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How Reasoning, Judgment, and Decision Making are Colored by Gist-based Intuition: A Fuzzy-Trace Theory Approach

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Abstract

Fuzzy-trace theory distinguishes verbatim (literal, exact) from gist (meaningful) representations, predicting that reliance on gist increases with experience and expertise. Thus, many judgment-and-decision-making biases increase with development, such that cognition is colored by context in ways that violate logical coherence and probability theories. Nevertheless, this increase in gist-based intuition is adaptive: Gist is stable, less sensitive to interference, and easier to manipulate. Moreover, gist captures the functionally significant essence of information, supporting healthier and more robust decision processes. We describe how fuzzy-trace theory accounts for judgment-and-decision making phenomena, predicting the paradoxical arc of these processes with the development of experience and expertise. We present data linking gist memory processes to gist processing in decision making and provide illustrations of gist reliance in medicine, public health, and intelligence analysis.

Keywords

fuzzy-trace theory; decision making; memory; heuristics and biases; development; expertise

In this article, we discuss how qualitatively different mental representations influence judgment and decision making, and how the reliance on these differing representations changes with age and expertise. Specifically, we draw a distinction between literal representations that capture the surface form of information, called *verbatim*, although the term applies to non-verbal as well as verbal stimuli, and meaningful representations that capture the essential *gist* of the same information. Some materials, tasks, and people focus cognition more on verbatim as opposed to gist representations. Nevertheless, for most adults, cognition tilts toward gist, despite encoding verbatim representations along with the gist. That is, adults unconsciously gravitate toward using the simplest meaningful representations that they can (within the constraints of a task) in reasoning, judgment, and decision making.

In the following, we provide an overview of fuzzy-trace theory (FTT), which distinguishes verbatim and gist representations, and is the source of predictions about reasoning,

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judgment, and decision making. We update the theory in the light of recent findings, reporting the first evidence linking theoretically predicted gist-based biases in memory and in decision making. We also review developmental differences in verbatim and gist representations and their implications for judgment and decision making in real-world contexts, such as public health, medicine, and intelligence analysis. In particular, we discuss increases in reliance on gist representations with age and experience. By “age,” we mean the mechanisms that unfold with biological maturation and environmental stimulation, such as the neurological changes that occur in the brain from childhood to young adulthood and from adulthood to old age (e.g., Reyna, 2012a; Reyna, Chapman, Dougherty, & Confrey, 2012). In FTT, then, development occurs because of both biology and experience; experience under the proper circumstances produces insight and, in turn, changes the brain (see also Stickgold, 2005).

Background

Mental Representations of Information in Reasoning, Judgment, and Decision Problems

FTT is a comprehensive theory of memory and reasoning that is grounded in psycholinguistic research on how information is represented, retrieved, and processed. The theory draws a distinction between two kinds of memory representations, verbatim and gist (Reyna, 2012a). Gist representations capture the bottom-line meaning, whereas verbatim representations capture precise detail of experiences. Gist and verbatim representations exist on a continuum (from the “fuzziest” gist to the most precise verbatim), and are encoded, stored, and retrieved separately and in parallel. With age and expertise comes an increased “fuzzy processing preference,” meaning that adults and experts tend to rely on the simplest gist necessary to complete a task. According to FTT, reasoning based on gist processing—the intuitive, bottom-line meaning—underlies advanced cognition.

Mental representations of these relations range from literal mental models that preserve precise details derived from information (e.g., representations of magnitudes of size or distance, e.g., Kosslyn, Ball, & Reiser, 1978) to approximate ordinal representations (e.g., of relative magnitudes of “more” vs. “less; “higher” vs. “lower”) to the simplest representations of all-or-none categorical gist (e.g., “some” vs. “none”; “high” vs. “low”). Research on memory for magnitudes, frequencies, and probabilities has shown that people encode these specific verbatim-to-gist level representations of quantity (e.g., for reviews, see Reyna & Brainerd, 1994; 2008).

Decision-makers encode multiple representations at differing levels of specificity. Reliance on simplified representations in decision making is exemplified by the following paradox discovered by Allais (1953; 1997), called the “common consequence effect” in Kahneman and Tversky’s paper on prospect theory (1979). Decision makers are given the following prospects, choosing either between A and B or between C and D:

- A. \$1 million for sure
- B. .89 probability of \$1 million, .10 probability of \$5 million, .01 probability of \$0
- C. .11 probability of \$1 million, .89 probability of \$0

D. .10 probability of \$5 million, .90 probability of \$0

When deciding between A and B, many decision-makers prefer option A. However, option D is typically preferred over option C. Note that both A and B include a .89 probability of \$1 million, leaving the comparison of an additional .11 probability of \$1 million in option A, and a .10 probability of \$5 million in option B – the same choice found between C and D. A decision-maker relying on a precise representation of the task would make consistent choices, choosing both A and C or B and D. Choices in tasks such as the Allais paradox predict everyday decisions such as making financial investments, buying insurance, or making medical decisions (e.g., Reyna, Nelson, Han, & Pignone, 2015).

Fuzzy-trace theory predicts that decisions makers process multiple representations of these options, including verbatim words and numbers, but give greater weight to the simplest gist representation (Reyna, 2012b). The simplest representation of quantities is categorical (i.e., nominal scale). That is, the first two options A and B boil down to a categorical gist of A--gaining something--versus B--gaining something or gaining nothing. This categorical representation leads to a preference for A, avoiding the possibility of gaining nothing (although computing the numbers, which is done in parallel, leads to a competing preference for B; see below). When deciding between C and D, the categorical comparison of something versus nothing does not produce a clear preference because both options are represented as gaining something or gaining nothing. The next simplest representation for C versus D is ordinal: C involves a low probability of gaining *less* (\$1 million) versus a similar low probability of gaining *more* (\$5 million), leading to a preference for D, the option with more money.

The verbatim representation involves taking the numbers in these choices at face value—taking them literally rather than gistifying them. Using the precise numbers, and computing what is called “expected value” (e.g., 1.0 probability X \$1 million = \$ 1million) reveals that options B and D are mathematically superior to options A and C. Even little children apply a rule like expected value, multiplying probabilities and outcomes (for a review, see Reyna & Brainerd, 1994). Combining each of these representations (categorical gist, ordinal gist, and literal numbers), produces conflicting preferences for A versus B, but a clear preference for D over C, which is the pattern of results that is usually observed (Reyna & Brainerd, 2011). The example using the Allais paradox underscores the fact that FTT is a model in which multiple representations are encoded simultaneously, all influencing final preferences.

Implicit in our discussion of preferences is the idea that people apply values and moral principles regarding money and other objects of choice. FTT assumes that people have such basic values stored in long-term memory (e.g., money is good, so more money is better than less money), and they retrieve those values to apply them to representations of options (Reyna, 2008; Reyna & Mills, 2014). Retrieval is a variable process and depends on external cues, as with retrieving anything stored in long-term memory. Therefore, preferences can differ depending on which values are retrieved in a decision-making situation (for details, see Mills, Reyna, & Estrada, 2008; Reyna, Estrada et al., 2011).

Further, the specificity requirements of a judgment or decision task dictate which level of representation is relied on for a response. Thus, decision-makers *calibrate* the specificity of

the mental representation to the demands of the task (e.g., choices, rankings, or numerical estimates). As illustrated with the Allais paradox, it is possible to make choices using simple categorical representations. However, categorical representations would not be sufficient to estimate how much money a person would be willing to pay for rent; monetary estimates require more fine-grained representations (Reyna & Brainerd, 1995).

Finally, variation in judgment and decision making can also be attributed to the diligence with which individuals monitor the quality of their thinking (Liberali, Reyna, Furlan, Stein, & Pardo, 2012). Research has shown that individual differences in monitoring are distinct from the basic processes that produce biases or paradoxes in judgment and decision making (e.g., Stanovich & West, 2008). In other words, monitoring thinking (and, consequently, mental subtraction) can lead to the realization that a \$10 discount on a \$100 plane ticket is equal to a \$90 ticket that just got marked down by \$10 from \$100 (all else being equal; see also Frederick, 2005). As we outline in more detail below, each of these concepts—representation (calibrated to each task), retrieval, and monitoring—offers insight into the processes underlying judgment and decision making.

Effects of the Task and Context on Reasoning, Judgment, and Decision Making

Task calibration—As we have discussed, the concept of task calibration in FTT is that individuals match the specificity of mental representation that they rely on with the specificity of the task demands (e.g., Reyna, 2012a). Adults use the simplest mental representations that they can to accomplish the task; the task itself presents constraints (e.g., Reyna, 2012a). A task could be *choosing* between two options, *ranking* options in terms of their perceived probability, or providing *exact* numbers from memory (e.g., memory for frequencies of events; Miller et al., 2005). More specific questions require calibration to more precise representations, such as when asked what the temperature is today, an appropriate reply is numerical (e.g., 80 degrees). However, the question about whether today is hotter than yesterday requires only an ordinal distinction (e.g., hotter than). Finally, when asked if it is hot today (a categorical question), a distinction between hot or not hot is sufficient.

The calibration principle accounts for inconsistencies in preference judgments when they are elicited with different tasks, such as choices, rankings, or exact dollar estimates of willingness to pay (e.g., Fischer & Hawkins, 1993; Kühberger & Grادل, 2013). In other words, people choose A over B, but are willing to pay a higher dollar amount for B than A. For example, when asked to choose between A) a 3/4 chance of winning \$1.20 and a 1/4 chance of losing \$0.10, or B) a 1/4 chance of winning \$9.20 and a 3/4 chance of losing \$2.00, people tend to prefer option A. Both options involve winning something and losing something, so technically the categorical level does not distinguish option A from B. However, people treat losing \$.10 as essentially nil or nothing (as argued by Stone, Yates, & Parker, 1994, using FTT), yielding a gist of gaining something or nothing versus gaining something or losing something, favoring A. In contrast to preferences in the choice task, when asked how much one would be willing to pay for each gamble (as opposed to choosing between them), people pay more for the gamble with the higher monetary gain (\$9.20) in option B, demonstrating a reversal in preferences (Slovic & Lichtenstein, 1983). In other

words, people use the dollars in the gambles as starting points, and \$9.20 is greater than \$1.20, producing higher willingness-to-pay amounts. Despite the fact that the expected values (the probabilities multiplied by the outcomes) of both gambles are equal (\$0.80), asking subjects how much they would pay puts the focus on comparing exact numbers (verbatim representations), as opposed to the previous question of which one prefers, which boils down to losing nothing versus losing something.

As demonstrated in the previous example, to prefer one option over another, it has to be greater on a dimension that is valued—more money, lives, social status and so on. Exact numbers of dollars, lives, and status do not necessarily matter for accomplishing the task of choosing: More is better than less and some is better than none for these dimensions. For example, it is immediately obvious that receiving \$10,741 is better than \$5,972 without subtracting these quantities; more money is better than less (ordinal gist). Likewise, it is obvious that \$5,972 is better than \$0 because some money is better than none (categorical gist). Early versions of FTT treated categorical gist as a special case of ordinal gist (Reyna & Brainerd, 1991), which is mathematically true but psychologically false (Mills, Reyna, & Estrada, 2008; Reyna, Chick, Corbin, & Hsia, 2014).

In sum, the task calibration principle applies to the level of representation used to accomplish the task; it does not imply that other levels of representation are not known, encoded, or stored. In fact, unlike most dual-process theories (see De Neys, 2006), FTT posits that verbatim representations are encoded and stored in parallel with multiple gist representations, an assumption grounded in evidence (for reviews of such evidence, see Reyna & Brainerd, 1992, 1995). Multiple levels of representation are encoded and stored, but task demands influence which level of representation is relied on. In other words, people can simultaneously represent the temperature as “90 degrees,” “hotter than yesterday,” and “hot,” but if they are asked if it is hotter today than yesterday, they will reply with the ordinal representation, matching the representation level of the question.

Context shapes gist—The precision of representations used to make choices among options also waxes and wanes depending on the context, including the context of other numbers in options. Twenty dollars is essentially nil or nothing compared to the prospect of a million dollars (Stone, Yates, & Parker, 1994), but the same \$20 is “some money” compared to the prospect of zero dollars (Mather et al., 2012; although psychophysical approaches sidestep the issue of meaning, which is focal for FTT, Vlaev, Chater, Stewart, & Brown, 2011). The nimble human mind can construe the gist of even concrete and familiar objects, such as money, in different ways depending on the context.

In ordinary life, contextual relativity is a good thing: No one should confuse the size of a “large” flea with that of a “large” elephant or a “loud” tie with a “loud” horn (e.g., Clark & Clark, 1977). Neurotypical individuals have little difficulty understanding such context. However, research has identified subgroups of people who vary in the ability to process contextual meaning or gist, such as people with autism who have higher verbatim and lower gist processing (Reyna & Brainerd, 2011). As predicted by FTT, those with autism show more consistency in preferences in cases in which changes in context and meaning would otherwise drive inconsistencies (e.g., De Martino, Harrison, Knafo, Bird, & Dolan, 2008).

However, they also are more literal, which presents problems in ordinary life. Gist takes context into account because it captures the meaning or interpretation of stimuli.

For example, whether a quantity is encoded as low or high depends on the context of other values (e.g., Ungemach, Stewart, & Reimers, 2011) as well as general and culturally specific knowledge (e.g., Reyna, 2008; Reyna, Nelson, Han, & Dieckmann, 2009). When decisions are taken out of context, they may appear arbitrary and irrational. For example, in the famous McDonald's coffee spill case, in which an elderly woman spilled searing hot coffee on herself, a jury awarded \$2.7 million in damages. The public reaction to this amount was very negative—people believed that this number was much too high. However, when one discovers that the plaintiff's lawyer suggested penalizing McDonald's the amount of one to two days of coffee sales (which totaled \$1.35 million per day; Gerlin, 1994), it is easier to understand the context in which the jury was making a decision (Hans & Reyna, 2011). Indeed, the \$2.7 million in damages seems small when compared to coffee sales (Reyna, Hans, Corbin, Yeh, Lin, & Royer, 2015).

Context also has an effect on the accessibility of values and principles that are applied to representations, which are sometimes retrieved and sometimes not, depending on cues in the retrieval environment. For example, whether a particular logical principle is retrieved will have a major influence on judgment and decision making. In the classic "Linda Problem," people are given a description of Linda, which is meant to convey the gist that she cares about women's rights and is politically active (Tversky & Kahneman, 1983). People are asked to rate the likelihood that Linda is a bank teller as well as the likelihood that she is a bank teller and also active in the feminist movement. Most people will erroneously rate the likelihood of the conjunction of feminist bank teller as higher than the likelihood Linda is a bank teller (Tversky & Kahneman, 1983). In this task, people fail to retrieve the correct reasoning principle called "class inclusion" (i.e., if class B contains Class A, then class B has a greater probability, or equal, compared to class A). People are also driven by an appealing gist (Linda as a feminist) and neglect the denominator of the likelihood ratio (bank tellers) focusing mainly on the numerator (the conjunction, feminist bank teller). Crucially, this error--the conjunction fallacy--occurs not because people are unaware of the correct reasoning principle because they recognize the validity of the class-inclusion principle in other tasks; they simply fail to retrieve it when making the judgment about Linda. Performance on the Linda problem (and similar problems) improves greatly when the correct reasoning principle is cued prior to the judgment task, for example, by having subjects answer the question "Are there more apples or more red apples?" (Reyna, 1991; Wolfe & Reyna, 2010). Thus, reminders in the context of reasoning help people retrieve principles that they know, reducing errors.

These theoretical ideas about context explain task variability, that tasks that ostensibly tap the same underlying dimension of reasoning (e.g., knowledge of the class-inclusion principle or preference) nevertheless can elicit judgments and decisions that contradict one another. The canonical example of task variability is framing effects, for example, preferring a program in which 200 people would be saved (a gain relative to zero) but rejecting the same program when it is described as allowing 400 people to die (a loss relative to zero), despite the fact that 600 people are expected to die without any program, making the two

outcomes equivalent (Tversky & Kahneman, 1986). Similarly, people exhibit task variability when they give a higher rating to an applicant who scores 80% correct on a test as opposed to one who scores 20% wrong on the same test (Peters et al., 2006).

According to FTT, task variability is a hallmark of human psychology. Context, such as reference points or magnitudes of other numbers, along with cues in the environment can change the gist of stimuli or the reasoning principles that are retrieved and applied to gist representations. Theories of psychology should not accommodate variability simply by relaxing constraints or allowing more noise. Instead, task variability should be explained and predicted as a central phenomenon of human psychology. FTT differs from other theories in explaining how sensitivity to context, which contributes to task variability, is a feature of advanced cognition—because it reflects meaningful gist. This gist can be specified scientifically; it has been measured and modeled using rigorous methods that avoid shortcomings of some other techniques (e.g., Abadie, Waroquier, & Terrier, 2013; Brainerd & Reyna, 2012; Reyna & Brainerd, 1995, 2011). In FTT, task variability is not chaos. Instead, people have stable values and preferences stored in long-term memory that are elicited to different degrees by different tasks, but in predictable ways (e.g., Reyna, Lloyd, & Brainerd, 2003).

Explaining Inconsistent Responses Using Underlying Psychological Processes

Inconsistent choices, or violations of the independence and invariance axioms of economics, then, are expected in FTT because they are effects of context (Epstein & Zin, 2001; Machina, 1982). Roughly speaking, independence is the assumption that preferences between options (or “lotteries”) should not change when another option is introduced—even if people do not select that option: If A is preferred to B, then adding an inferior option C to the choice set should not affect the preference of A over B. Nevertheless, psychologically, the context of unchosen options can affect the preference of A over B because it invites qualitative—or gist-based—contrasts that reinforce or undercut preferences (Medin, Goldstone, & Markman, 1995; Pothos, Busemeyer, & Trueblood, 2013). For example, choosing between a product costing \$20 with a quality rating of 25 (out of 100), a product costing \$40 with a rating of 50, or a product costing \$90 with a rating of 55 will lead to the larger preference for the \$40 dollar (middle) option as compared to a choice between only the first two options (known as the asymmetrical dominance effect, or attraction effect; Huber, Payne, & Pluto, 1982). Adding the third, \$90 option changes the context of the decision, making the \$40 option look better overall (because the \$90 option is more similar, but inferior to the \$40 option), even though economic models would assume independent evaluations of each option.

Similarly, invariance is the assumption from economics that the same outcomes should be treated consistently: People should feel as good about gaining \$100 as about being given \$200 and losing \$100 because the net outcomes are the same (\$100). Psychologically, however, people do not feel the same about these literally identical outcomes (e.g., Jasper, Bhattacharya, Levin, Jones, & Bossard, 2013). Hence, they exhibit framing effects, which we have briefly discussed (see also below) and other inconsistencies in judgments and decisions, such as the Allais paradox.

The violations of strict literal processing reflect gist-based intuition –thus they are intelligent processes in FTT, but when incoherent responses are noticed (e.g., when subjects notice that they have given conflicting responses in within-subjects framing tasks), different psychological processes of monitoring and inhibition come into play to suppress that incoherence (e.g., Adam & Reyna, 2005; Reyna & Mills, 2007; see also Evans & Stanovich, 2013). By monitoring, we mean mentally reflecting on one's judgments and decisions, so that similarities across materials or inconsistencies between answers are noticed and censored. People try to maintain consistency across decision problems by monitoring their responses and inhibiting those that appear inconsistent, regardless of their actual preferences.

More fundamentally, FTT's process assumptions imply that no behavior can be taken at face value. Choices do not reveal preferences any more than eye movements reveal processes; all behaviors—choices, eye movements, and other manifest behaviors—are the product of underlying neurological and psychological processes that shift as the environment changes (Reyna & Huettel, 2014). The outputs of these processes should not be taken to be the processes themselves, which must be corroborated with rigorous hypothesis testing. Thus, task variability at the level of outputs, such as inconsistencies in manifested preferences (e.g., in choices vs. ratings), does not imply that people do not have stable underlying preferences (Slovic, 1995) once mental representations, values/principles (analogous to social and moral norms in FTT), and contextual factors are disentangled. Consistency of actual *preferences* is more accurately assessed at the underlying process level rather than by uncritically examining behavior (Reyna et al., 2003).

People can achieve consistency (or coherence) in the outputs of reasoning, judgments, and decisions in two main ways. One way is that they can understand the essential gist of information at a deep level, and thus avoid inconsistencies that turn on superficial features of information, recognizing underlying consistencies. A famous example was provided by Wertheimer (1982) in which the area of a parallelogram can be determined by generalizing the approach to calculating the area of a rectangle. Applying the rote formula for rectangles to parallelograms by multiplying the lengths of the sides, verbatim computation, does not work. As long as the parallelograms are regular figures, a standard procedure can be applied (making lines perpendicular from the corners of the base). However, if a parallelogram with a novel shape or orientation is provided, the standard procedure will not work and people must solve the problem by understanding the true structure of a parallelogram (i.e., the figure can be bisected anywhere if the ends are joined). A rectangle, then, is a special case of a parallelogram, and the more generalizable reasoning approach--based on understanding--was called productive thinking by Gestalt theorists because it transferred to superficially different but conceptually similar reasoning problems (see Reyna, 2012a). Thus, understanding the underlying gist of a parallelogram produced consistent reasoning.

Another way to achieve consistency is to monitor the outputs of processing, as explained above, and modify outputs so that they agree with one another. In other words, if one judges 80% correct to be good performance, then it is possible to realize that 20% incorrect on the same test is the same level of performance, and adjust judgments so that they agree. Most research on individual differences taps the latter processes of monitoring and inhibition that

allow people to censor inconsistent behavior (Kahneman, 2003; LeBoeuf & Shafir, 2003; Reyna, 2013; Stanovich & West, 2008).

Evidence for such strategic monitoring and inhibition has been found in both false memory and judgment-and-decision-making research, but these processes can be distinguished from verbatim and gist processing (Reyna & Mills, 2007). Supporting this distinction, gist processing goes up with age during childhood, *increasing* semantically driven errors, whereas monitoring and inhibition also go up, *decreasing* computationally driven errors (e.g., Reyna & Farley, 2006). For example, compared to younger children, older children monitor their computations more often in mathematical problems and correct their answers. Among adults, some are higher in need for cognition or cognitive reflection, which manifests in greater monitoring of cognition and inhibition of incorrect responses (Liberali et al., 2012). One example of this can be found in the Cognitive Reflection Test – a task with questions such as “A bat and a ball cost \$1.10 together, and the bat costs a dollar more than the ball. How much does the ball cost?” that elicits an intuitive, automatic, and incorrect answer of 10 cents. Checking whether the initial intuitive response is correct in the Cognitive Reflection Test reduces biased answers (e.g., if the ball is 10 cents, then the bat must cost \$1.10, yielding an incorrect total cost of \$1.20 of the bat and ball together; Frederick, 2005; Liberali et al., 2012). Therefore, this test is a measure of the degree to which people reflect on, and censor, their initial intuitive responses.

However, monitoring and inhibition--when combined with rote verbatim processing--lacks insight, and, thus, can *increase* errors. Research suggests that people high in numeracy actively monitor their numerical processing and tend to spontaneously convert numbers into different forms, such as percentages into frequencies and vice versa. In some instances, this tendency to convert numbers makes high numerate people more subject to specific cognitive biases than low numerate people (see Reyna et al., 2009).

For example, when asked to make judgments involving percentages (e.g., 10%), high numerate people will spontaneously transform percentages into frequencies (e.g., 10 out of 100), inducing the well-documented phenomenon of denominator neglect effect for frequencies (i.e., most people give more weight to the numerator of a fraction or ratio, and therefore perceive the overall amount as larger than a percentage; similar overweighting of 1 relative to 10 could occur if this fraction were simplified to 1/10; Peters et al., 2006; Reyna & Brainerd, 2008). Peters et al. asked high and low numerates to rate how risky it would be to discharge a psychiatric patient (a) who had a 10% risk of committing a violent crime or (b) for whom 10/100 individuals like this one committed a violent crime after being released. High numerates gave relatively high risk judgments for both percentage and frequency formats, whereas low numerates gave lower risk judgments for the percentage than the frequency format.

Whereas the traditional interpretation of these results suggests that high numerates are more consistent and that this reflects more objective (advanced) processing (Peters, 2012), the FTT account holds that high numerates in this study were more biased than low numerates because both estimates were biased upwards, consistent with the established direction of bias for frequencies in this task. People high in numeracy appear to translate 10% to 10/100,

inducing denominator neglect for both formats (Reyna et al., 2009). Ironically, this effect demonstrates *increased* bias due to monitoring because it sparks spontaneous conversion of percentages into a more biasing frequency format. Similar ironic effects associated with high numeracy have been identified in other tasks, including rating lower-value gambles as more attractive than higher-value gambles (Reyna et al., 2009). Thus, more active monitoring and higher mathematical skills do not necessarily improve cognitive performance if the resulting analysis reflects verbatim processing—that is, engaging memorized skills such as conversion of percentages without deeper conceptual thinking.

Traditional dualist theories assume an associative, intuitive process that is error-prone and an analytical process that corrects for the faults of intuition and reasons at a higher level (see Evans & Stanovich, 2013). FTT differs substantially from traditional dualism because it distinguishes gist-based intuition, verbatim-based analysis, and monitoring/inhibition, such that (1) cognition reflects gist-based intuition and verbatim-based analysis operating in parallel, (2) advanced cognition is generally intuitive in the sense of being gist-based, and (3) advanced cognition is not conflated with monitoring and inhibition, making it possible to predict opposing developmental trajectories as well as other paradoxical patterns.

Specific Predictions for Risky Choice

With this background, we can discuss in greater detail how gist predicts specific biases in judgment and decision making and how such biases increase with development.

Furthermore, we explain how gist-based processing in false memory (e.g., misremembering hearing an unrepresented word, such as “doctor” after studying a list that contained medical words such as “hospital” and “nurse” with which “doctor” is semantically related; Brainerd & Reyna, 2012), is related to gist-based processing in judgment and decision making.

A classic choice task pits a sure option (e.g., a sure gain of \$100) against a risky gamble (e.g., a 50% chance to gain \$200 and 50% chance to gain nothing). Most adults prefer the sure option over the risky gamble; they are risk averse. Now, imagine being given \$200, but a choice has to be made between losing \$100 for sure versus a risky gamble – a 50% chance to lose \$200 and a 50% chance to lose nothing. For losses, most adults are risk-seeking; they prefer the risky gamble over the sure loss.

As is apparent when the gain and loss versions are presented back-to-back, they are equivalent because subtracting a sure loss of \$100 from \$200 amounts to a \$100 gain and so on throughout the problem. As we discuss below, this bias in risk preferences for gains and losses emerges in adolescence as a result of gist-based intuition, and risk takers who compromise their health (e.g., by having unprotected sex with more partners) are less subject to this bias and think about risk more literally (e.g., Reyna et al., 2011; Reyna & Mills, 2014). (Children have different attitudes towards risks involving gains vs. losses, but some-none categorical thinking about risk emerges later in development.) In addition, as FTT predicts, adult experts with more experience making risky choices continue to develop as a function of their experience; they, too, are more subject to the gain-loss bias than adults with less experience (Reyna et al., 2014).

Theories of risky decision making such as prospect theory and cumulative prospect theory characterize gains and losses as changes relative to a zero reference point (Tversky & Kahneman, 1986), although reference points can be expectations or other baselines for comparison (K szegi & Szeidl, 2013). The reference point provides a context against which gains or losses are defined (McKenzie, 2004). A gain of \$100 is an increment up from zero, whereas a loss of \$100 is a decrement down from zero. According to FTT, which builds on prospect theory and its descendants, the gist is determined by qualitative distinctions among the numbers in options and people begin with the simplest distinctions they can—categorical gist. The categorical contrast in our choice example with \$100 is between some money and nothing. Therefore, the representation of the options boils down to gaining some money for sure versus gaining some money or gaining nothing. Then, people retrieve relevant values—for money in this example—and apply them to the representation of the options. Because some money is valued more than nothing, people prefer the sure gain. The same steps are followed for the loss decision, which boils down to losing some money for sure versus losing some money or losing nothing. People prefer losing nothing to losing something, so now they prefer the risky option.

Figure 1 displays choice percentages for 30 gain and loss decisions presented to three groups of people: college students, post-college adults, and intelligence agents who were trained experts in risky decision making (e.g., about national security; see Reyna, Chick et al., 2014). (Trained experts in other areas of decision making, such as medicine and public health, have also been shown to rely more on gist in their domain of expertise compared to novices; Reyna & Lloyd, 2006.) The “complete” condition in the middle of the figure corresponds to the classic description of these decisions consisting of a sure option (e.g., \$100 for sure) and both complements of a risky gamble (e.g., both “50% chance of \$200” and “50% chance of nothing”). The original variations on the standard mixed condition—labeled “zero present” (50% chance of nothing) and “non-zero present” (50% chance of \$200) in Figure 1--were introduced as critical tests of FTT (Reyna & Brainerd, 1991, 1995; see Reyna, 2012a).

On the one hand, the zero-present condition on the right focuses attention on the zero part of the risky gamble, for example, the “50% chance of nothing,” placing the 50% chance of \$200 in the background information about the problem. Hence, the zero-present formulation of choice options emphasizes the *categorical* contrast between the sure and risky options (e.g., gaining some money vs. maybe gaining nothing), which FTT predicts should increase gain-loss framing effects. On the other hand, the non-zero present condition on the left of Figure 1 deletes that zero complement of the risky gamble (and places it in the background information); so, instead of both “50% chance of \$200” and “50% chance of nothing,” it merely reads “50% chance of \$200.” The non-zero formulation de-emphasizes the categorical contrast, which should reduce gain-loss framing effects.

Prospect theory, rank-dependent expected utility theory, and other major theories of decision making, all predict that choices in the mixed condition should be the same as the choices in the zero-deleted condition on the left (non-zero present; Kühberger & Tanner, 2010; Reyna & Brainerd, 2011). For example, prospect theory predicts that people calculate an analogue to expected value by multiplying subjective values of outcomes (e.g., \$200) by subjective

values of probabilities (Tversky & Kahneman, 1986); a 50% chance of \$0 is equal to zero. Therefore, prospect theory predicts identical risk preferences for the complete condition versus the non-zero present condition (because mathematically, zero literally adds nothing to the problem), whereas the observed stark difference in choice is predicted by FTT (because the zero highlights the categorical distinction between something and nothing). In the experiment shown in Figure 1, and in other replications of these truncation effects, subjects were carefully instructed about the deleted portions of the gamble (see Chick, Reyna, & Corbin, in press, for experiments testing various ambiguity hypotheses). Thus, the problems were not ambiguous because subjects were fully informed about the “missing” information as part of the background information (they also passed a quiz for this missing information at the end of the experiment). Because there was no ambiguity about deleted information, subjects in all three conditions received the same information, albeit with different parts of the information highlighted.

Notice that although the gamble described as a “50% chance of \$200 and 50% chance of nothing” is mathematically equivalent to the description as a “50% chance of \$200,” the gist is not the same: The latter emphasizes a quantitative tradeoff (i.e., verbatim-based analysis) relative to the sure option of \$100 for sure, a lower probability of a higher amount. Nevertheless, despite mathematical equivalence, the deletion manipulations produced large predicted differences for all three groups of subjects: exaggerated framing effects when the zero complement is highlighted and attenuated framing effects when the zero complement is missing. As we discuss in greater detail below, Figure 1 illustrates that these effects—original framing effects and truncation manipulations—are not restricted to college students under artificial conditions (cf. Henrich, Heine, & Norenzayan, 2010).

Developmental Differences in Risky Decision Making: Experience and Expertise

According to FTT, risky choice framing effects reflect reliance on gist-based intuition, the use of simple categorical gist representations along with retrieved social values and principles. Moreover, as shown in Figure 1, the intelligence agents who were the most advanced subjects in terms of training and experience regarding risky decision making displayed the largest framing effects. They also showed robust effects of truncation manipulations. These truncation effects have been demonstrated with a variety of outcomes; similar effects are obtained with lives, money, and other valued dimensions (e.g., Reyna, 2012a).

Risky choices are not just made in the laboratory, however. Using FTT, gist-based intuition has been shown to characterize risky decision making in medicine. For example, Reyna and Lloyd (2006) compared decisions of medical students, general medical practitioners, cardiology specialists and subspecialists (most expert) for patients with chest pain who are not having a heart attack. Such patients are at varying risk of having a heart attack, but physicians cannot admit them all. As cardiology expertise increased, physicians were more likely to base admission decisions on simple gist representations: They used fewer dimensions of medical information and processed that information in a more categorical all-or-none fashion. That is, specialists and subspecialists were more likely to use one dimension of information and to either admit patients to intensive care--the highest level of

care--or to discharge them for outpatient follow-up--the lowest level of care (see also Adam & Reyna, 2005; Reyna & Adam, 2003; Reyna et al., 2003). Again, as in Reyna et al. (2014), the most advanced subjects were most likely to use simple gist-based intuition in decision making, as opposed to complex analysis of multiple dimensions.

At the other end of the life-span, as predicted by FTT, young children are less likely to show risky choice framing effects than adults (e.g., Reyna & Ellis, 1994; Reyna & Farley, 2006; Weller, Levin, Denburg, 2009). Children treat gaining one toy as the same as being given two toys and losing one toy. Even young children take roughly calculated risks, trading off the amount of potential prizes (number of toys) against risks as communicated by shaded areas of spinners. Indeed, FTT's prediction of increasing gain-loss framing bias from childhood to adulthood in risky choice was the first demonstration of a "developmental reversal" prediction (Reyna & Ellis, 1994; see also De Neys & Vanderputte, 2011; Jacobs & Potenza, 1991; see Weldon, Corbin, & Reyna, 2013, for a review). These reversals of traditional expectations occur because children rely more on representations toward the verbatim end of the verbatim-gist continuum, compared to adolescents and adults (the latter rely more on gist, a fuzzy-processing preference; see also Wolfe & Fisher, 2013, for a method of measuring individual differences in fuzzy-processing preference).

Developmental reversals cannot be explained away as merely greater knowledge (e.g., of social stereotypes when base rates are rejected in favor of such stereotypes) because wrong answers become increasingly more prevalent from childhood to adulthood even when knowledge differences are controlled or equated. False memories based on gist, for example, increase from childhood to adulthood, even when to-be-remembered words are specially selected to be familiar to children (e.g., as predicted by FTT, Reyna, 2012a). Adults demonstrate larger biases in probability judgments, too, compared to children, rejecting numerically correct answers (Reyna & Brainerd, 1994).

Comparable effects of *increased* rejection of numerically correct answers have been demonstrated in charitable giving. Older children and adults are more likely than younger children to donate money to a single victim than to a larger group containing that victim, a developmental reversal that has been attributed to the growth of reliance on categorical gist (Kogut & Ritov, 2005). Specifically, Kogut, Slovic, and Vastfjall (2014) conducted a between-subjects experiment in which each subject was instructed to share any number of candies with either an individual child or with a group of six children. They demonstrated a developmental reversal in preference for sharing candies, such that the youngest group (nursery school) gave more candies to the group than to a single individual, pre-elementary and first-graders did not differ in number of candies given to the group versus individual, and the second graders shared more with one identifiable individual than they did with the group. Therefore, younger children were more likely to provide the normatively correct and unbiased response of giving more candies to a greater number of individuals -- an indicator of quantitative verbatim processing. Adults and older children apparently use a some-none gist when asked to donate to or share with a single individual, as in framing effects, whereas numbers larger than one cue quantitative processing.

Thus, in risky choice framing tasks, children as young as preschoolers can demonstrate that they know how to roughly multiply magnitudes of probabilities and outcomes in decision tasks that are designed to be fully understandable for children (e.g., Nikiforidou & Pange, 2010; Reyna & Brainerd, 1994; Téglás, Girotto, Gonzalez & Bonatti, 2007). They are also more risk-seeking than adults; all other factors equal, preference for the risky gamble declines from childhood to adulthood (e.g., Boyer, 2006; Reyna & Farley, 2006). For equal-expected value problems, this means that they prefer the gamble over the sure option in both gain and loss frames (e.g., about 70% of the time in Reyna & Ellis, 1994). They can discriminate different probabilities of outcomes, and thus do not choose to gamble 100% of the time, gambling more often when the probability of winning something is higher (or the probability of losing something is lower).

Children are loss averse when losses are real, in other words, when they are not net gains. Children lack sensitivity to context when they focus on net returns in risky choice problems, rather than focusing on the history of “losses”—as subtractions from previous quantities (two toys minus one toy). This lack of sensitivity to context is not due to failing to remember prior quantities; memories for quantities in this task have been assessed and do not account for framing effects. Older children and adults faced with the identical experimental stimuli treat outcomes differently depending on whether they are gains or net gains (“losses”)—despite their objective equality.

Decision making becomes less objectively quantitative—less verbatim—as children get older. Around 8–9 years of age, they begin to rely mainly on only one dimension in decision making, namely, outcomes (i.e., rewards). When expected values are equal, the gamble always offers a larger reward than the sure thing; in our earlier example, \$200 is larger than \$100 (and the sure loss offers a smaller loss than the gamble). This kind of information processing focusing on numerical differences in outcomes produces evidence of reverse framing: greater preference for the gamble (which has higher rewards than the sure option when expected values are equal) in the gain frame and greater preference for the sure option in the loss frame (which has lower losses, relative to the sure option). Reverse framing is larger when differences between outcomes are greater, as might be expected, which suggests a motivational aspect to this cognitive representational effect (Chick & Reyna, 2012; Reyna, Estrada et al., 2011). However, motivational factors, such as sensation seeking (which reflects reward sensitivity), and reverse framing each account for unique variance in predicting risk taking behavior, demonstrating that these factors cannot be reduced to one another (Reyna, Estrada et al., 2011).

Standard framing effects emerge in early adolescence, observable initially when numerical differences between outcomes are small, but they become more prevalent as adolescents transition to gist-based intuition in adulthood. Ironically, a sizeable portion of risk taking behavior in multiple real-world domains seems to be linked to verbatim-based analysis rather than gist-based intuition (Reyna & Farley, 2006). In addition, some adolescents are impulsive and unthinking—they insufficiently monitor and inhibit their behavior, reflecting less mature executive function (Casey & Caudle, 2013; Steinberg, 2008). However, many others seem to consider risk-reward tradeoffs and intentionally take roughly calculated risks, as predicted by FTT (IOM & NRC, 2011). That is, verbatim-based analysis is risk

promoting when perceived benefits are high and risks are low. In contrast, gist-based intuition applies the same thinking we discussed in risky choice gain and loss problems: better to have some fun than to take a risk and either have some fun or none (if a bad outcome occurs) (Rivers et al., 2008).

For instance, for most of the risk taking behaviors that have been studied, adolescents' ratings of risks and rewards (benefits) predict their behavior (rewards have a more robust effect than risks; Reyna, Estrada et al, 2011; Reyna & Farley, 2006). This literal thinking produces poor outcomes for many adolescents, although most escape the adolescence-limited period of heightened risk taking (Moffitt, 2003). "Playing the odds" pays off in the aggregate, but it can have catastrophic effects for individuals. Scales that assess gist-based thinking have been designed, such as categorical thinking and ordinal risk perception, as well as verbatim-based thinking scales (e.g., Mills et al., 2008; Reyna, 2008; Reyna, Croom et al., 2013; Reyna, Estrada et al., 2011). As FTT suggests, and research using these scales has shown, verbatim-based analysis is generally associated with greater unhealthy risk taking and gist-based intuition is associated with healthier behaviors (e.g., later initiation of sex and fewer sexual partners in adolescence; e.g., Mills et al., 2008; Reyna & Mills, 2014).

These findings that verbatim-based analysis is associated with unhealthy risk taking, whereas gist-based intuition is associated with less risk taking, make sense according to FTT because the former is less developmentally advanced than the latter. Moreover, inculcating gist thinking reduces self-reported health risks, as shown using experimental designs (e.g., Fraenkel et al., 2012; Reyna & Mills, 2014; Wolfe et al., 2015). Literal thinking misses the essential bottom line of many health risks, such as HIV-AIDS, which are low probability but catastrophic events (Reyna & Adam, 2003; Wilhelms, Reyna, Brust-Renck, Weldon, & Corbin, 2014).

Further evidence for the maladaptiveness of literal verbatim thinking is that, although those with autism are more resistant to gist-based biases, they are less able to make the global, non-literal inferences that support real-world pragmatic functioning (e.g., De Martino, Harrison, Knafo, Bird, & Dolan, 2008; Miller, Odegard, & Allen, 2014). In sum, FTT predicts the growth of gist-based intuition as experience and expertise develop, which supports paradoxical increases in specific semantic biases, but these reflect global cognitive advances (Weldon et al., 2013).

Caveats and Cautions

It is important to acknowledge that verbatim versus gist thinking does not account for all judgment and decision making effects (for an excellent review, see Strough, Karns, & Schlosnagle, 2011). Among other factors, emotion is extremely important, although emotion interacts with mental representations; indeed, mental representations shape emotional responses (Lerner & Keltner, 2001; Rivers, Reyna, & Mills, 2008). Also, many psychologically different tasks have been called framing tasks. For example, attribute framing—describing beef as 90% lean versus 10% fat—has been shown to be empirically distinguishable from risky choice framing (Jasper et al., 2013; Levin, McElroy, Gaeth, Hedgcock, & Denburg, 2014). In addition, tasks that are variously referred to as involving ambiguity, learning about outcomes (experiential tasks), and probability learning differ

psychologically from risky choice paradigms that we have discussed (Dutt, Arlo-Costa, Helzner, & Gonzalez, 2014). As examples, children are less able to remember outcomes learned from experience compared to adults, as has been known for decades. Thus, when memory supports are provided, developmental differences in such learning paradigms are curtailed (Van Duijvenvoorde, Jansen, Bredman, & Huizenga, 2012). Prior reviews have mistakenly interpreted these memory findings as reflecting developmental differences in decision making; once these task demands are recognized, seemingly conflicting findings can be reconciled.

Also, the ability to reliably compute expected value improves from childhood to adulthood (Levin, Bossard, Gaeth, & Yan, 2014; Reyna & Brainerd, 1994; Weller, Levin, & Denburg, 2011). Thus, performance for children and adults for framing problems that differ in expected value reflect developmental improvements in the ability to execute verbatim-based analysis, as well as the representational, retrieval, and monitoring factors that we have discussed. For example, children learn to multiply in elementary school, which allows them to more easily estimate expected value (Weller et al., 2009). Therefore, the ability to suppress framing effects when expected values work against framing effects (e.g., the risky option is superior in the gain frame, but the sure option is superior in the loss frame) improves in childhood (Reyna & Brainerd, 2008). FTT differs from most other dual-process theories in assuming that both verbatim and gist processes are engaged simultaneously in both memory and decision-making tasks, as reflected in the finding that the complete condition in Figure 1 which taps both processes differs from zero-absent (verbatim emphasis) and zero-present (gist emphasis) conditions.

Relations between Gist-based False Memory and Framing Effects

Research on FTT has implicated the use of verbatim and gist representations in a wide range of memory, reasoning, and decision making tasks (for reviews, see Reyna, 2008, 2012a). For example, FTT predicts similar developmental trends across tasks, as well as points out that similar mental representations are used in both memory and judgment tasks (e.g., ordinal and categorical gist memories in probability judgment tasks and in decision-making tasks). In the Deese-Roediger-McDermott (DRM) paradigm, for example, subjects see or hear lists of words that share semantic relations with one another (e.g., table, legs, seat, cushion) and are then given a recall or recognition test (Brainerd & Reyna, 2005; Gallo & Roediger, 2003). Presented words are called “targets” because the standard DRM task involves a *verbatim* memory test: Subjects are instructed to say “yes” only to exact copies of presented words. Critical lure words (e.g., chair) were not presented in the initial list, but are falsely remembered at very high levels, due to a *gist* memory of the semantic theme of the list (see Brainerd & Reyna, 2012, for a more extensive review of gist and verbatim memory).

Studies have also shown that third variables, such as sleep, which foment gist-based false memories, also foment intuitive reasoning and problem solving (Payne, Stickgold, Swanberg, & Kensinger, 2008). Individual differences (e.g., in intelligence) also provide indirect links between memory, on the one hand, and reasoning and decision making, on the other hand; for example, higher intelligence has been linked with higher levels of gist-based false memory (McGeown, Gray, Robinson, & Dewhurst, 2014; Reyna, Holliday, & Marche,

2002; Weekes, Hamilton, Oakhill, & Holliday, 2008; but see Stanovich & West, 2008). However, there has been no direct evidence that false memory was directly associated within-subjects to gist-based judgment-and-decision-making biases.

Figure 2 displays results from 104 adults (47 subjects were female and mean age was 36.1 years, with a standard deviation of 12.11 years) recruited on Amazon Mechanical Turk (see Corbin, Russo, & Reyna, 2015, for additional results). Subjects received blocks of five gain and five loss framing problems (the blocks were counterbalanced for order across subjects; see Reyna, Estrada et al., 2011). The five problems in each frame varied only in the magnitude of outcomes (from 60 to 10,000 lives saved or lost). Subjects also received the six 15-item DRM word lists that have been shown to elicit the highest levels of false memory (Stadler, Roediger, & McDermott, 1999), followed by a standard old-new recognition test. Decision-making and recognition memory tasks were counterbalanced across subjects. Significant framing and false-memory effects were obtained.

Most important, Figure 2 shows the positive relation between gist-based false memory for related distractors and framing effects (the number of risky choices in the loss frame minus the number in the gain frame), controlling for true memory for presented words and unrelated distractors (or response bias). That is, subjects who were more likely to misremember gist-consistent words as having been presented, controlling for response bias and verbatim memory for presented words, also showed larger framing effects. This result is consistent with FTT's explanation that both semantic false-memory and framing effects are supported by gist-based intuition (e.g., Reyna & Brainerd, 1995; Reyna et al., 2014; Reyna, Mills, Estrada, & Brainerd, 2007). In other words, individuals more likely to rely on gist in a recognition task (as opposed to verbatim memory for presented words) were also more likely to rely on gist in the decision task (e.g., categorical distinctions in framing as opposed to verbatim analysis of numbers). These results indicate that the verbatim-gist distinction is not restricted to individual tasks, but suggest a broader property of information processing.

Also consistent with FTT, true memory for presented words was inversely related to framing effects—better verbatim memory was associated with more consistent responses across frames, consistent with verbatim monitoring (and inhibition of gist-based responses) in both paradigms. In other words, some subjects are better able to remember problems in one frame when they move to the alternate frame; they care about consistency (Russo, Carlson, Meloy, & Young, 2008), and, hence, censor inconsistent responses (Kahneman, 2003; Shafir & Leboeuf, 2002). Monitoring and inhibition of gist-based false memories through retrieval of verbatim memories, also called recollection rejection (see Brainerd, Reyna, & Estrada, 2006), is thus likened to within-subjects suppression of framing effects—monitoring and inhibiting of inconsistent responses to risky choices based on remembering literal similarities across frames (Reyna & Brainerd, 1998; Stanovich & West, 2008).

Summary and Conclusions

Ultimately, FTT describes a cognitive system that strives for meaningful understanding, which supports improved reasoning, judgment, and decision making. This cognitive orientation makes sense because gist representations are long lasting, robust to interference,

and generally preferred for information processing as people gain experience in a domain. Experts in medicine and in intelligence analysis seem to rely more on gist-based intuition, compared to novices. Alternatively, verbatim representations are fragile, easily disrupted, and only relied on when the situation demands precision (e.g., in recalling exact dosage of a drug or in eyewitness testimony). FTT offers insight into cognitive processes that underlie behaviors in the laboratory and real life.

As we reviewed, FTT has disentangled the independent contributions of gist and verbatim representations to inferential reasoning, probability judgment, and decision making about risky options. FTT also predicted developmental reversals in decision biases, such as framing effects, indicating that such biases should grow from childhood to adulthood, which was observed. The theory has generated critical tests, too, experimentally demonstrating the importance of categorical gist representations, as well as effect of monitoring and inhibition, for risky choice framing effects. Experimental manipulations that induce verbatim processing make adults behave as though they were younger; conversely, manipulations that induce gist processing make younger subjects seem older.

In contrast to theories that consider detailed analysis to be the pinnacle of advanced cognition, FTT considers gist to be advanced. Supporting evidence comes from social, cognitive, developmental, and neurobiological psychology. As individuals develop, they are more likely to make inferences that go beyond surface-level details – and become more likely to mistake inferences for memory. Furthermore, adults tend to rely more on categorical distinctions of risk and reward, which make them less risk-prone, whereas adolescents, who rely more on verbatim-based analysis, take more risks involving health-compromising consequences. Finally, experts, such as physicians and intelligence analysts, rely on meaningful, qualitative distinctions rather than precise details when making decisions. Thus, theoretical principles that we have discussed play out in applied domains, demonstrating the ecological validity of basic psychological mechanisms.

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Highlights

- Fuzzy-trace theory predicts that reliance on gist increases with experience and expertise, and is adaptive.
- Reliance on gist—the essence of information—creates biases in cognition.
- The first evidence of a predicted link between false memory and framing biases in risky choice is reported.
- Experts' reliance on gist is illustrated in medicine, public health, and intelligence analysis.

Figure 1.

Proportion of risky choices for college students, post-college age adults, and post-college age intelligence experts.

Figure 2.

Regression line (with 95% confidence intervals) of acceptance rates for related distractors in a Deese-Roediger-McDermott memory task predicting framing scores while controlling for acceptance rates for targets and bias (i.e., acceptance rates for unrelated distractors).