Published in final edited form as:

Vaccine. 2012 May 28; 30(25): 3790–3797. doi:10.1016/j.vaccine.2011.11.070.

Risk Perception and Communication in Vaccination Decisions: A Fuzzy-Trace Theory Approach

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Abstract

The tenets of fuzzy-trace theory, along with prior research on risk perception and risk communication, are used to develop a process model of vaccination decisions in the era of Web 2.0. The theory characterizes these decisions in terms of background knowledge, dual mental representations (verbatim and gist), retrieval of values, and application of values to representations in context. Lack of knowledge interferes with the ability to extract the essential meaning, or gist, of vaccination messages. Prevention decisions have, by definition, a status quo option of “feeling okay.” Psychological evidence from other prevention decisions, such as cancer screening, indicates that many people initially mentally represent their decision options in terms of simple, categorical gist: a choice between (a) a feeling-okay option (e.g., the unvaccinated status quo) versus (b) taking up preventive behavior that can have two potential categorical outcomes: feeling okay or not feeling okay. Hence, applying the same theoretical rules as used to explain framing effects and the Allais paradox, the decision to get a flu shot, for example, boils down to feeling okay (not sick) versus feeling okay (not sick) or not feeling okay (sick, side effects, or death). Because feeling okay is superior to not feeling okay (a retrieved value), this impoverished gist supports choosing not to have the flu vaccine. Anti-vaccination sources provide more coherent accounts of the *gist* of vaccination than official sources, filling a need to understand rare adverse outcomes.

Keywords

risk perception; risk communication; gist; fuzzy-trace theory; meaning; values

Vaccinations have become a mainstay of public health programs to prevent disease. However, such programs have come under scrutiny around the world, with controversial charges being leveled that vaccines cause diseases, rather than prevent them. The particular diseases purportedly caused by vaccines vary across countries—narcolepsy was associated with the H1N1 vaccine in Sweden and Finland, whereas autism was associated with the measles, mumps, and rubella (MMR) vaccine in the United Kingdom and in the United States.¹ In the era of Web 2.0, the contagion of ideas, transmitted rapidly through social

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¹The association between narcolepsy and the pandemic vaccine is currently under investigation, and I do not mean to imply that such an association is necessarily unfounded. As I discuss, the human tendency to interpret events as meaningfully connected applies to both actual and illusory correlations, yielding both hits and false alarms (for a discussion about the adaptiveness of this focus on meaning, or gist, see Reyna & Farley, 2006; Reyna, Lloyd, & Brainerd, 2003).

media, is as concerning as the contagion of diseases because of their power to reduce vaccination rates, leaving populations vulnerable to preventable morbidity and mortality.

In this article, I present a process model of how people make vaccination judgments and decisions, grounded in empirical evidence about risk perception, risk communication, and decision making, drawing out implications for public health (e.g., Brewer, Chapman, Gibbons, Gerard, McCaul, & Weinstein, 2007; Kuhberger & Tanner, 2010; Lipkus & Peters, 2009; Reyna, 2008; Rothman & Salovey, 1997; Valente & Fosados, 2006). Derived from a broader theoretical perspective known as fuzzy-trace theory, this model takes advantage of advances in research on memory and information-processing, on heuristics and dual processes, and on how risk and probability are understood and applied (e.g., Brainerd & Reyna, 2005; Kahneman, 2003; Keren & Schul, 2009; Reyna & Brainerd, 2008; Reyna, Nelson, Han, & Dieckmann, 2009; Weber & Johnson, 2009). More generally, I argue that evidence-based theory is essential to designing public health messages and to predicting reactions to those messages, especially under conditions of widespread and rapid communication of misinformation using the internet and social media (Asur & Huberman, 2010; Bakshy, Hofman, Mason, & Watts, 2011; Cha, Haddadi, Benefenuto, & Gummadi, 2010; Leavitt, Burchard, Fisher, & Gilbert, 2009; Liben-Nowell, & Kleinberg, 2008).

Background: Fuzzy-trace Theory

Although it is impossible to review all of the evidence that underpins the assumptions of fuzzy-trace theory, it is important to note that any viable theory in science should be based on sound empirical evidence. Moreover, it must accommodate all of the relevant evidence, including that generated from independent laboratories. For example, fuzzy-trace theory retains features of schema theory that are useful, but jettisons those that led to widespread criticism (and lack of empirical support) in the 1980s (e.g., Alba & Hasher, 1983; critical tests have also ruled out alternative theories, confirming novel predictions, e.g., Reyna & Brainerd, 2008, in press; Reyna & Farley, 2006; Reyna & Lloyd, 2006). Ideally, a theory should also be generative, giving rise to new questions and approaches that would not have been salient without the perspective provided by the theory. These ideals have guided the development of fuzzy-trace theory from its inception in the 1990s (e.g., Reyna & Brainerd, 1995).

Specifically, fuzzy-trace theory makes predictions regarding memory, judgment, and decision making—and their development from childhood to old age (for a summary, see Reyna, 2008). The theory integrates research on psycholinguistics, gestalt theory, emotion and social judgment, memory and cognition, and, more recently, neurobiology and neuroscience (e.g., Reyna & Brainerd, in press; Reyna & Rivers, 2008; Reyna, Estrada, et al., 2011). Psycholinguistics provided the initial definitions and measures of gist (essential meaning) and verbatim (surface form, such as exact wording) representations of verbal information (e.g., Kintsch, 1974). In fuzzy-trace theory, the concepts of gist and verbatim representations were extended beyond verbal information to numbers (e.g., risks and probabilities), images (e.g., pictures or graphs), and events (e.g., a patient's experience during a visit to the doctor or a witness's experience during the commission of a crime).

According to fuzzy-trace theory, any meaningful inputs are assumed to be encoded into memory in two forms: a verbatim representation (the objective stimulus or what actually happened) and a gist representation (the subjective interpretation of information or interpretation of what happened). Gist is not derived from verbatim representations, as once thought, but both representations are encoded roughly in parallel as a person perceives a stimulus. Usually, several gist representations—multiple representations of the same information or events—are encoded by the same person (see Figure 1). Consider a sentence

such as “In a study of 791 healthy children aged 1–15 years, postvaccination fever was noted among 12% of those aged 1–5 years, 5% among those aged 6–10 years, and 5% among those aged 11–15 years” (<http://www.cdc.gov/flu/professionals/acip/adverseTIV.htm>). Verbatim representations would include memories for exact words and numbers (e.g., “fever was noted among 12% of those aged 1–5 years”), but the sentence has multiple gist interpretations even for the same person—for example, that risk is low and that risk goes down with age.

Gist interpretations also differ across individuals. Because gist representations are subjective interpretations, they depend on everything about a person known to affect interpretation, such as culture (including social identity, for instance, gender roles), worldview, knowledge (e.g., numeracy), life experience (including developmental differences in experience), prejudices and beliefs about plausibility (e.g., Reyna & Adam, 2003). For example, “12%” would be interpreted as “low risk” by one person, but as “high risk” by another person (see Reyna, 2008). Similarly, “fever” would be interpreted as a “mild” side effect by one person, but as a “serious” side effect by another person.² Crucially, the gist, or interpretation, of the information guides judgments and decisions, not the verbatim facts.

Gist representations are used in reasoning, judgment, and decision making in the short-term (within minutes of information presentation, despite easy access to verbatim memories in that time interval) and in the long-term (after days, weeks, months or years) (Brainerd & Reyna, 2005). That is, people have a fuzzy-processing preference; they rely on gist (a *fuzzy* or vague representation relative to precise verbatim representations) rather than verbatim representations whenever they can, for example, when exact answers are not mandatory. Gist representations support intuitive processing, which is generally unconscious, parallel, and impressionistic (Reyna, 2004). Verbatim representations, in contrast, generally support conscious, analytical, and precise processing (e.g., quantitative tradeoffs between risk level and outcome severity). Ironically, the preference for fuzzy, or gist-based, processing tends to improve reasoning, judgment, and decision making because gist memory is more stable and less subject to interference, compared to verbatim memory (e.g., Reyna & Farley, 2006; Wolfe & Reyna, 2010).

Hence, gist, or fuzzy, representations are far more useful than they might appear to be at first blush. Most reasoning, judgment, and decision-making tasks can be accomplished to a high standard of performance using simple gist (e.g., admission decisions in the emergency room; Reyna & Lloyd, 2006). Although tasks, such as exact recall, might appear to require verbatim representations, they are often accomplished accurately by reconstructing items (e.g., studied words on a long list) from vague gist representations (see Brainerd, Reyna, & Howe, 2009, for a mathematical model of recall illustrating how this feat is accomplished). However, taking advantage of the robustness of gist representations hinges on having sufficient background knowledge to be able to extract a meaningful gist (e.g., Reyna & Brainerd, 2007). As I discuss in the next section, such background knowledge is often lacking in medicine and public health, in particular, regarding vaccinations (Kata, 2010).

Gist-based processes differ from intuitive processes in standard dual-process approaches and from fast-and-frugal processes in several respects (e.g., Reyna & Brainerd, 2008). For example, differing from dual-process theories, seemingly irrational thinking about vaccines is not attributed mainly to emotion, or otherwise primitive System 1 processing, that can be overridden by higher order deliberation, System 2 processing (e.g., Epstein, 1994; Evans,

²Fever, for example, could refer to a low fever that passes quickly or it could signal a serious condition, and, thus the word “fever” is ambiguous. However, although gist interpretations can vary across individuals, they are not arbitrary and there is often consensus around a few gist representations among people with similar knowledge and experience.

2003; Peters et al., 2006). Emotion plays a role in fuzzy-trace theory, but the role is not the standard dual-process dichotomy between smart deliberation and dumb emotionality (Rivers et al., 2008). Differing from fast-and-frugal approaches, gist is processed when people are familiar with options and when memory load is low (e.g., see Kuhberger & Tanner, 2010; Shafir & LeBoeuf, 2003, for additional evidence). Another key difference is that, unlike fast-and-frugal-approaches, gist is not simply processing “less” information (e.g., as in the recognition heuristic; Gigerenzer & Gaissmaier, 2011). Rather, gist involves *meaning*--connecting the dots in inputs to apprehend the essence of information or experience (e.g., Lloyd & Reyna, 2009). In short, gist is the difference between simple and simple-minded.

Therefore, gist is predicted to be relied on *more* heavily as development progresses, from child to adult and from novice to expert. Experience and knowledge facilitate connecting the dots (i.e., interpretation and inference), producing systematic biases that generally improve performance, but they also have predictable pitfalls. For example, “false” memories that go beyond actual experience are typically the product of gist-based interpretations and inferences--and they increase from childhood to adulthood (Brainerd & Reyna, 2005).

Indeed, developmental reversals—that children would be expected to outperform adults under specific conditions—were predicted by fuzzy-trace theory (e.g., Reyna & Brainerd, 1994; Reyna & Ellis, 1994; for recent reviews of evidence, see Brainerd, Reyna, & Ceci, 2008; Reyna & Brainerd, in press). For example, when judgmental biases and heuristics are based on gist, as most are, they are expected to *increase* with age and experience (see also Stanovich & West, in press; Strough, Mehta, McFall, & Schuller, 2008; De Neys & Vanderputte, 2011). This developmental progress from verbatim-based, or literal, thinking to gist-based intuition implies that the goal of health communication ought to be the facilitation of higher order gist-based intuition.

In summary, research indicates that people encode two kinds of mental representations of information, gist and verbatim, into memory, but they tend to rely on the gist—the essential meaning—in making judgments or decisions. Background knowledge, beliefs, and other individual differences influence the meaning that is encoded. In this view, memory is multifaceted; it is composed of multiple abilities and processes. Memory includes forming a mental “picture” of information or events (encoding a representation), as well as maintaining and manipulating information in the mind, also called information processing. Memory, therefore, is much more than rote memorization (i.e., verbatim recording). An important implication of this research for vaccination decisions is that *meaning* is at the core of how people process, and, then, communicate about health information.

A Process Model of Vaccination Decisions

As the previous discussion suggests, being informed about vaccination decisions involves more than having information. According to fuzzy-trace theory, there are four aspects of decision making: knowledge (having background information or experience needed to understand the gist of options), representations (especially appreciating the meaning of key facts—the gist—of options), retrieval of values (recognizing the relevance of key values or knowledge in context), and processing (understanding how values apply to the options). Obstacles to good decision making exist for each of these four aspects of vaccination decisions.

To begin, few members of the public have sufficient background knowledge to understand public health messages about vaccination (e.g., Downs, Bruin de Bruine, & Fischhoff, 2008; Kata, 2010). Knowledge is lacking about how vaccination works at the level of individuals or society (e.g., herd immunity), which compromises comprehension and retention of messages. Moreover, public health messages mainly warn and persuade, but they do not

explain vaccination. Without background information or explanations to fill in the gaps, it is hard to extract the essential bottom line, or gist, of the decision to vaccinate. People can understand each word and each sentence of a message, and still be unable to “connect the dots” (i.e., achieve global coherence) without background knowledge (Bransford & Franks, 1972; Lloyd & Reyna, 2009).

With little background knowledge, decision makers must rely on anecdotes, personal experience, and minimal information that is widely available. Under these circumstances, what is the gist of the decision to vaccinate? Fuzzy-trace theory predicts that decision makers begin with all-or-none categorical distinctions, the simplest gist. To illustrate this principle of fuzzy-trace theory, I begin with a classic decision dilemma: a choice between less money with certainty versus taking a risk to possibly gain more money (and possibly gain nothing). These classic dilemmas have been the proving ground for new theories of risky decision making because they show how people make choices with risks and consequences (e.g., benefits such as gaining money or protecting oneself against disease).

So, a monetary choice between receiving \$100 for sure versus a 50% chance of \$200 (or nothing) becomes mentally represented as receiving some money versus taking a chance on receiving some money or no money. All of the quantitative information (gains and probabilities) is encoded into the mind in terms of exact numbers (verbatim representations), but, more importantly, also in terms of simple dichotomies (gist representations) of those quantities, such as some money versus none. Note that the sure option (receiving some money) is pitted against a gamble with two possible outcomes: receiving some money or none. As noted above, in order to choose, values are retrieved and applied to these mental representations. Retrieving the value “some money is better than no money” favors choosing the sure thing, which is what most people choose (Kahneman, 2003). This account explains framing effects and the Allais paradox, among other classic decision effects (see Kuhberger & Tanner, 2010; Reyna, 2008; Reyna & Brainerd, 1991; 1995).

Applying the same rule to dichotomize dimensions, prior research showed that other prevention decisions similarly boiled down to choosing between feeling okay (no screening test) versus either feeling okay (negative screening result, absence of disease) or not feeling okay (positive screening result, presence of disease). Among 33 adults offered a variety of alternatives, for example, 91% selected this description as the bottom-line gist of their cancer screening decision (Reyna, 2008). Naturally, retrieving the value that “feeling okay is better than not feeling okay” favors not screening. That is, if one is asymptomatic, this gist discourages screening because screening is the only option that has “not feeling okay” as a possible outcome.

Prevention decisions all have, by definition, a status quo option of “feeling okay.” Hence, applying the same rule as before, the decision to get a flu shot, for example, boils down to feeling okay (not sick) versus feeling okay (not sick) or not feeling okay (sick, side effects, or death). Again, because feeling okay is superior to not feeling okay, this impoverished gist supports choosing not to have the flu vaccine. A straightforward prediction can be generated if the status quo changes; when people have the flu, they are likely to view the gamble’s upside potential as superior to the status quo. Thus, the decision to vaccinate will look good when people have the flu, but look bad when they are well.

Certainly, there are other reasons that people might not get a flu shot or other vaccination. They might be unaware that the shot is available to them at no cost or they might believe that they can get flu from the flu shot, a kind of verbatim matching or literal thinking (Nisbett & Ross, 1980; Reyna & Brainerd, in press). In the gist I have discussed, other “costs” of vaccination have been treated as nil (Stone, Yates, & Parker, 1994). However, a

psychological barrier to vaccination for many people is a fear of needles (a fear associated with violating the integrity of the body; Rozin et al., 1999). From this perspective, vaccination is not a gamble (more than one possible outcome), but instead incurs a sure cost: being stuck with a needle. A sure cost of vaccination compares unfavorably with taking a chance that one might or might not get the flu. In other words, the options boil down to a bad outcome for sure (getting stuck) versus taking a chance that either the outcome will be bad or it won't, which supports choosing the gamble (not vaccinating) in the hope of escaping a bad outcome. If the risks of flu were perceived to be low and the benefits of the vaccine were perceived as uncertain, these beliefs would reinforce the decision to avoid vaccination. For these individuals, either changing the perception of the needle stick so that the cost is "nil" or changing the perception of the flu so that it is perceived as essentially "a sure thing," or both, would be predicted to shift preferences for vaccination.

Thus far, I have reviewed only gist representations that support not vaccinating. However, many people do vaccinate because they see the gist of their options differently. If one perceives the risks of vaccination as nil, then the options boil down to protection against the flu versus taking a chance on getting the flu or not getting the flu, favoring vaccination. Like the status quo gist of feeling okay, the structure of the gist is a categorically good outcome versus the possibility of a categorically good or bad outcome. The decision to vaccinate would be imperative for those who feel that they cannot afford to get the flu, for example, because of serious illness (e.g., if contracting the flu would likely be lethal). For still others, the gist of the decision to vaccinate boils down to the good of the group, as opposed to the good of the individual, analogous to voting or the tragedy of the commons (Fehige & Frank, 2010; Reyna & Casillas, 2009). Note that, for those who perceive that they or society have a problem (e.g., they are sick or cannot afford to get the flu), taking a chance on a vaccine is more palatable.

Susceptibility to Anti-Vaccination Messages: The Search for Meaning

Although many of the gist representations and values discussed in the prior section support not getting vaccinated, they are not adamantly anti-vaccine (Poland & Jacobson, 2011). Strident anti-vaccine messages are attempts to predict or explain adverse outcomes, and to link them to vaccinations. As the fastest growing source of health information, the internet has enormous potential to spread such messages (Zimmerman et al., 2005). The internet and social media can amplify the perceived frequency of adverse events as rare events can be quickly shared around the globe (Liben-Nowell & Kleinberg, 2009; Watts & Peretti, 2007; Wu, Hofman, Mason, & Watts, 2011).

According to fuzzy-trace theory, such anti-vaccine messages are expected when people do not understand vaccination (which is widespread) and when mysterious adverse events occur in close contiguity to vaccination (Figure 2). The search for meaning and the tendency to interpret events—to connect the dots—provides a powerful impetus to generating strident anti-vaccine messages under the right conditions.

As long ago as 1948, Skinner demonstrated that pigeons would connect their own arbitrary behaviors (that happened to occur at the moment of delivery) to a food reward, even when food delivery was random. This so-called superstitious behavior is also evident in humans, for example, when baseball players continue to wear a lucky hat or use a lucky bat in the hope of recreating home runs. Connecting events that merely co-occur randomly is a rote or verbatim strategy because it does not depend on understanding (e.g., inferring a causal mechanism). Thus, individuals with very low levels of causal knowledge are likely to engage in superstitious behavior, much like Skinner's pigeon, connecting vaccinations to the adverse events that might follow them.

However, the fuzzy-processing preference suggests that most adults will attempt to *understand* associations rather than connect them arbitrarily (see also Proulx & Heine, 2009). For example, when events occur randomly, people will test hypotheses about why the events occurred in order to predict future occurrences (Wolford, Newman, Miller, & Wig, 2004; see Slovic, 1986, regarding the importance of the “signal potential” of an event in determining risk perception). They perceive illusory correlations, seeing a relation even when none exists (Nisbett & Ross, 1980). Thus, they are better able to detect non-random patterns when they occur, but their performance is woefully inadequate when events are actually random (Gaissmaier & Schooler, 2008).

Events such as autism are increasing in frequency, and appear connected to vaccinations because they manifest around the same age that children receive vaccinations and because anti-vaccination messages “explain” their co-occurrence. As Downs et al. (2008) showed, official communications, such as those from the Centers for Disease Control, are “sparse” and seem cryptic to those who lack background knowledge, whereas anti-vaccine communications “tell more coherent stories, supported by narrative explanations” (p. 1599; see also Editorial, 2008). In other words, anti-vaccination messages attempt to create a highly coherent gist, but official sites often do not. Because of the drive to extract meaning, the widespread lack of knowledge about vaccination creates fertile ground in which misleading “explanations” can take root.

Hence, in addition to low knowledge, strident anti-vaccination messages are predicted when: (a) specific ideas have a priori plausibility (that the government would deliberately infect people with a dread disease; that authorities are untrustworthy) and when (b) adverse outcomes occur that are poorly understood (e.g., autism, multiple sclerosis, and fibromyalgia) (Kata, 2010). Regarding b, mysterious adverse events, such as diseases whose causes are unknown, are a “meaning threat,” challenging what Albert Camus called our “wild longing for clarity” (Proulx & Heine, 2009). Anti-vaccine messages that make sense of unexplained events and associations, that satisfy that longing for clarity, are apt to diffuse more rapidly through the internet and social media (see Iribarren & Moro, 2009, for experimental data about information diffusion through social media).

Regarding a, plausibility has been shown to increase the uptake of suggestions in false memory studies, for example, presumably because plausible events that never happened are consistent with the gist of events that did happen (Brainerd & Reyna, 2005). Belief bias also colors logical inference, making believable conclusions easier to infer than unbelievable ones (Evans, 2003). Therefore, conclusions that might seem irrational (that MMR causes autism, that Obama was not born in the U.S., or that humans never landed on the moon) will achieve greater uptake among subgroups who hold prior beliefs that make such conclusions plausible.

Drawing on beliefs and plausibility, gist is extracted at the level of words or numbers (individual items), across lists of items or inferences across sentences, and at the level of whole narratives (Reyna, 2004; Reyna & Brainerd, 1995). At the level of narrative, the gist representation is a coherent story about causality. Hence, the tendency to jump to conclusions, to connect the dots, is a cornerstone of normal cognition. However, some people jump to conclusions more readily; paranoid delusions represent an extreme point along a continuum of inference and explanation (Garety & Hemsley, 1994).

For example, Peters and Garety (2006) showed that in a simple random draws task with two jars (one jar with a ratio of 85 black beads to 15 orange beads and the other with the opposite ratio), patients diagnosed with paranoid delusions required significantly fewer draws to jump to the conclusion about which jar was being sampled, compared to non-

clinical subjects. Depressed patients required significantly *more* draws than non-clinical subjects to jump to the conclusion about which jar was being sampled. These results again illustrate that jumping to conclusions is a natural outgrowth of seeing meaning and patterns, even in random events. Carried too far, this natural tendency can become irrational, as in delusional patients.³ Likewise, anti-vaccination messages fill in a vacuum of knowledge, and nature abhors a vacuum, which in some instances lead to conspiracy theories and other apparently irrational beliefs. Using concepts from fuzzy-trace theory, Table 1 provides a summary analysis of Web-based risk messages about vaccinations.

Implications for Public Health Communications

A major implication of this approach is that anti-vaccination messages connect rare and unexplained diseases such as MS or autism to vaccinations and thereby exploit a human bias towards identifying something as meaningful signal or pattern rather than random noise. The psychological processes of forming gist representations (Figure 2), and combining them with retrieved social and moral values to make decisions (Table 1), apply broadly. However, social media in the age of Web 2.0 amplify these processes. Web 2.0 favors emotionally charged personal narratives and allows anti-vaccination messages to spread rapidly, in particular, as they provide more coherent accounts of the gist of vaccination, relative to official government sites.

Another important implication of this approach is that information processing can be changed. Because both verbatim and multiple gist representations are encoded, and both analysis and intuition are available as modes of processing, varying how information is presented (e.g., arranging information so that the gist “pops out”; changing how a question is phrased) can change the dominant mode of processing (e.g., Mills, Reyna, & Brainerd, 2008; Reyna, Estrada, et al., 2011). Note that emphasizing simple bottom-line meaning is a very different strategy than emphasizing facts and details.

Specifically, our analysis of a status quo gist of “feeling okay” implies that it would be a straightforward public health strategy to manipulate the perceived status quo. If people perceive themselves as currently having a problem—being in a categorically distinct state of “not okay” as opposed to feeling okay, the outcome of the gist-gamble would be pro-vaccination. This strategy (of emphasizing essential meaning and, specifically, changing the categorical perception of the status quo) goes beyond simply framing decisions as gains versus losses.

Most people who are encouraged to vaccinate do not have a problem, however, and thus manipulating perceptions of their status quo would be difficult. Instead, for these individuals, fuzzy-trace theory suggests both a categorical (nominal level) and ordinal strategy: As noted above, one can argue that the risks of vaccination are nil, creating a categorical contrast between a “non-risky” vaccine and gambling on avoiding disease; in this view, not vaccinating becomes the risky choice because there is a possibility of a bad outcome. The concept of “nil” risk can be conveyed by presenting absolute levels of vaccination risks and comparing those risks to everyday risks that are treated as nil (i.e., people routinely do not change their actions based on the risk), such as getting struck by a meteorite (a non-zero, but nil risk; Reyna, 2008; Reyna et al., 2009; Stone et al., 1994).

³Decision theory suggests that jumping to conclusions can be rational when the costs of a miss outweigh the costs of a false alarm. As the discussion of developmental reversals suggests, jumping to conclusions—going beyond the data based on inference and plausibility—is often adaptive, but for reasons in addition to the costs of misses. Gist-based intuition has cognitive advantages over verbatim-based analysis by organizing cognition around representations that are relatively stable, easy to manipulate, and resistant to interference (e.g., from stress; see Reyna & Brainerd, 1995; Reyna et al., 2003).

An ordinal strategy could take the form of comparing the risks of disease to those of the vaccine: Both risks are low for healthy people, but the risks from getting the flu are much larger than the risks of the vaccine. As illustrated in Figure 1, both categorical and ordinal messages could be delivered as people typically extract both levels of gist: Vaccinations risks are essentially nil, and are also much lower than the risks associated with disease. A careful perusal of official Web sites today suggests that the simple bottom line gist messages that I have described would be hard to extract (Table 1).

Although space does not permit extensive discussion of the salutary effects of cuing social and moral values, this strategy has also been shown to be effective in changing health behavior (especially in concert with gist representations of health messages; Reyna & Casillas, 2009; Reyna, Estrada et al., 2011; Reyna & Farley, 2006). For example, the risks of not vaccinating for one's community, and the magnitude of these risks, are rarely mentioned in official communications (implicit in herd immunity), but mentioning them would trigger retrieval of social values. Thus, public health messages can be designed, in principle, to facilitate the encoding of a particular gist from health information; to cue retrieval from long-term memory of relevant knowledge (e.g., herd immunity) and values (e.g., not hurting other people by putting them at risk); and to encourage processing that relies on the targeted gist, knowledge, and values.

Summary

An important implication of fuzzy-trace theory for vaccination decisions is that *meaning* is at the core of such decisions—and is heavily dependent on knowledge, experience, and prior beliefs. The meaning of vaccination decisions can be described in terms of simple categorical gists, such as a choice between feeling okay (not sick) versus taking a chance by vaccinating and either feeling okay (not sick) or not feeling okay (sick, side effects or death). Prevention decisions, by definition, incorporate an asymptomatic status quo, which is compared to a gamble involving risks, discouraging vaccination. Although gist representations differ across individuals, and some representations encourage vaccination, status quo comparisons generally encourage inertia.

However, unexplained adverse health outcomes disturb the status quo. People are motivated to seek meaning, especially when faced with threats such as epistemic uncertainty (unexplained adverse events) and to the integrity (literally) of the self, as in inoculation. The search for meaning goes beyond the facts, and includes jumping to conclusions even about random events (e.g., isolated cases of narcolepsy), which sometimes is justified and other times verges on irrationality. The internet and social media provide unprecedented opportunities to share stories that address the need to understand rare health outcomes, and anti-vaccination sources seem to provide more coherent accounts than official sources, ensuring their popularity.

References

- Alba J, Hasher L. Is memory schematic? *Psychological Bulletin*. 1983; 93:203–231.
- Asur S, Huberman BA. Predicting the future with social media. 2010 IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology. 2010; 1:492–499. doi: 10.1109/WI-IAT.2010.63.
- Bakshy, E.; Hofman, JM.; Mason, WA.; Watts, DJ. Identifying ‘influencers’ on Twitter.. Paper presented at the Fourth ACM International Conference on Web Search and Data Mining.; Feb. 2011
Paper retrieved from http://research.yahoo.com/files/bakshy_wsdm.pdf
- Brainerd, CJ.; Reyna, VF. *The science of false memory*. Oxford University Press; New York: 2005.
- Brainerd CJ, Reyna VF, Ceci SJ. Developmental reversals in false memory: A review of data and theory. *Psychological Bulletin*. 2008; 134(3):343–382. [PubMed: 18444700]

- Bransford JD, Johnson MK. Contextual prerequisites for understanding: Some investigations of comprehension and recall. *Journal of Verbal Learning and Verbal Behavior*. 1972; 11:717–726.
- Brewer NT, Chapman GB, Gibbons FX, Gerard M, McCaul KD, Weinstein ND. Meta-analysis of the relationship between risk perception and health behavior: The example of vaccination. *Health Psychology*. 2007; 26:136–145. [PubMed: 17385964]
- Cha, M.; Haddadi, H.; Benfenuto, F.; Gummadi, KP. Measuring user influence in Twitter: The million follower fallacy.. *Proceedings of the Fourth International AAAI Conference on Weblogs and Social Media*, 10-17; 2010. Paper retrieved from <http://www.aaai.org/ocs/index.php/ICWSM/ICWSM10/paper/view/1538>
- De Neys W, Vanderputte K. When less is not always more: Stereotype knowledge and reasoning development. *Developmental Psychology*. 2011; 47:432–441. [PubMed: 21142361]
- Downs JS, Bruin de Bruine WD, Fischhoff B. Parents' vaccination comprehension and decisions. *Vaccine*. 2007; 26:1595–2607. doi:10.1016/j.vaccine.2008.01.011. [PubMed: 18295940]
- Nature. 2008; 452:128. Editorial: On message, off target [Editorial]. doi:10.1038/452128a. [PubMed: 18337775]
- Epstein S. Integration of the cognitive and psychodynamic unconscious. *American Psychologist*. 1994; 49:709–724. [PubMed: 8092614]
- Evans, J. St.B.T. In two minds: dual-process accounts of reasoning. *Trends in Cognitive Sciences*. 2003; 7(10):454–459. [PubMed: 14550493]
- Fehige C, Frank RH. feeling our way to the common good: utilitarianism and the moral sentiments". *The Monist*. 2010; 93:141–165.
- Gaissmaier W, Schooler LJ. The smart potential behind probability matching. *Cognition*. 2008; 109:416–4221. [PubMed: 19019351]
- Garety, PA.; Hemsley, DR. *Delusions: Investigations into the psychology of delusional reasoning*. Oxford University Press; Oxford: 1994.
- Gigerenzer G, Gaissmaier W. Heuristic decision making. *Annual Review of Psychology*. 2011; 62:451–482.
- Holford, P. *New optimum nutrition for the mind*. Piatkus; New York: 2007.
- Iribarren JL, Moro EE. Impact of human activity patterns on the dynamics of information diffusion. *Physical Review Letters*. 2009; 103(3):038702. doi:10.1103/PhysRevLett.103.038702. [PubMed: 19659326]
- Kahneman D. A perspective on judgment and choice: mapping bounded rationality. *American Psychologist*. 2003; 53(9):697–720. [PubMed: 14584987]
- Kata A. A postmodern Pandora's box: Anti-vaccination misinformation on the internet. *Vaccine*. 2010; 28:1709–1716. doi:10.1016/j.vaccine.2009.12.022. [PubMed: 20045099]
- Keren G, Schul Y. Two is not always better than one: A critical evaluation of two-system theories. *Perspectives on Psychological Science*. 2009; 4:533–550.
- Kuhberger A, Tanner C. Risky choice framing: Task versions and a comparison of prospect-theory and fuzzy-trace theory. *Journal of Behavioral Decision Making*. 2010; 23:314–329.
- Leavitt A, Burchard E, Fisher D, Gilbert S. The influentials: New approaches for analyzing influence on Twitter. *The Web Ecology Project*. 2009; 4:1–18. Retrieved from <http://www.webecologyproject.org/wp-content/uploads/2009/09/influence-report-final.pdf>.
- Liben-Nowell D, Kleinberg J. Tracing information flow on a global scale using Internet chain-letter data. *Proceedings of the National Academy of Sciences of the United States of America*. 2008; 105(12):4633–4638. doi:10.1073/pnas.0708471105. [PubMed: 18353985]
- Lipkus IM, Peters E. Understanding the role of numeracy in health: proposed theoretical framework and practical insights. *Health Education & Behavior*. 2009; 36(6):1065–1081. DOI: 10.1177/1090198109341533. [PubMed: 19834054]
- Mills BA, Reyna VF, Estrada S. Explaining contradictory relations between risk perception and risk taking. *Psychological Science*. 2008; 5:429–434. [PubMed: 18466401]
- Nisbett, RE.; Ross, L. *Human inference: Strategies and shortcomings of social judgment*. Prentice-Hall; Englewood Cliffs, NJ: 1980.

- Peters ER, Garety PA. Cognitive functioning in delusions: A longitudinal analysis. *Behavioural Research and Therapy*. 2006; 44:481–514.
- Poland GA, Jacobson MD. The age-old struggle against the antivaccinationists. *New England Journal of Medicine*. 2011; 364(2):97–99. [PubMed: 21226573]
- Proulx T, Heine SJ. Connections from Kafka: Exposure to meaning threats improves implicit learning of artificial grammar. *Psychological Science*. 2009; 20:1125–1131. [PubMed: 19656338]
- Reyna VF. How people make decisions that involve risk. A dual-processes approach. *Current Directions in Psychological Science*. 2004; 13:60–66. doi:10.1111/j.0963-7214.2004.00275.x.
- Reyna VF. A theory of medical decision making and health: Fuzzy-trace theory. *Medical Decision Making*. 2008; 28:829–833. [PubMed: 19020341]
- Reyna VF, Adam MB. Fuzzy-trace theory, risk communication, and product labeling in sexually transmitted diseases. *Risk Analysis*. 2003; 23:325–342. doi:10.1111/1539-6924.00332. [PubMed: 12731817]
- Reyna VF, Brainerd CJ. Fuzzy-trace theory and framing effects in choice. Gist extraction, truncation, and conversion. *Journal of Behavioral Decision Making*. 1991; 4:249–262.
- Reyna, VF.; Brainerd, CJ. The origins of probability judgment: A review of data and theories.. In: Wright, G.; Ayton, P., editors. *Subjective probability*. Wiley; New York, NY: 1994. p. 239-272.
- Reyna VF, Brainerd CJ. Fuzzy-trace theory: An interim synthesis. *Learning and Individual Differences*. 1995; 7:1–75.
- Reyna VF, Brainerd CJ. Numeracy, ratio bias, and denominator neglect in judgments of risk and probability. *Learning and Individual Differences*. 2008; 18(1):89–107.
- Reyna VF, Brainerd CJ. Dual processes in decision making and developmental neuroscience: A fuzzy-trace model. *Developmental Review*. in press.
- Reyna, VF.; Casillas, W. Development and dual processes in moral reasoning: A fuzzy-trace theory approach.. In: Ross, BH.; Bartels, DM.; Bauman, CW.; Skitka, LJ.; Medin, DL., editors. *Psychology of Learning and Motivation*. vol. 50: Moral Judgment and Decision Making. Academic Press; San Diego, CA: 2009. p. 207-239.
- Reyna VF, Ellis SC. Fuzzy-trace Theory and framing effects in children's risky decision making. *Psychological Science*. 1994; 5:275–279.
- Reyna VF, Estrada SM, DeMarinis JA, Myers RM, Stanis JM, Mills BA. Neurobiological and memory models of risky decision making in adolescents versus young adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. 2011; 37:1125–1142. doi: 10.1037/a0023943.
- Reyna VF, Farley F. Risk and rationality in adolescent decision making: Implications for theory, practice, and public policy. *Psychological Science in the Public Interest*. 2006; 7:1–44. doi: 10.1111/j.1529-1006.2006.00026.x.
- Reyna VF, Lloyd FJ. Physician decision-making and cardiac risk: Effects of knowledge, risk perception, risk tolerance, and fuzzy processing. *Journal of Experimental Psychology: Applied*. 2006; 12:179–195. [PubMed: 16953744]
- Reyna VF, Nelson W, Han P, Dieckmann NF. How numeracy influences risk comprehension and medical decision making. *Psychological Bulletin*. 2009; 135:943–973. [PubMed: 19883143]
- Reyna VF, Rivers SE. Current theories of risk and rational decision making. *Developmental Review*. 2008; 28(1):1–11. [PubMed: 19255598]
- Rivers SE, Reyna VF, Mills BA. Risk taking under the influence: A fuzzy-trace theory of emotion in adolescence. *Developmental Review*. 2008; 28:107–144. dx.doi.org/10.1016/j.dr.2007.11.002. [PubMed: 19255597]
- Rothman AJ, Salovey P. Shaping perceptions to motivate healthy behavior: The role of message framing. *Psychological Bulletin*. 1997; 121:3–19. [PubMed: 9000890]
- Rozin P, Lowery L, Imada S, Haidt J. The CAD triad hypothesis: A mapping between three moral emotions (contempt, anger, disgust) and three moral codes (community, autonomy, divinity). *Journal of Personality and Social Psychology*. 1999; 76:574–586. [PubMed: 10234846]
- Skinner BF. 'Superstition' in the pigeon. *Journal of Experimental Psychology*. 1948; 38:168–172. [PubMed: 18913665]

- Slovic P. Informing and educating the public about risk. *Risk Analysis*. 1986; 6:403–415. [PubMed: 3602512]
- Stanovich KE, West R, Toplak ME. The complexity of developmental predictions from dual process models. *Developmental Review*. in press.
- Stone ER, Yates JF, Parker AM. Risk communication: Absolute versus relative expressions of low-probability risks. *Organizational Behavior and Human Decision Processes*. 1994; 60:387–408.
- Strough J, Mehta CM, McFall J, Schuller K. Do older and younger adults make different decisions about sunk costs? *Psychological Sciences*. 2008; 19:650–652.
- Valente TW, Fosados R. Diffusion of Innovations and Network Segmentation: The Part Played by People in Promoting Health. *Sexually Transmitted Diseases*. 2006;33S23–S31. doi: 10.1097/01.olq.0000221018.32533.6d.
- Watts DJ, Peretti J. Viral marketing for the real world. *Harvard Business Review*. 2007; 85(5):22–23.
- Wolfe CR, Reyna VF. Semantic coherence and fallacies in estimating joint probabilities. *Journal of Behavioral Decision Making*. 2010; 23(2):203–223.
- Wolford G, Newman SE, Miller MB, Wig GS. Searching for patterns in random sequences. *Canadian Journal of Experimental Psychology*. 2004; 58:221–228. [PubMed: 15648726]
- Wu, S.; Hofman, JM.; Mason, WA.; Watts, DJ. Who says what to whom on Twitter.. Paper presented at the 20th International Conference World Wide Web Conference, Hyderabad, India; Mar. 2011 Paper retrieved from <http://research.yahoo.com/pub/3386>
- Zimmerman RK, Wolfe RM, Fox DE, Fox JR, Norwalk MP, Troy JA, Sharp LK. Vaccine criticism on the World Wide Web. *Journal of Medical Internet Research*. 2005; 7(2):e17. doi:10.2196/jmir.7.2.e17. [PubMed: 15998608]

Highlights

Based on fuzzy-trace theory, a new psychological model of vaccination decisions is introduced.

The model explains effects of background knowledge, dual mental representations (verbatim and gist), retrieval of values, and application of values in vaccination decisions.

The model describes how anti-vaccination messages proliferate rapidly in Web 2.0 in the presence of meaning threats and plausibility of anti-vaccination beliefs.

Anti-vaccination sources provide more coherent narratives of the *gist* of vaccination than official sources, filling a need to understand rare adverse outcomes.

Figure 1.

Two examples of verbatim (literal) and gist (meaningful) mental representations of risk messages about vaccination. A person reading a Web site generates multiple gist representations of information that vary in specificity, such as nominal or categorical distinctions (e.g., no risk vs. some risk) and ordinal distinctions (e.g., low vs. high risk; a few children vs. a lot of children). Gist representations are less precise than verbatim representations because the latter represent exact words, exact numbers, and other details as presented or experienced.

Figure 2.

A process model explaining how gist is generated for vaccination decisions. Meaning threats are gaps or conflicts in understanding that increase the desire for meaning. Factors such as knowledge and experience, beliefs about plausibility, and exposure to causal narratives influence meaning making, as people make inferences in an attempt to make sense of information on the Web and social media.

Table 1
Examples of Psychological Factors Predicted to Influence Vaccination Decisions

Information	Background Knowledge	Prior Beliefs: Plausibility	Gist Representations	Relevant Values	Decision
"In one analysis of American babies six months old, the average intake of mercury was 111.3mcg. Tiny amounts of mercury have been shown to promote abnormal methylation. Although not proven, this provides a plausible explanation as to why the MMR vaccine could trigger autism" (Holford, 2007, pp. 100-1).	Mercury is a poison.	Environmental toxins are plausible causes of unexplained diseases. Toxic pollutants are widespread. Humans introduce poisons into the environment through vaccines and other activities that interfere with nature.	Babies have mercury poisoning. MMR contains a poison that could cause autism. MMR and autism are linked.	Avoid poison. Natural is good.	Avoid vaccination.
Web site posting critical of MMR/autism link. http://holfordwatch.info/2007/07/18/holford-mercury-and-mmr-is-mercury-a-plausible-explanation-as-to-why-the-mmr-vaccine-could-trigger-autism/	Mercury is a poison. MMR is a live vaccine. There is no mercury in the MMR vaccine.	It is not plausible that a preservative, such as thimerosal, would be added to MMR because it is a poison and would "kill" the vaccine, rendering it ineffective.	Mercury could not be involved in any MMR/autism link. MMR and autism are not linked. MMR risks are unproven.	Science is good. Research is good. "It's the ideas, science and analysis that count."	Take vaccine. "There is no reason on grounds of safety to change current immunization practices with thimerosal-containing vaccines, as the risks are unproven."
"The weight of the available scientific evidence does not support the suggestion that hepatitis B vaccine causes or worsens MS." http://www.cdc.gov/vaccinesafety/Vaccines/multiplesclerosis_and_hep_b.htmlhttp://www.cdc.gov/idu/hepatitis/vaccines.pdf	MS involves demyelination. About 5000 people a year die as a result of hepatitis B. Hepatitis B vaccine prevents disease.	It is not plausible that the government would approve a vaccine if it were unsafe.	No risk of MS from hepatitis B vaccine. Little evidence that hepatitis B vaccine causes MS. Hepatitis B vaccine and MS are not linked.	Better to be healthy than sick. Better to be alive than dead.	Take vaccine.
"Most published scientific studies do not support a causal relationship between hepatitis B vaccination and MS or other demyelinating diseases." http://www.cdc.aov/vaccinesafety/Vaccines/multiplesclerosis_and_hep_b.html	MS is a fatal neurological disease.	It is plausible that drug companies want to cover up vaccine problems.	Some studies support a hepatitis B/MS link. A few studies support a hepatitis B/MS link.	Natural is good.	Avoid vaccination.
"According to a study published in the Oct. 8, 2000 issue of <i>Neurology</i> (Mikaeloff, 2008), the majority of children vaccinated against hepatitis B are not at an increased risk of developing CNS inflammatory demyelination. http://www.cdc.gov/vaccinesafety/Vaccines/multiplesclerosis_and_hep_b.html	MS involves demyelination.	It is plausible that anything that causes demyelination will cause MS.	A minority of vaccinated children will get an MS-like condition. A lot of vaccinated children will get an MS-like condition (note: a minority is still a lot of children). Hepatitis B and MS are linked.	Better to be healthy than sick.	Avoid vaccination.

Note. The examples of each theoretical concept are not intended to be exhaustive. Although the concepts can be distinguished operationally, they are not independent of one another; instead, they represent related parts of organized knowledge schemas or world views. Some entries in the table were generated by the author to illustrate concepts, and do not necessarily represent the thinking of those who constructed the messages. Research has shown that a message recipient typically generates multiple gist representations for the same input (e.g., a risk message). Gist representations are generated at multiple levels: at the level of individual words or numbers, at the level of sentences (and inferences that connect sentences), and at the level of an entire narrative or event. Gist representations reflect the

beliefs and understanding (sometimes inadequate understanding) of an individual, and therefore can be mistaken. Source material for the hepatitis B vaccine comes from the same CDC Web page, entitled "FAQs about Hepatitis B Vaccine (Hep B) and Multiple Sclerosis." Because each of these messages on the same page suggests different gists, the page as a whole could be perceived as incoherent and confusing.