaluation and Research Director Peter Marks confirm that "[o]n first principle, it is quite implausible that the residual small DNA fragments located in the cytosol could find their way into the nucleus through the nuclear membrane present in intact cells and then be incorporated into chromosomal DNA" (16). Marks states as well that the 1 billion doses of administered COVID-19 mRNA vaccines have elicited no evidence of genomic harm ("genotoxicity"). The CDC website (accessed May 27, 2025) dismisses the DNA-integration concern in even more categorical terms, saying: "COVID-19 vaccines do not affect or interact with our DNA. These vaccines do not enter the nucleus of the cell where our DNA (genetic material) is located, so they cannot change or influence our genes" (35).

Mainstream reporters have treated that conclusion as reliable knowledge. *New York Times* reporter Kate Zernike noted, for example, that "[i]n fact, mRNA vaccines cannot change the genetic code, because they cannot access the nucleus of the cells, where DNA resides. Small amounts of DNA are in all vaccines—often, as with the flu vaccine, because they are made from eggs—but the Food and Drug Administration enforces strict limits, and the levels are so small that they are negligible" (36).

Online and in major mainstream news sources—including YouTube (37), MedPage Today (38), CNN (39), Scientific American (40), FactCheck.org (41), Reuters (42), and PolitiFact (43)—Paul Offit, Director of the Vaccine Education Center and attending physician in the Division of Infectious Diseases of Children's Hospital of Philadelphia, rebutted Ladapo's inferences with an explanation of how the mRNA vaccine works and how our cells protect themselves from foreign DNA. The models and messaging in our two experiments build from the messaging delivered by Offit in response to the Ladapo announcement.

Because our DNA-protection model is designed for introductory biology courses, it lacks technical details found in some fact-checking of DNA-integration claims. So, for example, where our Study 2 animation notes that "[a] tiny fragment of foreign DNA is harmless because it doesn't have *the tools* to insert itself into our DNA (emphasis added)," a debunking of a DNA-integration claim published by the Global Vaccine Data Network identifies specific enzymes as those tools by noting that "[e]ven if the DNA reaches the nucleus, it would then need to integrate into the host's genome. This process is complex and requires specific enzymes, like integrases, which are not present in mRNA vaccines," (21) a point Offit also made in a number of his rebuttals of Ladapo claims (37, 39, 42, 43).

A Mental Model Approach. Although lack of understanding of scientific information does not "fully" explain "why more people do not appear to accept scientific claims or engage in behaviors or support policies that are consistent with scientific evidence" (44), vaccination-related knowledge has been found to predict vaccination acceptance (45) as has belief that the COVID-19 vaccination does not change a person's DNA (13). However, these studies focused on discrete knowledge items rather than structured, detailed, modeled knowledge.

The experimental materials in our preregistered studies draw on a facet of the mental model theory of reasoning which holds, among other things, that individuals reason using mental models representing the functioning of the external world and the events in it (46), including models of how biological and physical systems operate (47). So central is modeling to science that Gilbert defines science as, "a process of constructing predictive conceptual models" (48). A focus on models and modeling is consistent with the shift in science education away from a focus on facts to a focus on conceptual understanding (49).

Drawing on Nersessian's work, we define a mental model as a "form of knowledge organization" (50), or "conceptual system representing the physical system that is being reasoned about" (51). When we use the term "modeled knowledge structure," we mean knowledge organized in a model showing the relationships among facets of the phenomenon or structure it represents. Rather than appealing to expert authority by asserting that the mRNA vaccines protect against serious COVID-19 infection or that our cells protect themselves from foreign DNA, the mental model approach tested in our experiments shows how they do so.

Such concept process models can both illustrate a process and help individuals learn about scientific practices (52). Accordingly, the high school biology text Campbell Biology includes a "realistic model of the scientific process" and a section on building a structural model of DNA (53).

Science education exposes students to expert models in an effort to overcome scientifically inaccurate models that they have developed (54). The ways that individuals learn expert mental models include exposure to visually or verbally expressed versions of the models in textbooks and classroom settings as well as in media coverage of what and how scientists know about scientific topics. Media coverage also can introduce models or increase their salience among

those already holding them if health experts and journalists post them as explanatory material when, for example, a DNA-integration claim is at issue or a new mRNA vaccine introduced. Consistent with the conclusion that people reason within the understandings created by mental models (55) which can be elicited by verbally or visually expressed models (56), reading about the mRNA vaccine's mechanisms has been shown to increase perceptions of the vaccine's effectiveness (57).

How a Mental Model Approach Addresses Challenges in Misconception Correction. Although refutative means such as Offit's that provide reasons to dismiss problematic claims have shown positive effects (58), as inoculation (59) and fact-checking (60) have, these approaches carry specific risks and limitations. For example, mentioning a misconception in the process of prebunking or debunking can increase its familiarity among those not previously exposed to it. Such exposure is worrisome because even after correction, misinformation can continue to influence its recipients. Moreover, those reached by the concerning information are not necessarily exposed to the corrections (61). Additionally, warnings about misinformation threats may increase distrust in accurate information (62, 63).

Our two preregistered experiments address these concerns by using a mental model approach that can increase science-consistent understandings before potential exposure to misconceptions or in the context of a live controversy. Because the models can be deployed in classrooms and health education settings, they can reach potentially susceptible audiences not yet cloistered within media sources skeptical of, or hostile to, vaccination. Unlike usual uses of inoculation or fact-checking, our mental model approach does not mention or detail the problematic claim or, in the case of inoculation, warn that exposure to it is likely. Instead, our approach preempts or rebuts the unwarranted concern that mRNA vaccination changes recipients' DNA. It does so with print and graphic models of how mRNA vaccination works and print and animated explanations of how cells protect themselves from foreign DNA.

Earlier work uncovered possible benefits of protective exposure. Research undercutting the effects of vaccination-related conspiracy theories has found positive effects for use of preemptive argument (64). Notably, the early inoculation literature contains suggestive evidence of the effectiveness of preemptive knowledge. McGuire and Papageorgis's study of the "various types of prior belief-defense in producing immunity against persuasion" included a "'supportive therapy' approach" (65). The study found that exposing individuals to arguments supportive of their beliefs had less immunizing effectiveness than the inoculation procedure of preexposing them to weakened forms of counterargument. However, the underpowered supportive therapy condition did produce results, albeit not statistically significant ones, tending in the direction of positive effects.

Deploying Science-Consistent Expressed Mental Models to Protect against Misconceptions about Fragmentary DNA. As a model becomes more cognitively accessible, it is more likely that it will be used as a highly central one (66). Exposure to science-consistent models in science classrooms as a result should increase the likelihood that exposed students treat them as central, depictive mental models. When competing models are at play, individuals are likely to perceive a single model as more accurate and salient (67). Exposure to science-consistent models also should increase working knowledge of their contents (68), and, with it, the amount of attitude-relevant information from which the respondent can readily draw. Thinking within the assumptions of preexisting mental models should increase the likelihood that discrepant information will be rejected and information consistent with them accepted (69, 70). Although individuals are able to simultaneously hold competing models, they are unlikely to do so (71).

The educational process exposes individuals to progressively more detailed models of phenomena, such as how vaccination works and how the body protects itself from foreign DNA, and also actively engages them in exploring the predictions that result. This process opens the possibility that expressed models, which we test in these experiments, could be introduced and complexified as representational depictions in the nonpolarized setting of middle-, high-school, and college classrooms. At the same time, these models could be introduced or their salience increased among those already holding them if health experts and journalists were to post them as explanatory material when a DNA-nucleus claim is at issue or a new mRNA vaccine introduced.

Consistent with research findings showing that detailed, corrective counterinformation is more effective than more abbreviated information (58), the models in our studies provided extensive detail (see Figs. 1 and 2). Because exposing individuals to visualizations of unseen phenomena and systems can enhance scientific understanding (72), our expectation is that exposure to our expressed models of how the mRNA vaccine works and how human cells protect themselves from foreign DNA will reduce the plausibility of the claim that the fragmentary DNA in mRNA vaccines affects the recipient's DNA.

One of our models works by bypassing, the other by foreclosing.

Bypassing. Unlike corrective methods such as inoculation and fact-checking, bypassing does not mention the problematic assertion even in weakened form but instead bolsters discrete pieces of information unrelated to the problematic claim. However, rather than bolstering such discrete pieces of information, as past instances of bypassing have done (73–75), our mental model approach in Model 1 [mRNA vaccination] anchors respondent understanding in a coherent, detailed structure of knowledge—an expressed mental model.

Foreclosing. Instead of bypassing, our second model (Model 2 [cell protection]) forecloses by detailing the multiple ways in which human cells protect against or destroy foreign DNA and by noting that "a tiny fragment of foreign DNA is harmless because it doesn't have the tools to insert itself into our DNA." This model is designed to decrease the plausibility of the DNA-integration claim before exposure to it or, if exposure has occurred, to counter its effects.

Although research is mixed on whether there is a net advantage to pre or postexposure (64, 76), we hypothesize that anchoring attitudes in a mental model before exposure to problematic content will be more effective than exposure after it because it will contextualize the misconception.

The Relationship between Study 1 and Study 2. Study 1's five conditions focus on testing the effects of exposure to: a comprehensive message integrating Models 1 and 2 that included ancillary material designed to bolster perceptions of mRNA vaccination safety (condition 5); a digest of the Ladapo content; Model+Ladapo; Ladapo+Model; and an active control (Fig. 3).

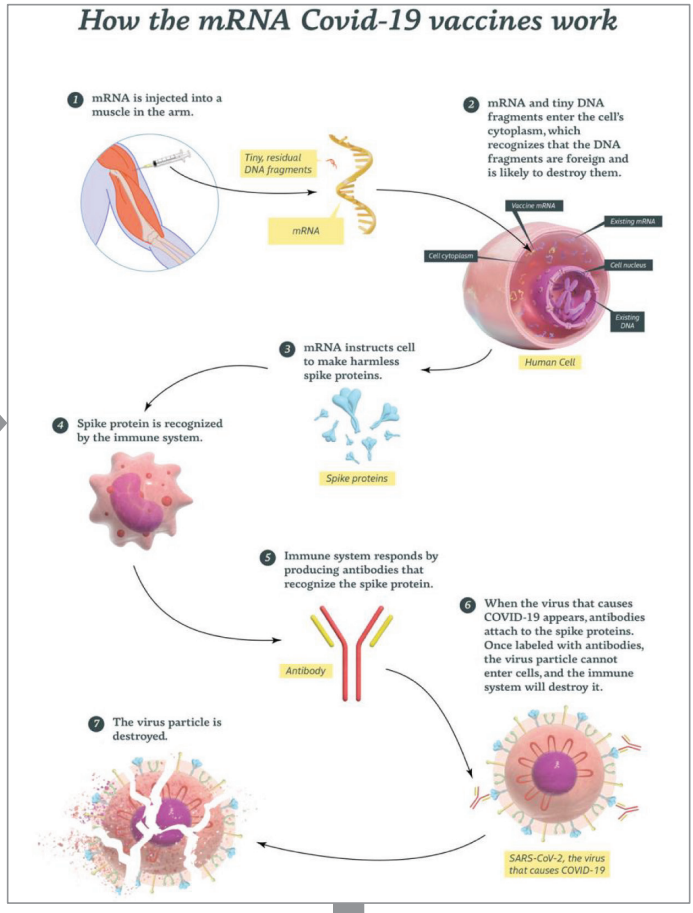
Study 2 corrected for two limitations in Study 1. The multiple parts of Study 1's modeled knowledge messaging condition make it difficult to know which accounts for the observed effects. Its length and extended print passages make consumption outside an experimental setting unlikely (77). To correct for these limitations, Study 2's modeled knowledge condition (condition 5) focuses solely on

Print preface of Model 1 (mRNA vaccination)

Messenger RNA (mRNA) molecules are pieces of genetic material in our cells. They tell a cell how to make different kinds of proteins. The COVID-19 vaccines use mRNA to tell our cells how to make one piece of the virus that causes COVID-19. This piece sits on the outside of the virus and is called a ***spike protein****. On their own, spike proteins are harmless and cannot give someone COVID-19. The mRNA vaccine is injected into a muscle. The muscle cells follow the mRNA instructions and make the spike protein. Our bodies see that the spike protein is foreign. They respond by making antibodies against it. This also activates other immune cells. These antibodies and immune cells help our bodies fight the COVID-19 virus.*

Please review this figure describing how mRNA vaccines work. To review, please click on the image and it will expand:

Graphic of Model 1 (mRNA vaccination)



Print of Model 2 (cell protect DNA) + ancillary material

DNA is used to make the mRNA in the mRNA vaccines. Almost all the DNA is cut up and removed during manufacturing. But a small number of DNA fragments remain. These are not harmful. Other commonly used ***non****-MRNA vaccines also contain DNA fragments. These include the vaccine that protects us against chickenpox. Our body has many defenses to protect our own DNA. It would take a series of very unlikely events for any of the leftover DNA bits to insert into our DNA:*

First, the DNA bits would have to enter muscle cells. Then, they would have to survive the cell's main compartment, called the cytoplasm. The cytoplasm is very good at detecting and destroying anything foreign, including DNA.

Second, if the DNA fragments somehow survived, they would then have to get into the nucleus. This is where a person's own DNA is. The nucleus is protected by a membrane except when cells are dividing. Muscle cells rarely divide. This means it is very unlikely that any DNA bits could get into the nucleus and reach our DNA.

Third, DNA fragments typically cannot insert themselves into a cell's DNA. They need certain enzymes to do this. These enzymes are not in the mRNA vaccines.

Finally, even if the DNA fragments survived the cytoplasm, entered the nucleus and were inserted into our DNA, this would be very unlikely to harm us. The short fragments contain little to no information to make a meaningful change in our DNA.

Also, any changes to a muscle cell's DNA can't be passed to our children. Only DNA changes to sperm or egg cells are passed from parent to child.

The Food and Drug Administration (FDA) reviews how vaccines are made and monitors them for safety in multiple ways. The agency says it is confident in the "quality, safety, and effectiveness of the COVID-19 vaccines." Worldwide, more than a billion doses of the mRNA vaccines have been safely administered.

Fig. 1. Modeled Knowledge graphic. See *SI Appendix*, Text S1 for additional information.

cell protection (Model 2) in a 105-s animation. In a separate condition (condition 6), Study 2 combines Study 1's modeled messaging (condition 5) and the Study 2 modeled knowledge animation condition (condition 5) to determine whether doing so produces an additive effect (Fig. 3). (For a detailed description of the differences between the studies, see *SI Appendix*, Text S3).

Hypotheses: Study 1. Our first underlying question asks whether exposure to detailed models of mRNA vaccination and cell protection can minimize susceptibility to assertions that tiny amounts of fragmentary foreign DNA in the mRNA vaccine change recipients' DNA, increasing their risk of cancer and heritable effects. A second question is whether placing the messaging of

Fig. 2. Modeled knowledge animation transcript (Study 2). See *SI Appendix*, Text S2 for a link to the modeled knowledge animation.

Study 1 or the animation of Study 2 before exposure to the Ladapo DNA claims is more effective than placing either in the rebuttal position (postexposure to the Ladapo content). In our preregistered experiments, we tested the hypotheses that: *H1*) exposure to the Ladapo claims would decrease endorsement of evidence-based knowledge and perceptions related to mRNA vaccines compared to control; *H2*) exposure to modeled knowledge would increase evidence-based responses compared to control; *H3*) exposure to both modeled knowledge and Ladapo (Model+Ladapo or Ladapo+Model) would increase evidence-based responses compared to Ladapo alone; *H3a*) exposure to modeled knowledge before exposure to Ladapo (Model+Ladapo) would increase evidence-based responses more than exposure to modeled knowledge after exposure (Ladapo+Model); *H4* (not preregistered), exposure to modeled knowledge would reduce the disfavoring of mRNA COVID-19 vaccines compared to the broader category of COVID-19 vaccines of which they are a part; and we asked *RQ1* (not preregistered) would effects in Study 1 persist 2 mo later?

Hypotheses: Study 2. To the hypotheses in Study 1, Study 2 preregistered *H4* and added: *H2a*) exposure to the complex multimodel message in Study 1 combined with the messaging in Study 2 (condition 6) would increase evidence-based responses compared to the animation alone (condition 5). It also added (*H3b*) exposure to either Modeled Knowledge conditions (conditions 5 and 6) would increase evidence-based responses more than exposure to either combined Modeled Knowledge and Ladapo conditions (Model+Ladapo or Ladapo+Model).

Results

Here, we report the results of both Study 1 and 2. In Study 1, a total of 1,716 participants were enrolled and randomly assigned to one of five conditions; 1,540 were included in the analyses. Study 2 enrolled and randomly assigned a total of 2,621 participants to one of six conditions; 2,038 were included in the analyses (*SI Appendix*, Figs. S1 and S2).

The demographics of the two samples are similar to the adult U.S. population and were weighted to match demographic benchmarks. Both studies had fewer than 4% of observations missing demographic data. Participants with missing data were listwise deleted. Just over 75% of participants in each study reported being vaccinated against COVID-19, and among those who reported a vaccination brand (for example, Pfizer, Moderna), nearly all were an mRNA vaccine. However, only 31% in Study 1 and 34% in Study 2 explicitly recalled being vaccinated against COVID-19 with an "mRNA vaccine" (*SI Appendix*, Tables S1 and S2).

Respondents were excluded from the analyses if they did not finish the survey, finished it in under 4 min, failed generic attention checks (see quality control checks in *SI Appendix*, Texts S7 and S8) or failed a validity check (i.e., chose options for conditions to which they were not exposed when asked "While some people pay a lot of attention, others do not. Thinking back, please select the option[s] below that best summarize what you just saw. You can select as many as apply"). In both studies, after those exclusions, participants had fairly high accuracy (75 to 98%) when answering comprehension questions about the information to which they were exposed (see *SI Appendix*, Text S4 and Tables S3 and S4 for more details).

For *H1* (Ladapo exposure will decrease evidence-based conclusions), *H2* (modeled messaging will increase evidence-based conclusions), and *H3* (modeled messaging+Ladapo or Ladapo+modeled messaging will increase evidence-based conclusions), we find hypothesis-consistent evidence using the preregistered 8-item scale of knowledge and perceptions related to mRNA vaccination in Study 1 and the 15-item scale in Study 2 (which includes the 8-item scale from Study 1; see item wording and preregistered coding in *SI Appendix*, Table S5) as the dependent variables. Summary statistics for the primary outcomes by condition are presented in Table 1. Exposure to Ladapo's claims about mRNA vaccines reduced evidence-based responses on both the 8-item (Study 1) and 15-item (Study 2) scales of mRNA vaccine knowledge and perceptions compared to active controls (*H1,* bs range −0.041 to −0.056; Table 2 and *SI Appendix*, Figs. S3 and S4). Exposure to knowledge models (print+graphic, animation, or both) led to more evidence-based responses relative to active controls (*H2,* bs range 0.033 to 0.069). Exposure to each of the four conditions with modeled knowledge+Ladapo's claims (Model+Ladapo and Ladapo+Model in Study 1 and in Study 2) was protective compared to exposure to Ladapo's claims alone (*H3,* bs range 0.049 to 0.086). For all pairwise condition comparisons adjusted for multiple tests, see *SI Appendix*, Tables S6 and S7. When the two primary outcomes are limited to the 10 knowledge items, support for hypotheses is the same as the preregistered outcomes (*SI Appendix*, Tables S8–S10). For more detail on the five other individual perception items, see *SI Appendix*, Tables S11–S13.

As detailed in the preceding paragraph, all effects for *H1–H3* are significant but relatively small. The absolute value of estimates for *H1–H3* on the primary outcomes ranged from 0.033 to 0.086 on a 0 to 1 scale. Putting these effect sizes in context (assessed by looking at education levels in the control condition), the differences are overlapping but only slightly smaller in size than the effect of having a college degree or more as opposed to some or no college education (Study 1: 0.062; Study 2: 0.108).

Evidence for *H3a* (model[s] more effective before than after) was inconsistent. In Study 1's within-participant analysis, presenting the models before Ladapo's claims had a more protective effect than presenting them after (b = 0.026, Table 2 and *SI Appendix*,

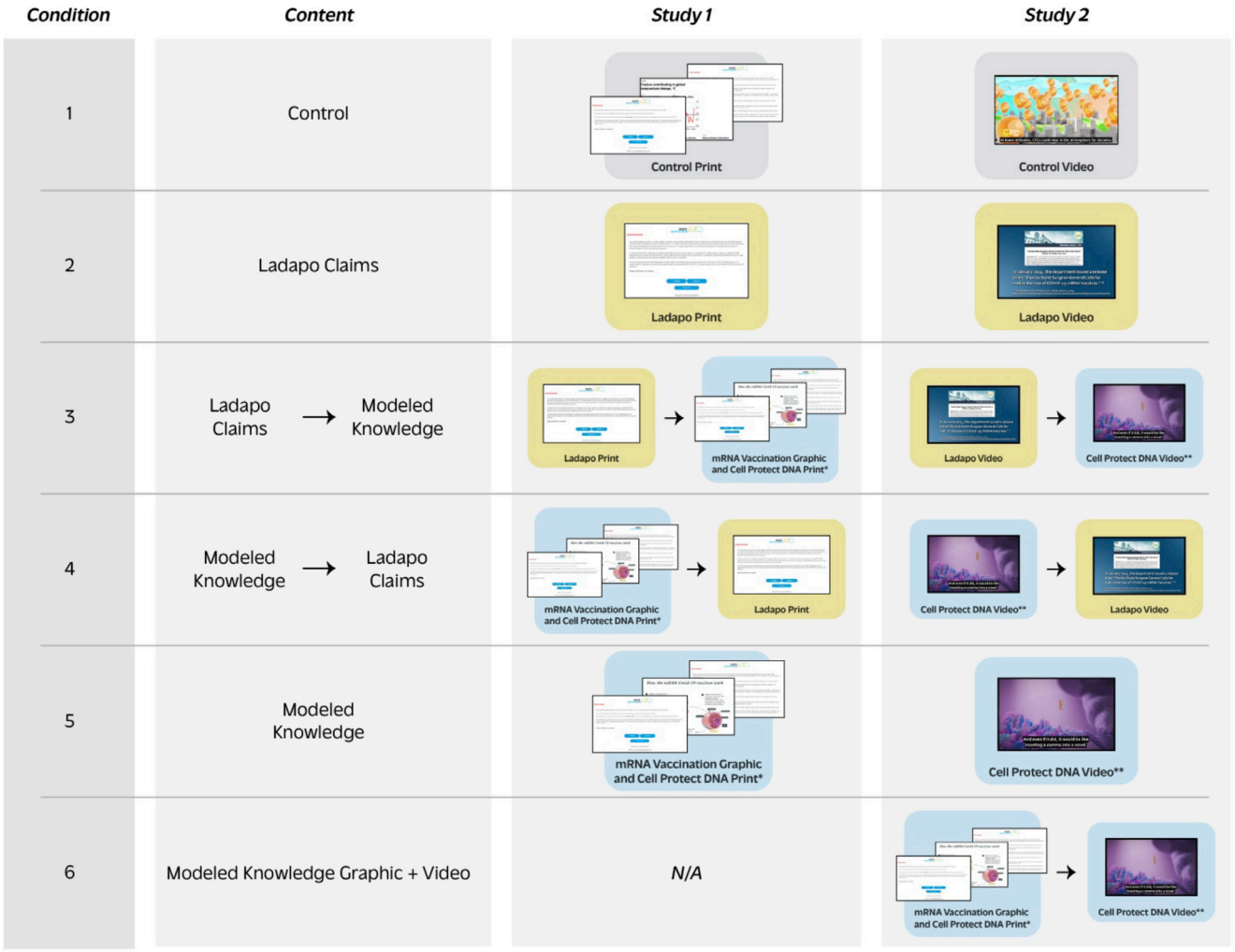


Fig. 3. Experimental designs, Studies 1 and 2. Study 1 used print and graphic materials. Study 2 used video materials throughout. The Modeled Knowledge graphic+video condition was only included in Study 2. *Print graphic developed internally by Zachary Reese. **Video developed by Don Mitchell in collaboration with Vaccine Education Center at Children's Hospital of Philadelphia and XVIVO.

Tables S6 and S7). However, there was no difference in the effects of presentation order in the between-participant analyses in either Study 1 or Study 2. But in no condition was refutative positioning superior to preemptive positioning.

Table 1. Summary statistics for primary outcomes (Study 1 and 2)

	Study 1, 8-item scale Weighted Mean (SD)	Study 2, 15-item scale Weighted Mean (SD)
Control	0.64 (0.19)	0.59 (0.21)
Ladapo (L)	0.57 (0.21)	0.55 (0.22)
L + MK	0.62 (0.22)	0.60 (0.22)
MK+L	0.63 (0.21)	0.61 (0.21)
Modeled Knowledge (MK)	0.66 (0.20)	0.65 (0.19)
MK graphic+animation	NA	0.66 (0.20)
Total	0.63 (0.21)	0.61 (0.21)

Note. The 8-item scale is the primary outcome for Study 1. The 15-item scale is the primary outcome for Study 2. All items comprising scales were recoded so that the most evidence-based response was coded as 1 and the most unwarranted response was coded as 0, with *not sure* as the midpoint (0.5).

For the two additional hypotheses in Study 2, *H2a* was not supported but *H3b* was. Exposure to the complex multimodel message from Study 1 in combination with the animated model of Study 2 (condition 6) was just as effective as exposure to the animation model alone (condition 5; *H2a*, Table 2 and *SI Appendix*, Table S7). However, the combined condition (condition 6) was more effective on Study 1's primary outcome, the 8-item scale (b = 0.033, not preregistered), suggesting that adding the comprehensive messaging of Study 1 to the animation of Study 2 added or increased the salience of some additional information for that smaller group of items, but did not impact effects with the 15-item scale. Grouping the two modeled knowledge conditions (conditions 5 and 6) showed they were more protective than the two modeled knowledge animation plus Ladapo conditions grouped (Model+Ladapo and Ladapo+Model; *H3b,* b = 0.051, Table 2 and *SI Appendix*, Table S15). Results were the same when limited to the knowledge items (*SI Appendix*, Tables S8 and S16) and in some cases similar for the secondary outcomes (*SI Appendix*, Tables S14 and S17).

H4 anticipated that exposure to modeled knowledge would reduce the disfavoring of mRNA COVID-19 vaccines compared to the broader category of COVID-19 vaccines of which they are a part. *H4* was partially supported. Unlike the other conditions, in Studies 1 and 2, respondents in the modeled knowledge

Table 2. Primary tests for *H1–H3* (Study 1 and 2)

Hypotheses Tested	b	95% CI	*P*
H1: Ladapo vs. control			
Study 1 Within 8-item scale	*−0.041*	*[−0.060, −0.022]*	<0.001
Study 1 Between 8-item scale	*−0.056*	*[−0.085, −0.027]*	<0.001
Study 2 Between 15-item scale	*−0.042*	*[−0.069, −0.015]*	<0.01
H2: Modeled knowledge vs. control			
Study 1 Within 8-item scale	**0.060**	**[0.041, 0.078]**	<0.001
Study 1 Between 8-item scale	**0.033**	**[0.005, 0.061]**	<0.05
Study 2 Between 15-item scale Modeled Knowledge animation	**0.048**	**[0.021, 0.074]**	<0.001
Study 2 Between 15-item scale Modeled Knowledge graphic+animation	**0.069**	**[0.042, 0.095]**	<0.001
H2a: Modeled Knowledge graphic+animation vs. Modeled Knowledge animation			
Study 2 Between 15-item scale	0.021	[−0.005, 0.047]	0.12
[Not preregistered] Study 2 Between 8-item scale	**0.033**	**[0.006, 0.059]**	<0.05
H3: [EITHER Model+Ladapo OR Ladapo+Model] vs. Ladapo			
Study 1 Within 8-item scale Ladapo+Model	**0.060**	**[0.041, 0.080]**	<0.001
Study 1 Within 8-item scale Model+Ladapo	**0.086**	**[0.067, 0.105]**	<0.001
Study 1 Between 8-item scale Ladapo+Model	**0.056**	**[0.028, 0.085]**	<0.001
Study 1 Between 8-item scale Model+Ladapo	**0.063**	**[0.034, 0.091]**	<0.001
Study 2 Between 15-item scale Ladapo+Model	**0.049**	**[0.022, 0.075]**	<0.001
Study 2 Between 15-item scale Model+Ladapo	**0.050**	**[0.024, 0.077]**	<0.001
H3a: Model+Ladapo vs. Ladapo+Model			
Study 1 Within 8-item scale	**0.026**	**[0.007, 0.044]**	<0.01
Study 1 Between 8-item scale	0.006	[−0.021, 0.034]	0.66
Study 2 Between 15-item scale	0.002	[−0.025, 0.028]	0.90
H3b: [Modeled Knowledge animation AND Modeled Knowledge graphic+animation] vs. [Model+Ladapo AND Ladapo+Model]			
Study 2 Between 15-item scale	**0.051**	**[0.032, 0.070]**	<0.001

Note. Unstandardized b coefficients, 95% CI, and *P*-values from weighted models. Between analyses include demographic predictors, within analyses do not. The relevant reference category for each test is listed in the hypothesis column. *Italics* indicate significantly lower than the reference, **bold** indicates significantly higher. The 8-item scale is the primary outcome for Study 1. The 15-item scale is the primary outcome for Study 2.

alone conditions did not disfavor the mRNA COVID-19 vaccines compared to the more general category of COVID-19 vaccines (*SI Appendix*, Table S18). The disfavoring that we found in the control condition suggests that there was a preexisting bias against mRNA COVID-19 vaccines that was overcome in the modeled knowledge conditions. This preexisting bias also could explain why exposure to the Ladapo content did not increase the level of disfavoring of the mRNA COVID-19 vaccine items that respondents presumably already held (*H4-H1*), while there was a decrease in disfavoring the mRNA COVID-19 vaccine compared to the COVID-19 vaccine in the Modeled Knowledge conditions in Studies 1 and 2 relative to control (*H4-H2*; bs range 0.013 to 0.025, Table 3). Exposure to the two conditions with modeled knowledge+Ladapo's claims decreased disfavor for the mRNA COVID-19 vaccine compared to Ladapo's claims alone in Study 1 but not Study 2 (*H4-H3;* Study 1 bs range 0.009 to 0.012, Table 3). In Study 2, a statistical test of whether the disfavoring in the two modeled knowledge animation+Ladapo conditions (Model+Ladapo and Ladapo+Model) differed from the lack of disfavoring in the two modeled knowledge conditions (conditions 5 and 6) was significant (*H4-H3b*; b = 0.009; Table 3 and *SI Appendix*, Table S19). We saw no statistically significant mRNA vs. COVID-19 vaccination spread differences between the conditions tested in *H2a* and *H3a.* See *SI Appendix*, Tables S18 and S19 for significant effects on individual spread items adjusted for multiple tests within hypothesis using the Holm–Bonferroni technique. Eight of these 10 spread items are knowledge items. Analyses limiting the spread scale to those eight items yielded similar findings (*SI Appendix*, Tables S20–S22).

Two key items (Changes DNA and Cells Recognize and Destroy Foreign DNA [hereafter Foreign DNA]), preregistered as two of the 15 individual item analyses, adjusted for multiple tests within hypothesis using the Holm–Bonferroni technique, largely showed anticipated effects. First, exposure to the Ladapo content increased unwarranted responses to Changes DNA (*H1*; bs range –0.068 to –0.092 in Studies 1 and 2) but did not affect the Foreign DNA belief (*SI Appendix*, Tables S11–S13). Second, exposure to the messaging in Study 1, which included Models 1 and 2, or to Model 2 alone in Study 2, increased evidence-based responses to Changes DNA and Foreign DNA in seven of the eight analyses (*H2*; bs range 0.057 to 0.194, only exception is Study 1 between analysis for Changes DNA). Third, when responses in either the Model+Ladapo or Ladapo+Model conditions are compared to responses in the Ladapo condition, unwarranted responses to Changes DNA were undercut in five of the six analyses (*H3*; bs range 0.058 to 0.141, the only exception being Study 1 between analysis for Ladapo+Model).

None of the hypotheses were supported when assessed with our single behavioral intention item (likelihood of taking a new mRNA vaccine, see secondary outcome wording in *SI Appendix*, Table S27 and full results in *SI Appendix*, Table S14). However,

Table 3. Primary tests for H4: Spread for "mRNA COVID-19" vs "COVID-19" vaccine (Study 1 and 2)

Hypotheses tested	b	95% CI	*P*
H4-H1: mRNA spread analysis, Ladapo vs. Control			
Study 1 Within 10-item spread scale	−0.002	[−0.010, 0.006]	0.63
Study 2 Within 10-item spread scale	0.007	[−0.002, 0.015]	0.12
H4-H2: mRNA spread analysis, Modeled Knowledge vs. Control			
Study 1 Within 10-item spread scale	**0.025**	**[0.017, 0.033]**	<0.001
Study 2 Within 10-item spread scale Modeled Knowledge animation	**0.013**	**[0.005, 0.021]**	<0.01
Study 2 Within 10-item spread scale Modeled Knowledge graphic+animation	**0.014**	**[0.006, 0.023]**	<0.001
H4-H2a: mRNA spread analysis, Modeled Knowledge graphic+animation vs. Modeled Knowledge animation			
Study 2 Within 10-item spread scale	0.002	[−0.007, 0.010]	0.69
H4-H3: mRNA spread analysis, [EITHER Model+Ladapo OR Ladapo+Model] vs. Ladapo			
Study 1 Within 10-item spread scale Ladapo+Model	**0.009**	**[0.000, 0.017]**	<0.05
Study 1 Within 10-item spread scale Model+Ladapo	**0.012**	**[0.004, 0.020]**	<0.01
Study 2 Within 10-item spread scale Ladapo+Model	−0.002	[−0.011, 0.006]	0.58
Study 2 Within 10-item spread scale Model+Ladapo	−0.002	[−0.011, 0.006]	0.58
H4-H3a: mRNA spread analysis, Model+Ladapo vs. Ladapo+Model			
Study 1 Within 10-item spread scale	0.003	[−0.005, 0.011]	0.42
Study 2 Within 10-item spread scale	0.000	[−0.008, 0.008]	0.99
H4-H3b: mRNA spread analysis, [Modeled Knowledge animation AND Modeled Knowledge graphic+animation] vs. [Model+Ladapo AND Ladapo+Model]			
Study 2 Within 10-item spread scale	**0.009**	**[0.004, 0.015]**	<0.01

Note. Unstandardized b coefficients, 95% CI, and *P*-values from weighted models predicting the scale difference of 10 "mRNA COVID-19" vs. "COVID-19" vaccine items (*SI Appendix*, Table S18). The relevant reference category for each test is listed in the hypothesis column. Positive values indicate decreased disfavoring of "mRNA COVID-19" relative to "COVID-19" vaccine. *Italics* indicate significantly lower than the reference, **bold** indicates significantly higher.

in a not preregistered analysis, participants in the Modeled Knowledge animation alone condition (Model 2, Study 2, condition 5) showed significantly greater intentions to take a new mRNA vaccine relative to those exposed to Ladapo's claims alone (b = 0.064). The effect did not appear in conditions that included Model 1 (Study 2, condition 6 or Study 1, condition 5).

Primary and secondary analyses were similar when unadjusted (*SI Appendix*, Tables S23–S26).

Two months (April 18-25, 2024) after Study 1 (February 22-28, 2024), the increase in evidence-based responses after exposure to the modeled knowledge messaging condition 5 of Study 1 compared to control persisted at a third of the size (not preregistered *RQ1-H2* within-participant analyses on a 7-item scale: Study 1 b = 0.061; follow-up b = 0.018; see *SI Appendix*, Table S28). Among key items (Changes DNA and Foreign DNA), the increase in evidence-based responses in the same analysis persisted for Changes DNA at 2 but not 11 mo (January 30-February 10, 2025; *RQ1-H2* within-participant analysis: Study 1 b = 0.057; 2-mo follow-up b = 0.039; 11-mo follow-up b = 0.009; see *SI Appendix*, Table S29) but did not persist at all for Foreign DNA. Among two perception items related to future harm (Child Health and Future Cancer), the increase in evidence-based responses in the same analysis persisted for Child Health at 2 and 11 mo (*RQ1-H2* within-participant analysis: Study 1 b = 0.189; 2-mo follow-up b = 0.094; 11-mo follow-up b = 0.090; see *SI Appendix*, Table S29) but not for Future Cancer.

Discussion

Although mRNA technology revolutionized vaccine creation, its use is threatened by unwarranted fear that mRNA vaccination may change the recipient's DNA, increasing cancer and heritable risks. Drawing on the mental model theory of reasoning, our two preregistered experiments found that when the visualized and/or verbally explained models of basic biological and vaccination systems were juxtaposed with the problematic content, endorsement of the problematic content was undercut. Both preemptive and rebuttal positioning of the models were effective. Within-person analyses suggested that preemptive positioning may be somewhat more effective than rebuttal positioning.

These studies found that messaging that included a detailed graphic visual model of how the mRNA vaccine works (Model 1) and an accompanying verbal print model of how our cells protect themselves from foreign DNA (Model 2; Study 1) along with ancillary material described earlier or an animation modeling how our cells protect their DNA from foreign DNA (Model 2; Study 2) increased evidence-based responses on a scale of 8 knowledge and perception items in Study 1 and the same items plus an additional seven in Study 2. The claim that cells in our bodies recognize and destroy foreign DNA was more likely to be accepted after exposure to the combined Modeled Knowledge+Ladapo conditions than after the Ladapo content alone.

Adding to prior work, which has produced mixed results (64, 76) these studies found evidence that modeled knowledge exposure preceding the Ladapo DNA claims was somewhat more effective than positioning the modeled knowledge in the rebuttal position. However, although preemption was more effective in one within-participant analysis, the difference was small (b = 0.026). In the other two between-participant analyses (two studies), responses were not different based on presentation order of the modeled knowledge and Ladapo claims. But in no condition was refutative positioning superior to preemptive positioning. Finding the effects of both preemptive and refutative modeling that we did is important because health communicators' audiences include individuals with prior exposure to problematic claims as well as individuals with no exposure. Our findings suggest that

modeled knowledge may have the ability to simultaneously function preemptively for some and refutatively for others.

Ladapo's concerns focused on the potential for mRNA COVID-19 vaccines to change people's DNA. Importantly, when exposed to the combined Ladapo and Modeled Knowledge stimuli, regardless of order, there were more evidence-based responses to "the cells in our bodies recognize and destroy foreign DNA" compared to exposure to Ladapo alone.

Our findings suggest that our mental model approach may be able to overcome some of the challenges facing usual uses of inoculation and fact-checking. By increasing evidence-based knowledge and perceptions without explicitly acknowledging the problematic claims, our two models and associated messaging in Study 1 and the model in Study 2 each produced positive effects while avoiding a potential problem inherent in the inoculation and fact-checking approaches. Although inoculation has been shown to be an effective strategy, these results suggest that the forewarning and threat that are central to it (78) may not be a necessary element in reducing susceptibility to misconceptions at least in some circumstances.

Because it could be deployed in classrooms and as part of campaigns introducing new vaccines, this mental model approach also could increase the likelihood that audiences will be exposed to it before confronting problematic claims. Use of these venues also could increase the reach of the preemptive models beyond partisan channels. Since forewarning is not a part of the mental model approach that we are offering, our approach does not risk creating wariness about accurate information. Future research might comparatively assess the effectiveness of our mental model approach to other approaches that explicitly detail the problematic content.

Future research also might test the effectiveness of models as a form of anticipatory rebuttal in inoculation or rebuttal in fact-checking. As we noted earlier, Offit rebutted Ladapo's claims by verbally modeling how human cells protect themselves from foreign DNA. Such instances provide a ready source of real-world stimuli.

In addition, future research should test whether exposure to the expressed models in a nonpolarized classroom setting increases students' acceptance of the models as a representational depiction of how the mRNA vaccine and human cells function. If so, thinking within the assumptions of the preexisting mental model should increase the likelihood that later exposure to discrepant information will prove ineffective. Both studies tested the materials on an adult population and not specifically on high school or college students. Future research should determine whether the findings replicate with samples composed solely of high school and college students and could be successfully deployed in their classrooms.

Also, in our experimental settings, participants were incentivized to focus on the materials. Other distribution methods will vary in how much attention is paid to the materials, but we expect it to be fairly high in classrooms and lower when delivered through other modes (e.g., social media accounts). Future research should assess the effectiveness of exposure in different settings.

Finally, we assessed effects immediately after exposure and, in the case of Study 1, also 2 mo later. Future research should determine whether effects persist beyond these points and, if so, the conditions under which they do so. Shortening the time between exposure to the models and vaccination decisions could potentially increase model impact. The likelihood that an individual will decide to accept an mRNA vaccine may increase if the person is exposed to models of how mRNA vaccines work and how our bodies protect themselves from foreign DNA in venues such as clinics in which vaccination is readily available.

Materials and Methods

Approach. In both studies, we tested whether detailed modeled knowledge was able to reduce susceptibility to Ladapo's claims. Participants were randomized in parallel in a 1:1 ratio to one of five conditions in Study 1 or six conditions in Study 2 (Fig. 3). The Institutional Review Board (IRB) of the University of Pennsylvania concluded that the Annenberg Survey of Attitudes on Public Health (ASAPH) longitudinal survey (IRB protocol number: 848621) and, separately, Study 1 (IRB protocol number: 855346), met eligibility criteria for IRB exemption authorized by the 45 CFR 46. 104, Category 2. Since the stimuli for Study 2 did not significantly change the study or the risk/benefit profile, an IRB representative concluded that it was exempt as well. Informed consent was obtained from all respondents (for consent language, see *SI Appendix*, Text S9). The preanalysis plans detailing the designs and hypotheses can be found at (https://osf.io/235jf and https://osf.io/ys9r2 or *SI Appendix*, Texts S5 and S6).

Participants. Participants in both studies were U.S. adults, 18 y or older, from the survey research firm SSRS's Opinion Panel. SSRS panel members were recruited using a nationally representative address-based-sample design. We only included participants who could take the survey online and in English. Expecting attrition, we aimed to recruit 350 participants per condition (*SI Appendix*, Figs. S1 and S2).

Participants in Study 1 were part of the ASAPH panel, randomly sampled from the SSRS Opinion Panel in April 2021. Those panelists are ineligible for other studies conducted by SSRS. This longitudinal sample allowed us to collect preexperiment baseline data on the 8-item primary outcome scale between February 6–12, 2024, in the 18th wave of that panel, 2 wk before administration of Study 1. The 1,486 online, English-speaking respondents from baseline were invited to participate in Study 1. Recruitment to Study 1 was supplemented with 557 participants from the SSRS Opinion Panel and the experiment was conducted February 22–28, 2024. We randomized 1,716 to one of five conditions and analyzed 1,540. Participants in the ASAPH panel were reasked a subset of the Study 1 postexposure battery 2 mo later (April 18–25, 2024; N = 1,222 from Study 1) and 11 mo later (January 30–February 10, 2025; N = 1,122 from Study 1).

Participants in Study 2 were sampled directly from the SSRS Opinion Panel. A strength of this sample was that respondents had not been sensitized by exposure to vaccination-related questions that were the focus of the 18-wave panel, although they may have participated in other vaccination-related studies. In Study 2, we randomized 2,621 participants to one of six conditions and conducted the experiment February 18 – March 4, 2025. We analyzed 2,038. See *SI Appendix*, Texts S7 and S8 for more details about recruitment methods.

Materials. Materials were standardized across conditions. Materials in the five conditions in Study 1 were either text-only or included a multipanel graphic with an explanation. Materials in the six conditions in Study 2 were animations or voiced print except condition 6 which combined the models from both studies (complex multimodel message+animation). The Study 2 animations and voiced print had similar readability scores and length, used the same synthetic voice-over, and presented open captions throughout. The readability of the modeled knowledge animation in Study 2 (Flesch reading ease score: 59) is comparable to the reading level of the Scientific American, MedPageToday, and CNN accounts of Offit's rebuttal of Ladapo's claims (Flesch reading ease scores: 51, 61, and 61, respectively) and more readable than the FactCheck.org and Reuters debunkings (Flesch reading ease scores: 42 and 34; see *SI Appendix*, Text S2).

Stimuli.

1. *Modeled Knowledge*: In Study 1, modeled knowledge was a 450-word description of how mRNA COVID-19 vaccines function in our cells (Model 1) and a description of why this process makes it implausible that mRNA vaccination will affect recipients' DNA (Model 2), paired with a 7-panel graphic visualizing how mRNA COVID-19 vaccines work (Model 1). It also included the ancillary material described earlier. In Study 2, the animation summarized how the human immune system handles fragments of foreign DNA that enter the body, including through an mRNA vaccine, and why these DNA fragments are unable to change recipients' DNA (Model 2). Both introduced a detailed, coherent, expressed model of understanding of a complex topic, opened with a question, and raised and resolved worry.

2. *Ladapo*: In Study 1, Ladapo's claims were digested into a 200-word summary of the Florida Department of Health press release "Florida State Surgeon General Calls for Halt in the Use of COVID-19 mRNA Vaccines," which describes Ladapo's fragmentary DNA-based rationale for calling for the vaccination halt. Study 2 used the same press release as the basis for the voiced print but lowered the reading level and added a recounting of a question-and-answer exchange between Tucker Carlson and Ladapo and a quotation from Carlson's social media promotion of his Ladapo interview. The reading level was calibrated to be similar to the reading level of the Modeled Knowledge content in Study 2 (*SI Appendix*, Texts S1 and S2). At the end of both studies, participants who only received the Ladapo information were debriefed with the Modeled Knowledge print (Model 1 and 2, but no graphic) from Study 1.
3. *Control*: In Study 1, the control was a 450-word news excerpt on climate change with an accompanying 5-panel graphic detailing different factors affecting global temperature change. The Study 2 control was an animation about chlorofluorocarbons and their impact on the ozone layer. Like the modeled knowledge stimuli, both opened with a question, raised worry, and introduced a coherent model of understanding of a complex topic (*SI Appendix*, Texts S1 and S2).

Procedures. Two weeks before Study 1, the 8-item primary outcome scale was asked as part of the 18th wave of the ASAPH panel to get respondents' baseline levels. In both studies, participants answered a few initial questions, including ones about their exposure to vaccine information in the news sources they trust. They were then shown the materials for their condition. Following exposure, respondents were asked items measuring how well they understood the materials. After those checks, respondents were asked the questions described earlier. The median study length was 18 min for Study 1 and 16 min for Study 2 (for length by condition, see *SI Appendix*, Tables S3 and S4). Some outcome items were then reasked of ASAPH panelists 2 and 11 mo after Study 1.

Measures. Our primary outcome for *H1-H3* in Study 1 was a single scale made from eight knowledge and perception items related to mRNA vaccination, which were asked of the ASAPH panelists 2 wk earlier. These eight items were relevant to the vaccine information environment at that time and either the Ladapo or Modeled Knowledge stimuli addressed them directly or indirectly (see *SI Appendix*, Table S5 for all outcomes and their preregistered coding).

Our primary outcome for *H1-H3* in Study 2 was a 15-item scale made from those eight items plus seven additional knowledge and perception ones. Ten of fifteen used the scale *definitely false* (1), *probably false* (2), *probably true* (3), and *definitely true* (4), with an explicit *not sure* option. All items were recoded so that the most evidence-based response was coded as 1 and the most unwarranted response was coded as 0, with *not sure* as the midpoint (0.5).

Our primary outcome for *H4* tested whether models led to less spread between responses to items about "mRNA COVID-19" compared to "COVID-19" vaccines. In addition to the 15 items about mRNA COVID-19 vaccines described above, both studies asked a matching subset of 10 items about just COVID-19 vaccines, three from the eight items for Study 1 (Changes DNA; reverse-coded, Safer than COVID-19, Harmful Effects; reverse-coded) and all seven additional items included in the 15-item scale. Pairs of items were asked sequentially with the COVID-19 item asked first. Two 10-item scales were created from each question set and then subtracted to form the primary outcome. Information on secondary outcomes are in *SI Appendix*, Tables S14 and S27.

Statistical Analysis. After removing participants who failed the time, attention, or validity checks, we conducted an exploratory factor analysis on the 15 mRNA vaccination knowledge and perceptions and the subset of eight items to determine whether we could treat them as scales of mRNA vaccination knowledge and perceptions. Since scales had Cronbach's αs over 0.80 and the scree plots indicated only one factor, we retained all items when creating the main scales by averaging across items.

Differences between conditions on primary outcomes were estimated using ordinary least squares models with indicators for treatment conditions. All analyses were weighted to represent the residential adult population of the United States. We report unstandardized bs in the text, Tables 2 and 3 and *SI Appendix*, Figs. S3 and S4, and several of the Supporting Tables, but estimated marginal means elsewhere, given the number of referent categories. All regression models that grouped conditions can be found in Supporting Tables testing *H3B*. To reduce variance around the estimates, all models also controlled for pretreatment demographics (age, education, gender, party identification, and racial/ethnic identity), as well as amount of prior exposure to vaccination information. These covariates typically predict vaccine-related knowledge and perceptions. We present unadjusted models in *SI Appendix*, Tables S23–S26. We also conducted 15 individual analyses, adjusted for multiple tests within hypothesis, across models, using the Holm–Bonferroni technique. Within-respondent changes for the ASAPH panel in Study 1 were estimated using linear difference-in-differences models with respondent-level fixed effects for nine models (the 8-item scale, and one for each of the 8 individual items).

Finally, we conducted two exploratory factor analyses to determine which of the 10 knowledge and perception items about mRNA COVID-19 vaccines and 10 identical items about COVID-19 vaccines could be included in each scale. Both scales had a Cronbach α over 0.80 and the scree plots indicated only one factor, so we kept all items when creating the main scales averaging across items. We then subtracted the COVID-19 scale from the mRNA COVID-19 scale to create a difference score for each person where positive numbers favor evidence-based responses to the mRNA wording. Ordinary least squares models estimating the impact of condition on the consistency between responses to mRNA and non-mRNA items are identical to fixed effects models. We also tested individual pairs of items separately, using Holm–Bonferroni to adjust for multiple tests within each hypothesis.

Data, Materials, and Software Availability. Anonymized survey data (79, 80) and analytic code for replication (81) have been deposited in OSF.

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Author affiliations: [a]Annenberg Public Policy Center, University of Pennsylvania, Philadelphia, PA 19104; and [b]Annenberg School for Communication, University of Pennsylvania, Philadelphia, PA 19104

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