



Target Article

Viruses, Vaccines, and COVID-19: Explaining and Improving Risky Decision-making

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Risky decision-making lies at the center of the COVID-19 pandemic and will determine future viral outbreaks. Therefore, a critical evaluation of major explanations of such decision-making is of acute practical importance. We review the underlying mechanisms and predictions offered by expectancy-value and dual-process theories. We then highlight how fuzzy-trace theory builds on these approaches and provides further insight into how knowledge, emotions, values, and metacognitive inhibition influence risky decision-making through its unique mental representational architecture (i.e., parallel verbatim and gist representations of information). We discuss how social values relate to decision-making according to fuzzy-trace theory, including how categorical gist representations cue core values. Although gist often supports health-promoting behaviors such as vaccination, social distancing, and mask-wearing, why this is not always the case as with status-quo gist is explained, and suggestions are offered for how to overcome the “battle for the gist” as it plays out in social media.

Keywords: COVID-19, Fuzzy-trace theory, Risky decision-making, Vaccination, Gist, Vaccine hesitancy

General Audience Summary

Throughout the COVID-19 pandemic, risky decision-making has determined its trajectory, from deciding whether to socially distance or wear a mask to whether to get vaccinated. Major theories of risky decision-making make different predictions about COVID-19, discussed in this article. According to expectancy-value theories, decisions are made based on relative risks and benefits, suggesting that interventions aiming to reduce risky decisions should focus on making sure people have objectively accurate perceptions about risks, often through providing detailed information. Dual-process theories emphasize two systems that govern decision-making: one unconscious and automatic, the other controlled and deliberative. According to both groups of theories, greater reflection or deliberation is expected to reduce risk taking related to COVID-19. Fuzzy-Trace Theory (FTT) emphasizes that multiple mental representations of information ranging from those that capture precise verbatim details to those that emphasize the underlying meaning, or gist, are encoded

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and processed separately in parallel. However, gist representations are more durable than verbatim representations and so influence decisions more. Gist can support either risk aversion or risk seeking depending on how decisions are framed and how the status quo is perceived (i.e., as categorically “okay” or “not okay”). Crucially, whether social norms or values influence a decision depends on people’s mental representation of their situation. Because young people are major vectors of COVID-19, developmental implications are discussed, and while some theories make bleak predictions about young people’s abilities to prevent the spread of COVID-19, FTT suggests that support in developing the right gist can help them avoid dangerous risks, especially when paired with strong prosocial values and norms. We close by highlighting how many of these themes play out in social media, where messages that are more gisty tend to be more widely shared regardless of whether they contain misinformation, and how providing accurate information is not a sufficient remedy by itself. According to FTT, when trusted sources provide accurate, boiled-down, and meaningful messages emphasizing key information about COVID-19, people are more likely to share such messages and have a better chance of making decisions in accordance with their values.

As we write these words, the world is in the grip of a coronavirus pandemic, dubbed COVID-19, that has killed more than 4 million people (World Health Organization, 2021). In a normal year, seasonal flu kills between 20,000 and 60,000 people annually in the U.S. alone and hospitalizes more than 80,000 young adults 18–49 years of age, posing a considerable risk (Centers for Disease Control, 2021a, 2021b). The lethality and transmissibility of the virus that causes COVID-19 dwarfs the risk of flu—and yet many individuals do not take steps to reduce their risk. As with the seasonal flu, older people are the most vulnerable to COVID-19 but younger people—who are more likely to take risks—are major vectors of infection (Monod et al., 2021). More generally, spreading (e.g., by going to large social gatherings) or preventing (e.g., by vaccinating) viral infections can be thought of as a decision that involves risk and uncertainty.

Here, we discuss relevant findings and apply evidence-based theories of risky decision-making to understand the choices people make to spread or prevent viral infections, such as COVID-19. By “theory,” we mean explanations of behavior that have scientific evidence to support them. We begin with the older foundational theories that continue to be applied (e.g., to COVID-19, Franz & Dhanani, 2021) and then move to contemporary alternatives that have advanced practice and policy, illustrating applications to COVID-19. Throughout, we build on and integrate multiple perspectives (Suleiman & Dahl, 2017). Our approach integrates basic with applied science and spans subdisciplines of psychology and neuroscience, including cognitive, emotional, social, and developmental factors, along with burgeoning work on the dissemination and uptake of social media messages. Using this approach, we discuss underlying mechanisms of risky decision-making that explain prevention behaviors, tested extensively in prior research on medicine and public health, and discuss implications and findings regarding COVID-19. We also discuss implications for the content of what is communicated via social media and how risk messages can be made more effective to combat predictable viral outbreaks in the future.

That is, as a society, we should plan on the prospect that our initial tools in new viral outbreaks will be human behavior, and, if we are fortunate in developing vaccines or therapeutics that reduce viral transmission, subsequent phases of risk reduction will also require human behavior, that is, seeking and accepting antiviral measures such as vaccinations (Matthews et al., 2021). The patterns we have just experienced are likely to be repeated and can be planned for: As the COVID-19 pandemic surged, the weapons to fight it were mainly human behaviors: mask-wearing, hand washing, and social distancing. Once vaccines were developed, the ideations and motivations that drive vaccination were the main line of defense (National Academies of Science, Engineering, and Medicine, 2020).

Therefore, understanding the causal mechanisms of human behavior regarding viruses is a long-term investment in saving lives and reducing suffering, as well as in providing direct and indirect economic benefits (Bloom et al., 2004). This longer view encourages, too, targeting interventions that are more stable over time and that can be applied to new situations, what we call “long-term retention” and “transfer of learning” in cognitive science, which are much needed in real-world settings because similar but not identical problems, such as viral outbreaks, epidemics, and pandemics, tend to recur—especially if people engage in risky behaviors.

Explanations of Risky Decision-making

Our goal is to better understand the choices that people make to spread or prevent viral infections, such as COVID-19, by viewing their behaviors through the lens of research on decision-making, a robust and interdisciplinary field (e.g., Kahneman et al., 2021). However, applying the word “decision” to these behaviors is likely to give the reader pause. The word “decision” conjures up a deliberative process through which individuals make informed and conscious choices. This assumption, that making a decision is a deliberative process, is consistent with traditional decision theories, though as we discuss below, it is not assumed to characterize all decision processes in dual-process approaches or fuzzy-trace theory.

Traditional decision theories applied in public health often incorporate an expectancy-value framework, such as the behavioral decision-making approach, health-belief model, protection-motivation theory, theory of reasoned action, and theory of planned behavior (e.g., Fischhoff & Broomell, 2020; for an exegesis of these theories, see Reyna & Farley, 2006). In this view, the basic building blocks of risky decisions are perceived probabilities (expectancies and personal vulnerabilities) and their associated outcomes, although modern versions of these theories add self-efficacy (belief in one's ability to act on perceptions), perceived behavioral control over outcomes, and social norms (e.g., Prasetyo et al., 2020). Expectancy-value approaches, derived from expected-value and expected-utility theories, imply that choices are reasoned, planned, or rational, at least once perceptions and preferences (rather than objective reality) are taken into account.

These theories have amassed empirical support (e.g., Armitage & Conner, 2001), and they make sense in explaining behavior, although they have major gaps as we discuss below. For example, it makes sense that people who view themselves as vulnerable to bad outcomes and who perceive risk-reduction remedies as effective (i.e., as having good outcomes) would engage in risk-reduction behaviors to the extent that they felt empowered to do so (Bruine de Bruin & Bennett, 2020). In the context of COVID-19, this would mean that providing information about personal vulnerability, effectiveness of vaccines, and accessibility to vaccines (e.g., vaccines are freely available in easy-to-reach locations) in doctors' offices or clinics, over mainstream or social media, and on Web sites would be expected to increase vaccination rates. The huge caveat, and a strength of these theories, is that they highlight that providing information about vulnerability, effectiveness, and accessibility is not the same thing as influencing *perceived* vulnerability, effectiveness, and accessibility (i.e., perceived control). Information (e.g., facts about risks and benefits of behaviors) is necessary but not sufficient. Expectancy-value approaches offer a psychological explanation for why providing information about risks and benefits of behaviors is *insufficient* in motivating risk reduction, namely, that there can be a gap between perceptions and reality and that people might not feel able (or be able) to act on their perceptions.

In contrast to people who perceive risks and thus avoid them, those who take risks are readily seen as thinking they are "invulnerable," a belief commonly attributed to adolescents (American Psychological Association, 2021). For example, if risks are perceived as not applying to the individual—an optimism bias—then risk-taking is encouraged (Shepperd et al., 2013). However, invulnerability has frequently been shown to not explain taking risks. Adolescents often think of themselves as being at higher risk than adults think of themselves as being; many adolescents also have a grossly exaggerated view of the likelihood that they will die young (Fischhoff, 2008). These findings are relevant to risky decisions, such as those surrounding COVID-19, because fatalism, too, encourages risk taking; one might as well enjoy life to the fullest now, regardless of the risk, if death is likely anyway. Avoiding fatalism has been identified as an important strategy in curtailing the spread of COVID-19 (Galván et al., 2020).

A concept related to optimism bias is optimistic *update* bias, which is that people update their beliefs to a greater extent when receiving good news compared to bad news (Sharot, 2011; Garrett & Sharot, 2017). Optimistic update bias is particularly acute in adolescence, which explains why adolescents are less informed by health-related risk information about negative consequences than adults are (Moutsiana et al., 2013). Adolescents learn less from bad news about their risk perceptions, that they are underestimating risks than from good news—that risks are being overestimated (less than anticipated). Still, allowing for adults' and adolescents' faulty perceptions, unhealthy risk taking is rational in expectancy-value approaches because behavior follows logically from the individual's perceptions of risks and benefits. These explanations also provide entering wedges for remediating risky behaviors: target perceptions of risks, benefits (e.g., incentives, but see Robertson et al., 2021), and control (e.g., accessibility; Volpp et al., 2021).

Implications of Expectancy-Value Theories for Risky Decision- Making About COVID-19

Evidence indicates that the elements of traditional expectancy-value theories correlate with risk-reduction behaviors, such as vaccination (Brewer et al., 2018). In addition, programs that implement them have produced promising results in other risk domains, such as HIV-prevention (for a review of effective curricula that apply these theories, see Kirby et al., 2007). Crucially, Romer and Jamieson (2020) showed that perceptions of risk, specifically personal and national threats from COVID-19, predicted vaccination intentions in March 2020 which then predicted mask wearing and vaccination intentions in July 2020, controlling for other factors, including media exposure. The longitudinal nature of this design, as well as controlling for prior beliefs in predicting subsequent intentions, supports causality, although their design was not an experiment designed to alter beliefs about risks, benefits, and control.

Sobkow et al. (2020) conducted such an experiment. They found that enhancing self-efficacy and using visual aids aimed at improving risk understanding were not effective in changing COVID-19-related behavioral intentions. However, correlational results were significant. Intentions toward preventive behaviors were *positively* predicted by self-reported worry about health, perceived controllability of the pandemic, and risk perception. Worry about restricting personal freedom predicted intentions, too, in the opposite direction: More worry about freedom correlated *negatively* with risk-reduction intentions.

Sobkow et al.'s (2020) results are broadly consistent with a literature review conducted by Brewer et al. (2018) regarding the psychology of vaccination, that the elements of expectancy-value approaches correlated with vaccination and vaccination intentions. Brewer et al. concluded that despite a great deal of such correlational evidence, theoretically motivated interventions to change vaccination intentions and behavior had rarely been demonstrated to be effective. Thus, they contended that external factors, such as incentives, defaults, sanctions, and mandates were more realistic alternatives to

change behaviors than internal factors, such as knowledge and attitudes.

Another element of many expectancy-value approaches, conformity to social norms, also need not involve knowledge or buy-in from decision-makers to be effective. Perceptions of what other people are doing, descriptive norms, and other social pressures generally influence behaviors (though not reliably for vaccination). Decision processes are not isolated in the individual mind but influenced by societal-political-cultural factors (in addition to internalized social values and norms; Gollwitzer et al., 2020). In fact, Graupensperger et al. (2021) found that estimated social norms were positively associated with young adults' own intentions and perceived importance of getting a COVID vaccine. However, as Young and Goldstein (2021) explain in the context of COVID-19, descriptive norms of social behavior are sometimes difficult to observe (e.g., when socially distant), and these can differ from injunctive norms, others' approval or disapproval. Nevertheless, human beings have a deep desire to conform to both descriptive and injunctive norms, even when they do not agree with them or understand why others are engaging in behaviors. Hence, expectancy-value theories typically distinguish between underlying attitudes, pro or con toward a behavior, and behavioral adherence.

Thus far, we have described decision processes that are essentially logical and rational, albeit with some motivational distortions (e.g., optimism bias), social influences, and potentially inaccurate perceptions of risks, benefits, and accessibility. (Social rewards could also be construed as "benefits" in a rational calculus; see Sunstein, 1996.) Practitioners need evidence-based theoretical principles to design effective interventions that can be adapted through knowledge about psychological mechanisms as conditions change, whether they are health messages, media, or curricula. The targets of interventions grounded in expectancy-value approaches would be to induce health-promoting perceptions, for example, of probabilities that are precise and accurate with respect to objectively risky realities (to the degree that exact probabilities are known). From this perspective, the ideal process of decision-making would be to trade off those precise and accurate probabilities against precise and accurate outcome magnitudes (and valences), and then to compare available options in terms of their overall expected values, bolstering self-efficacy, perceived control, and healthy social norms to reveal underlying preferences.

For example, consider the probability of an unvaccinated person contracting COVID-19 by attending a party with 30 unvaccinated people versus staying home and watching a movie with a roommate. In an expectancy-value formulation, the question becomes, is the amount of enjoyment to be had (the potential outcome) of a large social gathering worth the risk of COVID-19 to oneself and others—and how does this option compare to its alternatives. According to expectancy-value approaches, the option with the highest overall expected value—taking into account perceived risks, benefits, norms, and barriers—would and should be chosen. The main challenge, then, is to communicate accurate information because,

as concluded in a recent summary of the implications of social and behavioral science for risk reduction in COVID-19, "Sound health decisions depend on accurate perceptions of the costs and benefits of certain choices for oneself and for society." (Bavel et al., 2020, p. 461). Initial evidence about COVID-19 supports this role for scientific, numerical, normative, and contextual information about rates of infection in preventative decisions (Broomell et al., 2020; Murray et al., 2021). The questions we take up in subsequent sections are what is missing from this account of health decision-making and whether there are crucial decisions for which this approach is fundamentally at odds with how people actually think.

Beyond Rational Choices: Emotions and Dual Process Theories

In their summary, Bavel et al. (2020) acknowledge that emotions often drive perceptions more than objective facts about costs and benefits. Sobkow et al.'s (2020) results about worry in the context of COVID-19, discussed above, are consistent with an important role for emotion. Similarly, Broomell et al. (2020) and Franz and Dhahani (2021) report variance attributable to fear/anxiety, in addition to knowledge and perceived severity, in behavioral responses to COVID-19. Expectancy-value theories have been criticized for neglecting the role of "risk as feelings" (Loewenstein et al., 2001; Weber & Johnson, 2009) and other non-rational influences on risky decisions (Kahneman, 2011; Evans & Stanovich, 2013). Strictly speaking, emotion is not necessarily irrational; it can be folded into other factors that determine utility (Lerner et al., 2015). Nevertheless, despite the sometimes salutary effects of fear, when people take risks that can adversely affect their health, such as not wearing masks or vaccinating, researchers often point to emotion as undermining rational choices.

The greatest empirical challenges to rational decision-making models attacked their most basic axioms, on which all of the other assumptions depend (e.g., Tversky & Kahneman, 1986), which was an impetus for dual-process theories (Kahneman, 2003). Dual-process theories differ in their specific characterizations of the two systems (De Neys, 2018). However, overall, they hold that human judgment and decision behavior is driven by automatic and unconscious mental processes (system 1), sometimes including emotions (e.g., Epstein, 1994; Slovic et al., 2005), as distinguished from controlled and reflective processes (system 2), and the latter inhibits biases generated by the former.

Thoma et al. (2021) tested dual-process theory in the context of COVID-19. What they termed "the quality of mental models," defined as knowledge about disease infection and transmission, predicted self-reported risk-reduction behaviors (e.g., mask-wearing). However, despite the importance of mental models (e.g., Downs et al., 2008), it is not clear the degree to which mental models of this sort are related to predictions specific to dual-process theories. Thoma et al. also used a measure of "cognitive failures" (Broadbent et al. 1982), thought to index working-memory capacity and, hence, represent operations of the system 2 algorithmic mind (Evans & Stanovich,

2013; but see Corbin et al., 2010). Fewer self-reported cognitive failures were predicted to support greater adherence to risk-reduction behaviors (see also Xie et al., 2020). An influential metric of dual-process theory, the Cognitive Reflection Test (CRT), was also applied in prediction models (Frederick, 2005). The CRT is thought to tap the reflective mind, another system 2 operation; the items on this test have compelling intuitive system 1 responses that can be overridden by system 2 thinking.

Although Thoma et al. (2021) found that cognitive failures were related as expected to precautionary behavior regarding COVID-19, the CRT was related in a direction that was the opposite of that predicted by dual-process theories: More reflective ability was related to *less* risk reduction. The authors had expected, and dual-process theories predict, that higher scores on the CRT would be positively related to risk reduction. That is, overriding automatic unthinking defaults of routine pre-COVID-19 behavior (e.g., not wearing a mask, not social distancing), simulating the consequences of risk-reduction behaviors, and other system 2 deliberations featured in dual-process theories would facilitate taking precautions to reduce health risks (see also Bavel et al., 2020). Arguments that detecting or reflecting on a problem does not always lead to appropriate behavioral responses (e.g., Risen, 2016) cannot explain Thoma et al.'s contrary results, namely, that more reflective individuals were significantly *less* likely to report reducing risk. These results are perhaps consistent, post hoc, with the greater cognitive ability of those higher in CRT to rationalize behavior in light of their ideologies and motivational biases, which would allow them to downplay inconvenient truths (Kahan, 2013). Interestingly, Thoma et al. also tested the theory of planned behavior and found that perceived behavioral control, but not other attitudes or beliefs about social norms, predicted risk reduction, accounting for about the same amount of variance as the dual-process constructs.

In summary, expectancy-value theories and dual-process theories emphasize cognitive reflection, planning, and deliberation in decisions to reduce COVID-19 and other risks. Increasingly, theories admit the role of emotion and intuitive processes in risky decisions, and emotion is sometimes even recognized as a beneficial influence (and system 2 as a source of errors). For example, fear, when accompanied by perceived control or efficacy, can be positively related to risk reduction (Wise et al., 2020; but see Jørgensen et al., 2021). Nevertheless, in contemporary theorizing, less advanced evolutionarily “older” system 1 processes are often juxtaposed against more advanced evolutionarily “newer” rational thinking of system 2 (Evans & Stanovich, 2013). Similar contrasts have been invoked to explain, on the one hand, belief in conspiracy theories and susceptibility to fake news (Pennycook & Rand, 2019) and, on the other hand, the effectiveness of accuracy nudges that encourage cognitive reflection to ameliorate this seemingly irrational thinking (e.g., reducing belief in COVID-19 misinformation in social media; Pennycook et al., 2020).

Below, building on the work discussed in this section but going beyond it, we present a theoretical framework that intro-

duces a third way of thinking—gist-based intuition—that is neither system 1 nor system 2, but which helps explain risky decision-making and disease prevention related to COVID-19, including vaccination. The implications of this framework are explored with respect to mental representations of meaning, elicitation of emotions, application of social values, and risk communication in mainstream and social media.

Fuzzy-Trace Theory

Our purpose in this section is to explain fuzzy-trace theory (FTT), give examples of critical results that test it, and illustrate how it applies to COVID-19. The theory has been tested across several empirical domains including very practical applications, ranging from NASA engineers making risky decisions about cargo missions to patients and physicians making risky decisions about medications (e.g., Fraenkel et al., 2015; Klein et al., 2017; Marti & Broniatowski, 2020). Its public health relevance has been demonstrated in randomized experiments encompassing transmission of viral disease, genetic risk, and cancer prevention (for a review of FTT's applications in health and medicine, see Blalock & Reyna, 2016).

The core concept of FTT is the assumption of multiple mental representations of information: verbatim representations of surface form (exact words or numbers, sentences, graphs, or other images as presented) and gist representations of meaning that vary in precision (for a review, see Reyna, 2012a). These mental representations are referred to as “memories” of a stimulus, but they apply from initial encoding—they are what is worked on in working memory—to long-term retention after days, weeks, or years. One of the implications of FTT's verbatim-gist independence assumption that is highly relevant in practical applications is that the effect of verbatim information is predicted to fade out on knowledge tests over time—but memory for the gist of health information is resistant to forgetting. Thus, all is not lost when people forget health information that has been communicated successfully to them because memory for the gist of that information (not memory for verbatim facts) is typically the active ingredient in health and medical decision-making.

People must not only retain health information over time but also use that information wisely to make health judgments and decisions (Sox et al., 2013). According to FTT, mental representations are input to thinking operations, some of which can be characterized as reasoning processes in the classical sense (e.g., deduction and induction) and others of which are heuristic as opposed to algorithmic (e.g., quantitative principles, such as the cardinality principle that more numerous things tend to be more probable or affective principles, such as saving more lives is better than saving none or more money is better than less money; Broniatowski & Reyna, 2018; Fukukura et al., 2013). As a result of operating on these representations, the brain generates outputs, as examples, probability judgments and risky decisions that inform risk-reduction behaviors (e.g., Reyna et al., 2009).

Encoding multiple representations and the associated processing of those representations occurs in parallel for most judgments and decisions; parallelism distinguishes FTT from

most dual-process models, which assume a default system 1 process that is sometimes overridden by system 2 (cf. [Martin & Sloman, 2013](#)). For example, FTT predicts the parallelism results found by [De Neys et al. \(2011\)](#) and [Thompson and Johnson \(2014\)](#), namely, that confidence decreases when an intuitive response conflicts with a normative analytical response, compared to no conflict. Research on FTT has investigated how intuitive and analytical processes operate in parallel (defined in terms of verbatim and gist representations, as required by data) and how this parallelism underlies information processing in reasoning tasks, as well as in risk perception and risky decision-making (e.g., [Reyna, 2004](#); [Reyna & Brainerd, 1994, 2008](#); [Wolfe & Reyna, 2010](#)). Understanding how intuitive and analytical processes operate—namely, theory—is crucial for understanding how people process information about COVID-19 and, more generally, about viruses and vaccines ([Bavel et al., 2020](#); [Reyna, 2020](#)).

FTT makes a series of counterintuitive predictions that have been tested in laboratory and applied settings regarding decisions about viruses and vaccination, for example, that people mistakenly believe that condoms prevent the spread of human papillomavirus because they block the exchange of fluids or that risk perceptions of HIV can be both positively and negatively correlated with risk-taking behaviors depending on whether verbatim or gist perceptions are elicited (e.g., [Adam & Reyna, 2005](#); [Fraenkel et al., 2016](#); [Reyna, 2012b](#); [Reyna et al., 2011](#)). Parallelism findings are relevant to these claims because they challenge standard dual-process theory, applied to COVID-19, as indicated above: Because intuitive system 1 responses are supposed to be observed in the absence of system 2 processes (i.e., when system 2 processes are not elicited), it makes it difficult to see how dual-process theory can account for evidence of both dual processes operating when reasoners give the intuitive response. These results about reasoning are relevant to COVID-19 because they tell us how the brain processes information, which allows scientists and practitioners to understand what seems to be inexplicably irrational human behavior when survival is at stake (e.g., not wearing a condom or not vaccinating): Conflicting cognitions proceed along separate tracks in the mind despite metacognitive monitoring sometimes detecting a conflict.

Recent research on COVID-19 confirms the existence of such conflict using sophisticated cognitive tracking procedures ([Murray et al., 2021](#)). Predicted relationships among judgments about new information, misinformation, and prior knowledge have been spelled out in mathematical models of FTT ([Reyna et al., 2016](#); see also [Reyna, 2012b](#)). An integrated model combining these ideas about memory, decision-making, social values, and socio-political-cultural beliefs (e.g., world view, conspiracy theories) has been developed for vaccine hesitancy and is being tested for COVID-19 ([Reyna, 2012b](#)).

Another surprising implication of the theory is that, although political ideology and selective exposure to information appear to combine to produce resistance to changes in opinion and behavior (e.g., [Kates et al., 2021](#)), some ideas can be predicted to be more intuitively appealing to specific audiences ([Reyna, 2012b](#)); for example, cultural differences

in uncertainty attitudes found to matter in COVID-19 ([Huynh, 2020](#)) have been modeled in the context of FTT ([Broniatowski & Reyna, 2018](#)). Furthermore, there are practical means to access knowledge and cue the application of core values that have instigated change in other emotionally and politically charged decision domains ([Reyna, 2021](#); [Reyna & Mills, 2014](#)). No one factor is a panacea, and multiple factors must be taken into account to achieve change. Communicating early in a pandemic about the gist of viral transmission and laying the groundwork in bottom-line knowledge (e.g., “prebunking” with gist-based messages) is also important ([van der Linden et al., 2020](#)). However, appealing to intuition does not have to mean relying on evolutionarily unsophisticated processes common to children and nonhuman animals or knee-jerk emotions that have no grounding in scientific literacy or numeracy.

For example, some sophisticated forms of logical and probabilistic knowledge are intuitive and are activated automatically when people engage in a reasoning task, and detailed processing models of logical and probabilistic reasoning have been offered that distinguish underlying competence from manifested performance in specific risk and probability judgment tasks (e.g., [De Neys, 2012, 2018](#); [Reyna et al., 2003](#); [Reyna & Brainerd, 1994, 2008](#); [Sloman, 1996](#)). These theoretical ideas have been applied to explain why sophisticated probabilistic reasoning can be observed in preliterate and prenumerate cultures (e.g., [Fontanari et al., 2014](#)) while educated adults worldwide display irrational biases and fallacies in such reasoning (e.g., [Reyna & Brainerd, 2014](#)), answering the intriguing question, why are there “smart babies, risk-savvy chimps, intuitive statisticians, and stupid grown-ups” when it comes to probabilistic reasoning ([Schulze & Hertwig, 2021](#)). By formatting probabilistic information in ways that tap this intuitive knowledge, theory-driven applications have shown that distortions in judgments and decisions can be diminished ([Reyna, 2008](#); [Lloyd & Reyna, 2009](#); [Wolfe et al., 2015](#)).

To summarize FTT’s account, the answer to the question above goes beyond differences between intuitions about probabilities described verbally instead of learned through experience and involves (a) characterizing basic cognitive competence in gist terms (e.g., understanding the concept of how ratios of frequencies of target and non-target events define probabilities); (b) identifying the gist of communicated information from the perspective of message recipients and experts; (c) identifying background knowledge that colors the interpretation, or gist, of information (including science literacy, numeracy, and world view); (d) identifying how different gist representations of information cue core values stored in long-term memory; and, finally, (e) tapping research on cognitive appraisals and other research on emotion to predict how these integrated gist representations and core values elicit emotions ([Lerner et al., 2015](#); [Reyna, 2021](#); [Rivers et al., 2008](#)). Like dual-process theories, FTT also assumes there are developmental and individual differences in metacognitive monitoring and inhibition (e.g., censoring inconsistent responses or inhibiting interference from contradictory mental representations, shown

to be distinct from the aforementioned factors; Broniatowski & Reyna, 2018; Stanovich & West, 2008). The psychology of each of these aspects of probabilistic reasoning and risky decision-making contributes to predictable variability in whether people apply the knowledge they have or fail to understand or be persuaded by risk communications.

Distinctions Between Fuzzy-Trace Theory and Dual Processes

Practitioners and policy makers care whether theories about risky decision-making are true (although no scientific theory is true; instead, they are more or less useful). After all, many lives are at stake in the COVID-19 pandemic and in other health and medical decisions. Scientific progress is hindered when the wheel continues to be reinvented or when innovations are misunderstood as reinventing the wheel. Clarifying theoretical claims in an applied context is essential for progress—and few journals are better suited to bringing forth these issues than this one.

In this connection, it is important to compare dual-process theories and FTT, which both have evidence-based implications for risk reduction, misinformation acceptance, and vaccine hesitancy. Differing from approaches that assume that logic and intuition are similar kinds (e.g., De Neys, 2012), FTT posits verbatim and gist representations of information, which cannot be reduced to system 1 versus system 2 (see Reyna, 2013, for an extended argument and additional evidence from research on memory, judgment, reasoning, and decision-making). FTT, unlike many dual-process models (Keren & Schul, 2009), has been subjected to rigorous empirical tests of whether there are two qualitatively different types of processing. Capturing the current debate about dual processes well, De Neys (2021) explains that “Popular dual-process models of thinking have long conceived intuition and deliberation as two qualitatively different processes. Single process model proponents claim that the difference is a matter of degree and not of kind (p. 1)” However, he concludes that “there is currently no good evidence that allows us to decide the debate (p. 1)” This conclusion does not apply to FTT because the theory is supported by evidence of single and double dissociations of verbatim and gist processes, stochastic independence of these processes, and mathematical models in which parameters vary differently as predicted, all of which bear on the hypothesis of “qualitatively different processes” (e.g., Abadie & Waroquier, 2020; Abadie et al., 2016; Brainerd et al., 2018; Reyna et al., 2016; Stahl & Klauer, 2008, 2009).

Among the most probative evidence for the reality of distinct verbatim and gist representations, and associated processing, is experimental manipulation that uses the same stimuli and participants to show opposite effects under theoretically predicted conditions (e.g., Reyna & Kiernan, 1994, 1995). As Murray et al. (2021) have shown, these conflicting cognitive effects apply to COVID-19. For example, suppose a person is given the following information about viral risks: “Seasonal flu kills between 30,000 and 60,000 people annually in the U.S. The death rate from the flu is estimated to be about

0.1% of all people who contract it. The death rate from COVID-19 has been estimated at 1%–25% of all cases, depending on the country.” As studies on health and medical decision-making have indicated, people presented with such information encode the literal verbatim representations in parallel with representations of categorical gist, for example, “A large number of people die from flu each year” and ordinal gist, for example, “COVID-19 is more deadly than the flu.” These specific kinds of gist representations involving categorizing numbers as small/large or some/none, as well as ordinally discriminating them as relatively smaller or larger than one another, have been shown to be routinely encoded (e.g., Brainerd & Gordon, 1994; Thompson & Siegler, 2010).

As illustrated by our examples, gist representations can essentially paraphrase separate inputs in a more general but meaningful form, or they can draw together multiple inputs into a logical or pragmatic inference that goes beyond stated information but similarly captures overall bottom-line meaning (Kintsch, 1988; Reyna et al., 2016; Singer & Remillard, 2008). It seems that gist has to be derived from verbatim representations and that independence is not a testable assumption in any case, but neither of these assertions is true. Reyna and Kiernan (1994, 1995) showed that memory for presented information (with elaborate controls for similarity in surface form, the length of study and test stimuli, and so on) was stochastically *independent* of memory for gist, even though these verbatim and gist memories were based on the same inputs when tested under immediate conditions after a short buffer. Thus, from the beginning of processing information, what people read or hear is independent of the gist they take away from the stimulus. Thus, the practitioner must design interventions with both verbatim facts and take-away gist in mind, which often changes how the message is framed.

Moreover, verbatim memory becomes rapidly inaccessible and gist representations form the primary basis for cognitions after a long-term retention interval of a week or more; after this delay, recognition of presented items and gist test probes are *positively* dependent on one another because they are both grounded in memory for gist. Thus, the objective and precise facts provided in risk communications about viruses such as COVID-19 are filtered through background knowledge and remembered as subjective gist—and this gist that was never explicitly presented governs risk perceptions and protective actions over time (Reyna & Mills, 2014).

Conversely, without a short buffer in between them, recognition of presented items and test probes are *negatively* dependent on one another because they are both based on verbatim memory; verbatim memory is used to reject gist probes as never having been presented (and thus they are judged “new” rather than as presented facts). This ability to engage in accuracy monitoring based on verbatim memory for facts is very short-lived and thus is unlikely to influence most risky decisions in real life (Ackerman & Thompson, 2017). Dandignac and Wolfe (2020) reviewed the evidence about how these FTT constructs apply to authentic medical texts that convey risks and showed that texts that promote gist representations are better retained. Risk communications regarding COVID-

19, therefore, should be designed with the goal of promoting gist from the outset as that is the residue of learning that will be available to resist misinformation and to guide behavior over the long run. Messages that communicate gist can not only be expected to have more enduring effects (because gist memories last longer than memory for verbatim details), but their abstraction makes them more easily transferred to new situations, supporting the practical goals of both long-term retention and transfer of learning.

How Memory Representations Predict Risky Decision-Making

Even in the short term, although multiple gist representations that vary in precision are encoded, cognition preferentially relies on the simplest gist representations that can be used to accomplish a task, called the “fuzzy processing preference.” This cognitive “preference” is not about overt likes and dislikes but instead involves the level of representation used, consciously or unconsciously, to perform a task. Contrary to dual-process theories, this preference and associated gist-based biases increase from childhood to adulthood, as predicted by FTT (“developmental reversals” with greater false memories, framing biases, conjunction biases, etc. as cognition advances; Reyna & Brainerd, 2011; Reyna et al., 2014). Evidence for this preference has been gathered from many tasks, including scientific and mathematical reasoning, logical reasoning, mental arithmetic, comprehension and memory for metaphors, narrative inference, and risky choice (see Reyna, 2012a). Mathematical models also incorporate the fuzzy processing preference (e.g., Brainerd et al., 2018; Broniatowski & Reyna, 2018; Reyna & Brainerd, 2011), and thus tests of the models are tests of this assumption, too.

These assumptions about representations produce straightforward predictions about risky decision-making (e.g., Reyna et al., 2014), and such choices have been linked to COVID-19 mask-wearing (Byrne et al., 2021). These assumptions provide specific conditions under which a variety of paradoxes in decision-making should be observed, such as why do choices diverge from expected value even when decision-makers can recall exact information and combine it correctly (according to expectancy-value theories; Reyna & Brust-Renck, 2020)? More concretely, imagine that you could have voted for one of two programs to combat COVID-19 that is expected to kill 600,000 people: One program saves 300,000 people’s lives for sure and the other program has a 50% chance of saving 600,000 lives and 50% chance of saving no one. Which would you choose? A corresponding personal decision dilemma is being faced with a certain option that offers modest benefits, such as staying at home to watch a movie but remaining safe, versus taking a risk, such as going to a large party where more fun can be had but incurring the risk of contracting COVID-19 (Edelson & Reyna, 2021). When this kind of dilemma is posed in terms of lives or money *gained*, people are generally risk averse. When the same dilemma is phrased in terms of deaths

or money *lost*, such as 300,000 will die for sure versus a 50–50 gamble that 600,000 die or no one dies, preferences shift to risk seeking. The shift from risk aversion for gains to risk seeking for losses is called a framing effect, and it challenges basic axioms of rational choice approaches, such as expectancy-value theories (e.g., Tversky & Kahneman, 1986).

Applying the fuzzy processing preference from FTT, and hence the simplest categorical distinctions between options translates these risky decisions into saving some people versus taking a chance on either saving some people or saving none in the gain frame, and some people dying versus some people dying or no one dying in the loss frame (Broniatowski & Reyna, 2018; see Figures 2 and 3 in Reyna, 2012a). This simple gist formulation clearly produces the framing effect, risk aversion for gains, and risk seeking for losses. Experiments have revealed that consistent with FTT’s predictions, gist representations are encoded in parallel with verbatim representations, and the latter captures something like expected values of options, which are equal in our examples: $1.0 \times 300,000 = 0.5 \times 600,000$. These and other results show that gist-based biases that have been widely demonstrated in health and medical decision-making occur even when decision makers have the requisite competence to reason more objectively.

For example, critical tests that eliminate parts of the gamble, such as the zero complement which amounts literally to removing nothing in expectancy-value theories (because any probability multiplied by zero is zero), have revealed that decision makers choose equal-expected-value options about equally often when zero complements are removed (Kühberger & Tanner, 2010). Thus, processing of numerical outcomes and probabilities, when the simpler gist is not available, does not elicit framing effects in risky-choice tasks, ruling out classical (rational choice) and contemporary (prospect theory) expectancy-value theories (see Reyna, Brainerd, et al., 2021). The latter—prospect theory—has also been incorporated into modern dual-process approaches (e.g., De Martino et al., 2006; Kahneman, 2003; Kahneman & Frederick, 2007). In contrast, FTT predicts that the risky shift in framing effects ordinarily hinges on categorical distinctions (e.g., between some people vs. no people), which can pivot on the presence of zero, as observed. (The ambiguity of options cannot explain these effects; see Chick et al., 2016.) Interventions based on FTT can magnify or eliminate framing effects and other biases, which are additional tests of the theory’s predictions (e.g., Reyna et al., 2014; Wolfe & Reyna, 2010) and these theoretical principles have been applied to foster healthy choices involving risk, as discussed below.¹

Social Values and Emotions in Fuzzy-trace Theory

Our account of framing effects highlights that mental representations of gist are important in risky decision-making, but they alone cannot predict risky choices. Knowing that some people are saved in one option and none saved in another does not evoke preferences if the decision maker cares little about

¹ FTT also applies to decisions about options with unequal expected values (e.g., Reyna & Brainerd, 2011; Reyna & Brust-Renck, 2021) and to categorical distinctions that do not involve zeros (e.g., Broniatowski & Reyna, 2018).

human life. Decision makers must have values that are applied to representations to favor one option over another. Thus, FTT draws on research on social norms, but it adds the crucial assumption that many social norms and moral principles are internalized as social values and, like decision options and other risk information, also represented in long-term memory as simple gist representations that incorporate valenced affect (i.e., “good/bad”; Peters, 2020). For example, applicable social values for the choices above would be “saving lives is good” and “people dying is bad.”

The assumption that values are mentally represented in this simple form, and then “compiled” or instantiated when their relevance in context is noted, explains a host of paradoxes and inconsistencies that would otherwise require the assumption of wholesale construction of preferences anew in each context (Lichtenstein & Slovic, 2006). Rather, core values seem to be fairly stable, but their elicitation, like any long-term memory, requires cues in context. The memory principle of encoding specificity further implies that when information or decision options are represented as simple gist representations (e.g., as categorical gist), those representations are better able to cue core values stored in a similar form in long-term memory, which has been demonstrated empirically (e.g., Fujita & Han, 2009). It follows that messages that are formulated in terms of the simplest categorical gist are more likely to retrieve core values, and therefore influence behavior, which has also been observed (for a review, see Blalock & Reyna, 2016).

One way that gist evokes emotion is through valenced affect, by connecting people to feelings about decision options or risky situations. Another way is that gist captures people’s interpretations of information or situations, and this interpretation (with rare biologically hard-wired exceptions; Levy & Schiller, 2021) determines emotional reactions, not the objective information or situation. Although some dual-process theories set cognition in opposition to emotion, cognitive appraisal theories and other attributional approaches to emotion emphasize that emotions occur as a result of cognitions. For example, if people perceive a risk as imminent and large, they justifiably feel fear, as exemplified with COVID-19 but also with other viruses, such as HIV (e.g., Reyna & Mills, 2014). Whether that fear then motivates appropriate actions or not depends on other factors (e.g., self-efficacy and perceived control), as well described in expectancy-value theories, such as the theory of planned behavior (Bavel et al., 2020; Thoma et al., 2021).

Although modern approaches, such as some dual-process theories, rightly point out that emotions deserve greater prominence in explaining risk-related behavior, some examples of so-called irrational thinking are more accurately attributed to reliance on the categorical gist of risk—the categorical possibility of a good or bad outcome even when the decision maker realizes that the objective probabilities are low—rather than unreasoning emotion (Mills et al., 2008; Reyna, 2008). Consistent with this view, conveying the categorical possibility of HIV from unprotected sex using a gist-based approach, alongside objective numerical information about relatively low probabilities, was effective in inducing even adolescents to reduce risk-taking over a long-term follow-up (Reyna & Mills, 2014).

Thus, FTT assigns central roles to emotions and social values that fall naturally out of getting the gist of a decision. Risk communicators do not, therefore, need to eschew social values or avoid eliciting emotions to be honest brokers of information about risk (Reyna, 2021). Indeed, emotions are appropriate responses to understanding the bottom line of many risky decisions, such as the decision to wear a mask to avoid risking the lives of family members or the decision to vaccinate to avoid a horrible death while struggling to breathe. Inferences are sometimes made that people take risks because they do not care about themselves or others (i.e., that they lack certain emotions or social values), but these inferences presume that the gist of a decision is perceived similarly by all. However, if the decision to vaccinate against COVID-19 is construed as the government telling people what to do, core values such as autonomy are likely to be evoked. If the same decision is construed as making a choice to preserve life, with nil risks from vaccination, then personal and prosocial values are likely to be evoked.

This is not to say that external social pressures and mandates do not also exert control over behavior (Brewer et al., 2018). The interpretation of the gist of events, as well as the priority and accessibility of values, are often influenced by the social, cultural, and political context (e.g., Swire et al., 2017). Thus, multiple levels of mental representation, central to FTT, bridge between detailed properties of a stimulus inherent in a verbatim representation and contextual factors that shape gist representations. Social, cultural, and political influences do not jump directly from the outside world into people’s behaviors—they become embodied in mental representations of gist and, along with external factors, then impinge on behaviors.

Implications for Prevention: The Status Quo of Risk

We have applied these ideas about categorical gist based on framing effects and other risk-related phenomena to prevention decisions, including vaccination (Reyna, 2012b). Prevention, such as cancer screening, applies, by definition, to situations in which people are currently asymptomatic. There are two categorical outcomes from screening: either discovering that one is okay (no sign of a problem, ironically termed a negative result) or that one is not okay (a problem is found, a positive result). When offered a variety of possible descriptions of how they viewed the decision to screen for cancer, including tradeoffs, most respondents chose what we call a status-quo gist (e.g., Reyna, 2008): They are okay now and if they get screened, they will either be okay or not okay. Since being okay is better than not being okay, agreement with this gist representation of the screening decision is predictive of not wanting to get screened. Thus, the gist that one is “okay,” a categorically positive status quo, promotes risk aversion. This analysis of a screening decision as taking a risk is not the conventional view that decision scientists or health professionals would probably take. Psychologically, however, the categorical gist of screening for many laypeople is an interpretation of options as a choice between a status quo (no screening) versus screening that is uncertain in that it has two categorically different possible outcomes: good news or bad news.

Perceptions of the status quo and outcomes of screening can be altered qualitatively from categorically okay to not okay (e.g., at-risk) to promote prevention, and vice versa. Web-based tutorials based on FTT have helped laypeople understand whether their family history and other factors put them at low or high genetic risk of cancer (e.g., Wolfe et al., 2015, 2016). Suppose that a person discovers that she has the BRCA genetic mutation for breast cancer; such a person is at-risk (essentially, not “okay”), but this does not guarantee that cancer will develop. A categorical gist does not mean that people believe that the probability is 100% but instead represents a fuzzy “gloss” of their situation—are they *essentially* in a good or potentially bad place.

According to FTT, risk communication that explains why people are in a good or bad place, that conveys the essential meaning behind information, is more likely to be effective. Effective communication would explain why one is at-risk (the threat is a “real possibility” if not a probability) for COVID-19 and that, for example, vaccinating for COVID-19 results in an outcome of being not at-risk (e.g., freedom from fear) with nil chances of bad outcomes, in which case vaccinating will be preferred. Naturally, merely telling people that this is true without explaining why it is true is unlikely to be effective, especially for large sectors of the population that lack scientific literacy, healthy literacy, and numeracy (e.g., Betsch et al., 2017; Bruine de Bruin et al., 2017; Reyna et al., 2009). Even among those who are highly educated and numerate, understanding the gist of such concepts as herd immunity is relatively rare (Downs et al., 2008).

These ideas about gist representations apply to a negative status quo, as well as a positive one, and the former promotes risk taking, a hypothesis tested in a series of studies of patients who presented at emergency departments. Presented with standardized scenarios of a serious respiratory infection that was likely to be viral, and hence not treatable with antibiotics, patients were asked whether they would prefer receiving antibiotics. Lack of background knowledge influences the nature of the gist that is extracted of risky decisions, so it was not surprising to find that patients who endorsed the gist that “germs are germs”—a common misconception about viruses that has been studied in the context of other viral infections such as HIV and human papillomavirus (e.g., Reyna & Adam, 2003)—would be more likely to expect antibiotics (Broniatowski et al., 2015; Broniatowski, Klein, et al., 2018; Klein et al., 2017). What is more, many patients who realized that the illness was viral and not treatable with antibiotics nevertheless expressed a preference to receive antibiotics. The gist that they endorsed amounted to being “sick” is the status quo, and treatment offered the possibility (though not the probability) of being “not sick.” In the likely event that they remained sick, they were back where they began, “not okay,” analogous to the loss frame in a risky decision task.

Although almost none of the physicians endorsed “germs are germs,” many physicians endorsed the status quo gist, and those who did were more likely to recommend antibiotics (Klein et al., 2017). This result with physicians illustrates that this phenomenon is not just about knowledge deficits. As with

epidemics and pandemics, taking antibiotics (and resulting antibiotic resistance) poses a threat to society at large, and appeals that formulate such choices in ways that convey the bottom-line risks to individuals and that tap widely endorsed values of not hurting other people are more likely to be effective than providing inscrutable details.

The same categorical representations of gist derived from framing problems and studied in the emergency department were applied to studies of flu and COVID-19. A study on the gist of flu vaccination decisions showed that, controlling for demographics, knowledge, and perceived behavioral control, decisions to vaccinate for the flu were negatively predicted by endorsements of gist representations of the status quo (vs. the possibility of an adverse effect of vaccination) and positively predicted by simple social values, such as not wanting to hurt other people (Reyna, Garavito, et al., 2021), both predicted in Reyna (2012b). Similarly, in another recent unpublished study, endorsement of the status quo gist for COVID-19 predicted both vaccination intentions and emotional responses to vaccination. Those who endorsed the status quo gist were less likely to intend to vaccinate and were more likely to feel angry about vaccination, actions taken to stop COVID-19, and social isolation because of COVID-19.

Developmental Implications

As we noted at the outset, transmission from and among young people has been identified as a major vector of disease for COVID-19 (Monod et al., 2021). Therefore, it is important to understand how risky decision-making differs developmentally so that risk-reduction measures are effective. Both dual-process theories and FTT make such developmental predictions about changes in risky decision-making, although developmental versions of dual-process theory are not quite the same as adult versions. The former theories emphasize different trajectories of socioemotional and cognitive control systems, reflecting neural development in brain systems (for a review, see Defoe et al., 2015). Thus, we refer to these developmental approaches collectively as a dual-systems model.

According to the dual-systems model, adolescents and young adults (e.g., college students) are particularly susceptible to taking risks that could transmit COVID-19 such as failing to socially distance or wear masks for three main reasons: heightened sensitivity to rewards, lower self-control particularly under emotionally arousing conditions, and vulnerability to taking risks when surrounded by peers (Shulman et al., 2016; Steinberg, 2020; Steinberg et al., 2018). According to this theory, little can be done to curb such risky behavior because these components reflect an immature brain that naturally translates into dangerous behavior (see Sunstein, 2008). Thus, proponents of this perspective advocate increasing the minimum legal age of activities involving emotional arousal under the assumption that young people have difficulty controlling themselves in such situations (Icenogle et al., 2019). This theory ultimately predicts that many high school and even college students (called “older adolescents”) will not abide by social distancing rules or mask-wearing requirements and will take risks despite dangers this behavior presents to their peers or vulnerable members of their communities (Steinberg, 2020).

FTT provides a different outlook. According to FTT, mental representations of information play a critical role in explaining risky decision-making and also offer inroads to helping youth make safer decisions. Per FTT, a developmental shift from reliance on more precise, verbatim mental representations that facilitate trading off risk for reward to more categorical gist mental representations that emphasize important distinctions between options (e.g., being gravely ill or well, dead or alive) has predicted and explained risk taking in health domains, including the spread of sexually transmitted infections or deciding whether to report a concussion (Garavito et al., 2020; Reyna & Mills, 2014). As explained above, reliance on gist helps bring to bear values relevant to decisions, illustrating another way that gist can help promote safer decisions. However, focusing on the details of risky choices (e.g., going to a party would be really fun, and the COVID-19 positivity rate on campus is really low so the chance of actually spreading or catching the virus is small) is more likely to promote taking risks that could transmit COVID-19.

Because gist-based thinking can be trained, (e.g., Reyna & Mills, 2014), FTT predicts that some high school and college students, like older adults, are capable of curbing the transmission of COVID-19 but doing so depends on cultivating and inculcating the right gist (Reyna, 2021; Boissin et al., 2021). Having a reliable source of accurate information about the gist of how SARS-CoV-2 is spread and what it means to get sick with COVID-19 is essential, although knowledge and gist representations of information are not sufficient. Applying strong prosocial values about protecting friends and vulnerable community members from severe illness further contributes to making safer choices, and a strong sense of community reinforces these values. Thus, schools that invested in comprehensive training for students about COVID-19 that emphasized key messages about the virus and fostered a strong sense of community surrounding preventing its spread may have had more success in limiting transmission (Edelson & Reyna, 2021).

Social Media and Misinformation

The research we have reviewed so far places a premium on crafting COVID-19 messages that communicate key components of risks, benefits, and agency or control (including self-efficacy and accessibility), that provide the background knowledge necessary to appreciate these messages, and that inculcate mental representations of gist that connect to core values, which elicit appropriate emotions. Social media messages amplify all of the psychological effects that we have described (Betsch et al., 2012).

Early in the pandemic, an “infodemic” was described as spreading on social media, “an overabundance of information—some accurate and some not—that makes it hard for people to find trustworthy sources and reliable guidance when they need it.” (World Health Organization, 2020; cf. Singh et al., 2020). Concerns about misinformation predated the pandemic (e.g., Lazer et al., 2018), and resulting misconceptions about viral illness, the transmission of disease, government, drug companies, and xenophobia have created fertile ground for risk-related misconceptions and conspiracy theories about

COVID-19 (Lewandowsky et al., 2017; Romer & Jamieson, 2020). Loomba et al. (2021) showed that such misconceptions were associated with reduced intentions to vaccinate for COVID-19, potentially prolonging the pandemic. Older adults appear to share the most misinformation (Brashier & Schachter, 2020). This susceptibility could, in part, be due to verbatim declines in older adulthood that are known to affect memory for sources of information, as opposed to general cognitive declines, but these age trends are likely multifaceted (Reyna & Brainerd, 2011).

Social media messages that express a gist are characterized by communicating a simple bottom-line meaning of facts (e.g., “vaccination saves lives”; Orenstein & Ahmed, 2017), as contrasted with superficial, detailed, but rote facts (e.g., COVID-19 vaccines use messenger RNA or viral vectors; Centers for Disease Control, 2021c; Reyna, 2020). The gist of a message conveys *why*, not just *what*, by integrating pieces of information into an essence in a way that foregrounds what is important and backgrounds what is trivial from the perspective of the communicator (Reyna, 2012b). Studying social media messages around the Disneyland measles outbreak, Broniatowski et al. (2016) reasoned that social media messages that conveyed a gist, as rated by human judges, would also be more widely shared. Supporting this hypothesis, they found that articles on Facebook that expressed bottom-line gists were more widely shared, although articles containing statistics were also more likely to be shared than articles lacking statistics. These results were robust controlling for the presence of narratives (stories) and vivid images that presumably are more engaging than plain text.

Importantly, the distinction between verbatim facts and the gist mental representations of those facts provides leverage for both understanding the efficacy of and responding to misinformation campaigns. Classically, the term “misinformation” refers to demonstrable falsehoods. Thus one major approach to combating misinformation is factual correction—a strategy that has shown mixed efficacy for reducing misinformation spread (Wood & Porter, 2019). To combat misinformation, the World Health Organization and several other groups have created several “mythbuster” resources, with prominent search engine companies, such as Google, automatically surfacing fact-based answers to questions that are based upon misinformation. For example, a Google search for “vaccine mRNA” yields a response to the question “Could an mRNA vaccine change my DNA?”: “An mRNA vaccine—the first COVID-19 vaccine to be granted emergency use authorization (EUA) by the FDA—cannot change your DNA.”

Empirical work shows that fact checks are effective in changing peoples’ assessments of the truth of false content, but these changes do not translate to differences in overall attitudes or beliefs (Nyhan et al., 2020). Indeed people often share content, including content about COVID-19, that they do not endorse as accurate (Pennycook et al., 2020, 2021). Notably, this work has focused on “cognitive reflection,” which taps metacognitive monitoring among other cognitive abilities, suggesting that individuals simply pay little attention to the truth value of online content (Pennycook & Rand, 2019). Consequently, when people are privately encouraged to consider

the accuracy of the content they share, they are less likely to share false content (but also less likely to share true implausible content; Roozenbeek et al., 2021) although sharing is far from eliminated (Pennycook et al., 2020, 2021). These findings are typically explained in terms of standard dual-process theories discussed earlier, where “slow” effortful deliberative thinking corrects reasoning biases and fallacies produced by default processing.

As mentioned above, FTT incorporates assumptions about metacognitive monitoring (and inhibition), akin to system 2 reflective processes, demonstrated as distinct contributors to individual and developmental differences in false-memory acceptance, reasoning fallacies, and decision biases (Broniatowski & Reyna, 2018; Liberali et al., 2012; Macera & Daurat, 2018). Verbatim versus gist processing have been explicitly contrasted with familiarity and recollection, which are phenomenological in FTT—they describe *feelings* that are vague or vivid, respectively (e.g., Brainerd et al., 2018) which, in turn, can be used metacognitively as an imperfect clue about veridicality. Examples of the imperfect relationship between feelings and accuracy, phantom recollection, a concept from FTT, refers to a gist memory that feels recollective although it was never experienced directly (e.g., Dennis et al., 2012), and illusory truth refers to the feeling of familiarity gained from repeating an untrue statement so that it feels true although it is not (e.g., Fazio et al., 2019).

Therefore, theories agree that accuracy nudges should be helpful in reducing the effects of misinformation; they serve as a cue for metacognition, encouraging those people who are not naturally inclined to critically examine their own cognitive outputs and critically evaluate their consistency and accuracy. However, these approaches fall short because metacognition is imperfect and these ideas do not explain the origins of misconceptions and conspiracy theories, to begin with. FTT attributes these origins to an effort to “connect the dots” of experience to explain adverse events that do not make sense or whose causes are unknown (Reyna, 2012b). In addition, accuracy nudges that merely trigger precise processing that focuses on details will fail when, as is often the case, isolated facts are technically accurate but decontextualized.

For example, consider a social media post stating “The recommendation to wear surgical masks in addition to other public health measures did not reduce the rate of SARS-CoV-2 infection among carriers in a community with modest infection rates.” This statement is a factually accurate representation of a randomized controlled clinical trial which did not detect a statistically significant difference in COVID-19 infection rates between subjects who were encouraged to wear masks and those who were not (Bundgaard et al., 2021). Although this study explicitly reports “inconclusive results, missing data, variable adherence, patient-reported findings on home tests, no blinding, and no assessment of whether masks could decrease disease transmission from mask wearers to others” as limitations, it was widely and incorrectly interpreted to indicate that “masks don’t work” to reduce COVID-19 infection, with this misinterpretation amplified by networks of automated accounts (Ayers et al., 2021). As a result, in a controversial

decision considered by some to be censorship, Facebook decided to ban several articles discussing this study (Abbasi, 2020). Online misinformation frequently presents “the facts” in a misleading manner, misinterpreting them out of context. Thus, combatting misinformation through promoting media literacy, fact-checking, or accuracy nudge interventions (Aird et al., 2018) may not be sufficient if they focus on rote facts since verbatim representations are easily forgotten and unlikely to transfer easily to new situations (MacLeod, 2020). Indeed, it is well-established that such “just the facts” responses are often ineffective antidotes to health misinformation (De Wit et al., 2008), especially in the domain of vaccination (Betsch et al., 2012).

Conventional wisdom suggests that narratives, anecdotes, or personal testimonials might be more compelling than “just-the-facts” approaches because they “include all of the key elements of memorable messages: They are easy to understand, concrete, credible . . . and highly emotional” (Betsch et al., 2012, p. 3730; but see Bekker et al., 2013), and there is ample evidence suggesting that online misinformation takes advantage of pre-existing “tropes” (Broniatowski et al., 2020; Dredze et al., 2016; Jamison et al., 2020; Kata, 2010, 2012) to construct misinformative narratives that might resonate online. Often, these tropes interpret spurious correlations or similar coincidences to provide a “factual” basis for conspiracy theories. For example, an online “report” claimed that birth defects due to the Zika virus were due to the use of a larvicide created by Monsanto that was sprayed in affected areas. Naturally, where there are mosquitos, there will be larvicide, thus creating the conditions for a spurious correlation.

The human need to interpret spurious correlation, in particular, to see causal coherence in otherwise meaningless or inexplicable events, helps explain the influence of misinformation and fuels its propagation online (Reyna, 2012b). Thus, online narratives, and especially conspiracy theories, are expected to be especially compelling if they can relate factual, yet decontextualized, information (e.g., a spurious correlation such as the fact that symptoms of autism often appear around the same time as when the CDC recommends that children receive their MMR vaccine doses) to existing explanatory or narrative tropes. To test this hypothesis, Broniatowski and Reyna (2020) collected 9,845 tweets about vaccination and identified those likely to express the gist that “vaccines cause autism”—that is, a coherent, causal story. Of the 1,388 tweets that had at least one retweet, they found that the “vaccines cause autism” gist was the strongest predictor of retweets per follower. Tweets likely to contain intimations of a vaccine-autism link, but no explicit causal connection, were more likely to be shared at least once but not to go viral. The results showed that commonly predicted effects, such as the presence of an image, are associated with at least one share but not with virality. Thus, the prediction that gist is an engine driving online virality, as found by Broniatowski et al. (2016), appears to replicate across social media platforms. In this way, online misinformation about both vaccines and COVID-19 (and, all the more so, vaccines for COVID-19) may be construed as a battle for the gist in the public mind.

In an effort to sow discord, it may be especially effective to take both sides in a battle for the gist. For example, recent research showed that Russian trolls were equally likely to promote pro- and anti-vaccine content (Broniatowski, Jamison, et al., 2018). What made this content especially harmful was not that the content was false, but rather that it portrayed pro-vaccine arguments in a way that attempted to demean those who had questions about vaccines (Broniatowski et al., 2021). Consider the tweet “#vaccines are a parent’s choice. Choice of a color of a little coffin #VaccinateUS” which was sent by a Russian troll—this tweet does not contain misinformation per se; however, its gist is that those advocating for “vaccine choice” are killers. Beyond this polarizing content, explicitly anti-vaccine organizations have been found to increasingly emphasize “freedom of choice” (the value of autonomy discussed earlier) in their advocacy, having progressively moved away from discussions about precise facts—for example, what specific harms a vaccine might cause—to claims that emphasize core values, such as those framing vaccination advocates as authoritarians who seek to deprive Americans of their fundamental freedoms (Broniatowski et al., 2020). Based on preliminary results from a machine-learning model of millions of Facebook posts and tweets from March to May of 2020, similar dynamics appear to be at play in the context of COVID-19 misinformation.

Summary

Online misinformation reflects the ideations and motivations that undergird risky decision-making regarding COVID-19, ranging from not wearing masks to vaccine hesitancy. As theory clarifies, these decisions are multiply determined. Factors include knowledge deficits, motivated reasoning (covered more extensively elsewhere, e.g., Lewandowsky et al., 2017), and “laziness” associated with low levels of cognitive reflection. Although decisions such as vaccination are subject to social and political pressures, changing hearts and minds is not a challenge that should be forsaken—and theory offers inroads to this goal that have been effective in other contexts. Failing to change hearts and minds risks eruptions of political disfavor because decision makers are coerced rather than convinced.

In addition, we argue that bottom-line meaning, such as coherent gists attributing causality, determines relevant emotional responses to risk communications, the effectiveness of risk-reduction interventions, and online message spread. Providing a gist interpretation is neither simply persuasion, which attempts to change values and beliefs, nor is it simply offering neutral facts. Instead, gist-based intuition is the third way of thinking that goes beyond those posited in expectancy-value and standard dual-process approaches. Building on laboratory studies of risky choice, practical predictions regarding reactions to information about viruses, vaccines, and COVID-19 can be derived, including the idea that risk prevention reflects categorical judgments about the status quo and its alternatives.

A key insight of FTT is that people might not interpret the gist of the facts in a way that evokes a relevant core value. FTT separates the interpretation of facts—gist—from the application of values. For example, one might endorse the overall gist that vaccines are safe yet not endorse mandating universal

COVID-19 vaccination because of the value of freedom. The implication is that each of these factors requires attention to effectively communicate about risky decisions. Furthermore, people are more likely to make decisions consistent with their core values when they are given a gist that enables them to see how these values are relevant to specific contexts. In this way, FTT’s focus on the interpretation of facts is different than, and goes beyond, the standard approach to online misinformation, which often focuses on the truth or falsity of online claims. Motivational factors, such as vivid media, may be helpful in getting a message noticed but do not necessarily make it go viral once it is noticed. Once noticed, gist amplifies virality. In sum, we cannot afford to ignore the science of risk communication and decision-making. We must take bold action to save lives during a pandemic while never giving up on explaining why those actions are being taken and how they connect to our shared values.

Conflict of Interest

The authors declare that they have no conflict of interest.

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