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25 Fuzzy-Trace Theory

Judgments, Decisions, and Neuroeconomics

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25.1 Introduction

In psychology and economics, scholars are increasingly combining behavioral and neuroscientific techniques to understand judgment and decision-making. In the following, we describe a major framework that takes this approach: fuzzy-trace theory. Fuzzy-trace theory (FTT) is a theory of judgment, decision-making, and memory and their development across the lifespan. To begin, we define some basic conceptual components of judgment and decision-making that explain economic behavior, including perceptions of probabilities and outcomes (i.e., payoffs or rewards). In this connection, we also briefly describe the evolution of ideas in behavioral economics and neuroeconomics from the perspective of FTT. We then focus on risk preferences and risky decisions, reviewing the theory's explanations for such phenomena as (a) risky choice framing effects (that risk preferences shift depending on whether choices are described as gains or losses); (b) variations on framing effects (e.g., what are called "truncation" effects because pieces of information are systematically deleted from gambles to test alternative theories); (c) time preferences and delay of gratification, including truncation effects also known as hidden-zero effects; and (d) individual and developmental differences among people, such as differences in age and expertise, sensation seeking (the desire for thrills or excitement usually associated with rewards), and numeracy (the ability to understand and use numbers). In each of these sections, we describe both behavioral and brain evidence that illuminates economic behavior. We conclude by summarizing the main tenets of FTT, how it differs from such approaches as prospect theory, and future directions for research on judgments, decisions, and neuroeconomics.

25.2 Economic and Psychological Approaches: Definitions

Economists and psychologists define "risky" decision-making in overlapping but distinct ways. Economists define risk in terms of the variance of possible outcomes (Fox and Tannenbaum, 2011). Risk seeking is preferring an option with a higher variance payoff over a lower variance one, all

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else being equal (ceteris paribus). For example, stocks are usually more variable in their payoffs than bonds, but they have a greater upside potential, so a risk-seeking person would generally prefer stocks over bonds. When we say "all else being equal," we are referring to the overall expected value of each option: the expected value of an option is the magnitude of each outcome (e.g., the "payoff" if the outcome is monetary gains) multiplied by its probability. Thus, gaining $1,000 for sure is equivalent in expected value to a 0.50 probability of gaining $2,000 (otherwise nothing). When options are equal in expected value, a higher variance payoff implies that the potential magnitude of the payoff is higher, although the probability of receiving that payoff is lower.

With this definition of risk, risk seekers choose risky gambles over equivalent sure options, and they choose more risky gambles over equivalent less-risky gambles. Risk-averse people have the opposite preferences. Risk-neutral people do not make distinctions related to variance in outcomes. These ideas have influenced all subsequent theories of risky decision-making in economics and psychology, and they capture some basic intuitions that most people would agree with, namely, that the desirability of an option depends on both the magnitude of potential outcomes and their probabilities. If two life insurance policies costs exactly the same amount of money, but one pays out $100,000 and the other pays out $200,000, most people would prefer the latter policy (all else being equal).

Although many psychologists who study judgment and decision-making apply the economic definition of risk, clinical psychologists and other professionals (those in public health or management) often define a "risky" decision as a choice that could potentially lead to loss or harm (Fox and Tannenbaum, 2011; Reyna and Huettel, 2014). Consider choosing to smoke cigarettes, engage in unprotected sex, or drive after drinking alcohol. Most people, even adolescents, know that these choices could have harmful – and potentially fatal – consequences. Therefore, psychologists would define these decisions as "risky" because of the potential negative outcomes of these courses of action. Negative outcomes (losses or harms) are uncertain when someone opts for a risky choice in these scenarios: smoking does not inevitably result in lung cancer, unprotected sex does not necessarily result in HIV, and drinking and driving does not always result in an automobile accident or legal sanctions. The willingness to take these kinds of risks is not wrong, according to economists, as long as the potential benefits to that person outweigh the costs. Hence, understanding underlying preferences – what matters to people and why – is essential regardless of the definition of risk. For professionals who wish to reduce social costs or human suffering, understanding underlying preferences is important so that unhealthy risk taking can be reduced (Reyna and Farley, 2006). For economists, it is important to understand whether people's choices are motivated by their values and are consistent with their risk attitudes. FTT builds on these approaches to illuminate the cognitive, social, and personality factors that determine whether people are acting in their rational self-interest (Reyna, 2008).

25.2.1 Basic Conceptual Components of Judgment and Decision-Making

FTT descends from a series of models of judgment and decision-making that have become increasingly "psychological" over time. As noted, classical economic theories of decision-making distinguish between two components, probabilities and outcomes, which are combined multiplicatively to determine the overall value of a prospect. The overall value of $1,000 of the prospect of gaining $2,000 with a 0.50 probability is called "expected value" because the expectation of a 0.50 probability of $2,000 over many trials is $1,000 on average. Theories that followed this mathematical formulation of overall value became successively more subjective or psychological, as we briefly review in this chapter. The upshot with respect to FTT is that this most recent theory emphasizes subjective meaning – the gist – of both probabilities and outcomes, so that mental representations of options can be very different from objective information about those options. It is those mental representations of probabilities and outcomes, combined with background knowledge that fills in gaps, that determines judgments and decisions (see Reyna, 2012, for an overview).

FTT differs radically from earlier approaches that tinkered with perceptions of probabilities and outcomes to capture distortions in perceived magnitudes. One of the most well-known examples of an elegant and powerful theory that attempted to account for psychological distortions is expected utility (EU) theory (von Neumann and Morgenstern, 1944). EU theory amends the concept of expected value by assuming that subjective value is nonlinear; subjective value negatively accelerates as objective value increases. This nonlinearity explains risk aversion given a choice between two prospects, such as the previously described options ($1,000 for sure versus $2,000 with a 0.50 probability). In EU theory, risk aversion is explained because the subjective value of the larger objective value in the gamble ($2,000) is distorted downward more than the smaller objective value in the sure thing ($1,000). Thus, the sure thing has greater subjective value than the risky gamble. Subjective expected utility (SEU) theory adds the idea of nonlinear distortion in the perceptions of probabilities to that of outcomes (Savage, 1954).

Like SEU theory, prospect theory (PT), too, assumes subjective distortions of both probabilities and outcomes. However, it adds the psychological idea of change relative to a reference point, such as the status quo, so that outcomes are perceived as gains (upward change) or losses (downward change) even when they are objectively equivalent (Tversky and Kahneman, 1986). Table 25.1 provides an example of objective gain–loss equivalence that nevertheless elicits very different risk preferences, called a framing effect. Furthermore, losses feel worse than gains of equal magnitude feel good, captured in the steepness of

Table 25.1 *Example of risky-choice framing task options and truncations with PT's and FTT's predictions*

	GAIN frame		LOSS frame		PT's predictions	FTT's prediction
	Sure option	Risky option	Sure option	Risky option		
Gist truncation	Win $1,000 for sure	1/2 chance of winning $0	Lose $1000 for sure	1/2 chance lose $0	Standard framing effect is observed.	Framing effect is strengthened.
Mixed condition: traditional framing task	Win $1,000 for sure	1/2 chance of winning $2,000 and 1/2 chance of winning nothing	Lose $1000 for sure.	1/2 chance of losing $2,000 and 1/2 chance of losing nothing.	Standard framing effect is observed.	Standard framing effect is observed.
Verbatim truncation	Win $1,000 for sure	1/2 chance of winning $2,000	Lose $1,000 for sure	1/2 chance lose $2,000	Standard framing effect is observed.	No framing effect is observed.

Note: PT = prospect theory. FTT = fuzzy-trace theory. In the loss frame, decision makers begin with $2,000 at stake so that gains and losses are equivalent.

the loss function. Thus, loss aversion (feeling worse about losses than comparable gains, regardless of risk) is distinct from risk aversion (but see Yechiam and Telpaz, 2013). Also, low probabilities are overestimated, whereas moderate to high probabilities are underestimated. Once again, the subjective value of the gamble suffers relative to the sure thing because probabilities (as well as outcomes) are perceived as smaller than they objectively are. Because the gamble is smaller, the sure thing is preferred for gains and the gamble is preferred for losses (i.e., a smaller loss is better than a larger loss).

Most recently, PT has been integrated into a more expansive dual-process approach to judgment and decision-making (Kahneman, 2003, 2011), which contrasts rational processes (e.g., deliberation drawing on logic and probability theory) with intuitive processes that foment biases, such as framing effects. Prospect theory laid the foundation for FTT, and FTT encompasses the assumptions of standard dual-process approaches, but it differs from these theories in important ways (Reyna and Brainerd, 2011). Additionally, as neuroeconomics has expanded, FTT has been used as a framework to explain and predict neuroscientific data on decision-making and risk taking, as discussed later in this chapter (Reyna and Huettel, 2014).

25.3 Risk Preferences and Risky Decisions

Like prior approaches, FTT assumes that subjective perceptions of probability and outcomes govern judgments and decision-making. However, rather than simply being less linear than objective values, FTT distinguishes a range of mental representations of probabilities and outcomes from verbatim – the literal words, numbers, or other surface features of information or events – to multiple levels of gist – the bottom-line meaning of the same information or events. A person encodes information into both types of representations separately and simultaneously, and although both gist and verbatim representations are encoded in parallel, these processes are independent and the representations are stored separately. More specifically, gist representations of information are not extracted from the verbatim representations of that same information (Reyna, 2012; Reyna and Brainerd, 2011).

Thus, the gist can be very different from the literal stimulus because it captures subjective interpretation, which is shaped by context, culture, worldview, knowledge, prior experiences, and other factors known to affect meaning (e.g., Reyna and Adam, 2003). The distinction between verbatim and gist representations (and associated thinking) is reminiscent of gestalt theory, which heavily influenced the development of FTT, in which productive nonliteral thinking is contrasted with nonproductive literal thinking (Wertheimer, 1938).

As an example of gist informed by context, a 1 percent chance of an insurance loss (e.g., from a major house fire) could be viewed as high when a person does not have the financial resources to rebuild, and, thus, could be accompanied by feelings of fear rather than complacency. (Note that the probability of 1 percent is the literal verbatim representation.) In this context, being unwilling to take a risk by failing to pay for insurance makes sense (although there is still a maximum cost of insurance beyond which people would not be willing to pay). According to FTT, the crux of this decision turns on a qualitative understanding of the gist of what "high" risk or "too much" money means, in parallel with verbatim analysis of literal numbers. The gist is fuzzy, not an exact number, but it is meaningful to that person in that context; a 1 percent chance of rain, for example, is likely to be viewed as a "low" chance of rain. In FTT, these contextual effects are seen as often a global strength of human cognition, despite producing systematic biases.

Another important tenet of FTT is that a person encodes multiple levels of gist with different amounts of detail, such as categorical versus ordinal gist. A representation described as categorical could include a description of information using a "some" versus "none" distinction, for example, some money as opposed to none or some risk as opposed to none. An ordinal gist representation, on the other hand, would contain a "less" versus "more" distinction, for example, a small as opposed to large amount of money or low as opposed to high risk. The specificity of the question or constraints of the task govern which level of gist is used to make a judgment or decision, but people generally rely on the least detailed level of representation (Corbin et al., 2015).

There is corroborating evidence for verbatim and gist representations in the memory literature (e.g., Reyna et al., 2016). Each type of representation supports a different kind of processing: verbatim representations have the precision to facilitate exact computations, but gist representations facilitate the fuzzy, impressionistic, often unconscious processes of intuition (Reyna, 2012). FTT accounts for behavior in a wide range of cognitive tasks (Reyna and Mills, 2007). To take one example relevant to economic behavior, in FTT, preference reversals are accounted for by different levels of precision imposed by the task: choice, ranking/rating, and numerical judgments (Corbin et al., 2015; Reyna and Brainerd, 1995). A preference reversal occurs when an option is preferred in a choice task (e.g., apartment A is chosen over apartment B as more desirable to rent), but that same option is not preferred in a ratings task (e.g., apartment A is rated as less desirable to rent than apartment B; Fischer and Hawkins, 1993). FTT's explanation is that simpler gist representations can typically be used to discriminate apartment A from B in a choice task, compared to rating the apartments' desirability; the latter requires more precision (see Corbin et al., 2015). In the following, we apply the same principles of FTT to explain risky decision-making for gains and losses.

25.3.1 Fuzzy-Trace Theory and Risky-Choice Framing

Returning to our example in Table 25.1, FTT explains gain–loss framing effects (and similar gist-based biases; Adam and Reyna, 2005; Weldon, Corbin, and

Reyna, 2013) through different means than traditional decision theories, such as EU theory, PT, or standard dual processes. FTT explains the effects found in the decision-making literature by taking into account a person's interpretations of the options in a decision task, which is reflected in their mental representation of gist (Kühberger and Tanner, 2010; Reyna, 2012). According to FTT, the switch in risk preference seen in framing bias occurs because people are deriving the *gist* of their options and applying their values to that gist. The simplest gist in many decision problems is the categorical contrast between some and none. For the example in Table 25.1, the simplest gist of the gains decision would be gaining some money versus gaining some money or gaining nothing. After extracting the gist of their options, participants retrieve and apply general (gist) principles or values to the extracted gist of the decision. An example of one of these gist principles would be "money is good," which supports choosing the sure option because some money is better than no money. These general principles can apply to many decisions because they ignore specific details about the potential risks or benefits (e.g., exact probabilities or magnitudes). In other words, people do not necessarily have "I like \$2,000 more than \$1,000" stored in long-term memory; rather, they have general principles that apply to a wide array of circumstances stored in a gist format. Therefore, when people represent the categorical gist of options in the risky-choice framing task, and they apply simple gist principles to those representations, they prefer the sure gain over the risky gamble.

The same types of some–none distinctions apply to representations of the loss frame. Using the loss frame that is analogous to our gain-frame example, the gist that one would extract from a sure thing of losing \$1,000 and a gamble for a 50 percent chance of losing \$2,000 and a 50 percent chance of losing \$0 would be "losing some money" versus "losing some money or losing no money." Again, people apply their relevant values or principles (e.g., "Losing money is bad") to the extracted gist of the decision. Because losing money is worse than losing no money, this principle supports the choice of the risky gamble. That is, the gamble is the only option that has a chance of losing no money at all. Laboratory framing tasks have tested this idea that people rely on the gist of choices when making decisions, and supportive results have also been found in real-world decision-making (Broniatowski, Klein, and Reyna, 2015; Kühberger and Tanner, 2010; Reyna et al., 2014; Reyna & Farley, 2006; Reyna and Mills, 2014; Wolfe at al., 2015).

FTT has been extended to explain neuroscientific results regarding risky decision-making and framing (e.g., Reyna & Huettel, 2014). For example, De Martino et al. (2006) conducted the first functional magnetic resonance imaging (fMRI) study of framing behavior. The authors found that framing behavior resulted in increased activation in the amygdala, which they concluded may reflect an affect heuristic driven by an underlying emotional system. A correlation was also found between susceptibility to the framing effect and activation in the medial and orbital prefrontal cortex. However, De Martino et al. (2006), as well as Roiser et al. (2009), confounded gains and losses by including both gain and loss wording in the risky-choice options for both frames. For example, in the gain frame, a safe option would be given: "Keep $20." The risky option was presented in a pie chart that represented the probability of "keep all" and the probability of "lose all." The gist of these options then becomes "keep some money" versus "keep some money" or "lose some money" in the gain frame (and "lose some money" versus "keep some money" or "lose some money" in the loss frame). This different categorical gist of framing options also predicts framing effects, but the preferences would be driven by avoiding the possibility of losing something in the gamble in the *gain* frame and avoiding the sure loss in the loss frame by seeking the possibility of gaining something in the gamble. Thus, the increased activation in the amygdala that has been observed in prior studies when people are framing may have been related to loss aversion rather than framing per se. This explanation aligns with findings from other fMRI framing studies that did not use the gain–loss wording for the risky option in both frames and did not observe amygdala activation (e.g., Gonzalez et al., 2005; Zheng, Wang, and Zhu, 2010).

Additionally, FTT assumes that there is metacognitive monitoring of judgments and decisions (e.g. Liberali et al., 2012). For example, when gain and loss problems are presented to the same person (a within-subjects design), some people notice that they are receiving different versions of similar choices, and there is an inhibition of framing effects (Stanovich and West, 2008; Kahneman, 2003). Supporting this, De Martino et al. (2006) found that, for people who showed less susceptibility to the framing effect, there was increased activation in the anterior cingulate cortex (ACC), right orbitofrontal cortex (OFC), and ventromedial prefrontal cortex (vmPFC) while participants were showing framing effects (choosing a sure gain or risky loss). Activity in the vmPFC and OFC seems to represent the subjective value of options, reflecting verbatim analysis of expected value, as expected in FTT (Reyna and Huettel, 2014; see also Kable and Glimcher, 2007). ACC activation, associated with resistance to framing, may be indicative of heightened decisional conflict inherent in the within-subjects' inhibition of framing that FTT predicts (see also Kahneman, 2003; Stanovich and West, 2008), as ACC activity is often correlated with conflict or error monitoring (Brown and Braver, 2008).

Together, this empirical evidence suggests, and FTT predicts, that framing effects result from a gist-based representation of options (e.g., "Saving some is better than saving none") that can be censored or inhibited when people detect that their responses are inconsistent with one another. Verbatim-based analysis of expected value then competes with gist-based intuition to suppress framing effects. When people resist the framing effect in a within-subjects design, they show greater activation in the neural networks that represent expected value, and, when their decisions are counter to their dominant strategy (i.e., the gist-based simplification of options that drives framing), ACC activation is increased. Conflict signals detected by the ACC are transmitted to the dorsolateral prefrontal cortex (dlPFC), suggesting heightened cognitive demands on executive processes when the nondominant strategy is selected (Reyna and Huettel, 2014).

25.3.2 Variations on Framing Effects

FTT not only predicts basic framing effects, but it also predicts variations on those effects and has predictable implications for decision-making in real-world settings (e.g., Broniatowski et al., 2015; Mills, Reyna, and Estrada, 2008; Reyna and Mills, 2014). One interesting theoretical variation of the standard framing task involves truncating parts of the risky option to emphasize or deemphasize the zero complement in order to manipulate reliance on categorical gist (which pivots on the contrast between zero, or nothing, and something). The zero complement consists of the part of the gamble in a framing task in which nothing is lost (in the loss frame) or nothing is gained (in the gain frame), and this variation was predicted to alter what type of processing (gist or verbatim) is relied on (e.g., Reyna and Brainerd, 1991). Truncating the gamble in this way and changing processing (and the representations associated with that) allows researchers to examine the effects of verbatim versus gist processing on framing effects. Note that if the *non*zero complement from the gamble in the gain frame in our earlier example were removed (e.g., "gaining $1,000 for sure or taking a 50 percent chance of gaining $0"), this would emphasize the categorical difference between the options ("winning some money" versus "winning no money"), favoring the sure option in the gain frame. (This condition is referred to as the "Gist" condition in Table 25.1.) However, if the zero complement were removed (e.g., "gaining $1,000 for sure versus taking a 50 percent chance of gaining $2,000"), this would deemphasize the categorical difference between the choices. This emphasis would, consequently, reduce framing effects because people would tend to choose the risky gamble as opposed to the guarantee in the gain frame. (This condition is referred to as the "Verbatim" condition in Table 25.1.)

It may seem that the effects of the truncations are caused by or confounded by ambiguity. It is important to note, though, that this is not the case. At the outset of the task, participants are given special instructions that remove any potential ambiguity in regard to interpreting the truncated options (e.g., Reyna et al., 2014). For example, they are told that if $2,000 are at stake for a loss, and there is a 1/2 chance that they will lose $1,000, that the omitted part of the gamble must be the complementary outcome and probability, namely 1/2 and $0. They are also tested in order to guarantee that they properly understood these instructions. When these special instructions are given, the effects of these truncations remain and are reliable (Chick, Reyna, and Corbin, 2016).

Although there has yet to be a neuroscientific study examining these specific variations on framing and their neural coordinates, this is an important empirical and theoretical question that should be further examined. From a theoretical standpoint, FTT would predict that the gist-emphasis condition (removing the nonzero complement in the gamble) would result in strengthened framing effects and associated activation in the parietal cortex and lateral PFC, whereas the verbatim-emphasis condition (removing the zero complement) should result in weakened framing effects and be associated with subjective values (e.g., areas in the vmPFC; Reyna and Huettel, 2014). The latter requires that expected value be varied across options, rather than keeping it constant. These neural hypotheses draw on literature on memory for verbatim and gist representations (e.g., Kurkela and Dennis, 2016; Reyna and Mills, 2007; see also Reyna et al., 2016). Although other neuroeconomic approaches take into account analysis of subjective value, they do not take these variations, nor their effects, into account (Rangel, Camerer, and Montague, 2008; Fox and Poldrack, 2009).

25.3.3 Time Preference and Delay of Gratification

The same ideas about representations and gist principles apply to understanding time preferences (Reyna and Wilhelms, 2016). Two tasks that assess time preferences are delay of gratification (DG) and temporal discounting (TD), which have been found to be important in predicting economic behavior (Berns, Laibson, and Loewenstein, 2007; Zayas, Mischel, and Pandey, 2014). DG is typically classified as the ability of a person *to wait for* a larger, later reward (e.g., $1,050 in a year) as opposed to a smaller, sooner reward ($1,000 right now). TD is, alternatively, defined as the degree of discounting of larger, later rewards relative to sooner, smaller ones as assessed using a series of choices with different amounts of reward and time. Both of these tasks describe different aspects of time preference (Doyle, 2013; Frederick, Loewenstein, and O'Donoghue, 2002; Reynolds and Schiffbauer, 2005).

TD, in particular, as well as the index associated with it (i.e., one's discount rate), is thought to be a stable individual difference (Kirby, 2009), although it changes over the lifespan (Green, Fry, and Myerson, 1994; Green, Myerson, Lichtman, Rosen, and Fry, 1996). fMRI studies of delay discounting tasks have typically found that (a) areas and dopaminergic systems associated with impulsivity display higher levels of activation when choosing immediate rewards (Kable and Levy, 2015; McClure et al., 2007), and (b) the areas and system associated with control had higher activation when choosing delayed rewards (e.g., McClure et al., 2007; Meade et al., 2011). These results are consistent with standard dual-process theories (but see Kable and Glimcher, 2010, for a contrasting view) and their explanations that time preference is associated with activation of two systems: one associated with control and the other with impulsivity (Bechara, 2005; Bickel et al., 2011; Jentsch and Taylor, 1999; Kahneman, 2011). However, research on FTT has shown that these dual systems are not sufficient to explain either risk preference or time preference.

FTT incorporates the effects of reward (e.g., the attraction of money) and the inhibition of behavior (Reyna and Mills, 2007). FTT goes further and predicts that intuitive, gist-based reasoning can improve a person's capacity to refrain from unnecessary risk taking (Reyna et al., 2015b) and delay gratification (Reyna and Wilhelms, 2016). This additional aspect differs from standard dual-process models, which conflate intuition and impulsivity under System 1 (or Type 1; Evans and Stanovich, 2013).

More specifically, according to FTT, the ability to delay gratification also involves using the bottom-line gist when making decisions (Reyna and Wilhelms, 2016) rather than trading off verbatim, precise details as is assessed in TD tasks. This explanation for DG and choices between sooner, smaller versus larger, later rewards is analogous to the predictions of FTT for framing tasks and choices between sure options and gambles (e.g., Kühberger and Tanner, 2010; Reyna et al., 2014).

Although research supports the idea that the discounting rate is stable over time, that tendency can be modified (Kirby, 2009; Odum, 2011; Ohmura et al., 2006; Simpson and Vuchinich, 2000). Discounting behavior has been effectively modified using specific manipulations that would be predicted by FTT (Koffarnus et al., 2013). In particular, altering the traditional presentation of discounting tasks to emphasize the "hidden zero" has been effective (Magen, Dweck, and Gross, 2008; Magen et al., 2014). The "hidden zero" in a discounting task is adding zero to standard choices, such as "$1,000 today or $1,050 in one year" so that they become "$1,000 today and $0 in one year or $0 today and $1,050 in one year." This manipulation reduced discount rates significantly, probably by emphasizing good and bad categorical distinctions for each option: some today but none later or none today but some later. Using the standard method of presentation for discounting tasks (in which zeros are hidden) does not facilitate categorical distinctions between different choices using gist representations.

However, adding zeros to both options should be less effective than adding a zero to one of the two options, similar to the truncation effects in framing tasks. (See also FTT's explanation of the Allais paradox in Reyna and Brainerd, 2011.) Returning to our example, adding the hidden zero only to the delayed choice creates a categorical difference equivalent to "something now versus nothing now and something later." This categorical difference, theoretically, would promote choosing the immediate option. In contrast, adding the hidden zero to the immediate choice (i.e., "something now and nothing later or something later") would highlight the categorical distinction "nothing later versus something later," which would result in more frequent delayed choices. Adding zeros would not be expected to affect discount rates in the sense that discounting involves trading off magnitudes of outcomes by magnitudes of

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time (verbatim processing of trade-offs) rather than comparing qualitative categories (gist processing).

These manipulations of the typical discounting task are based on FTT's predictions involving representations and gist principles, such as some money is better than none. The manipulations and their effects are analogous to the truncation effects that can be used to manipulate framing effects (Reyna et al., 2015b). These manipulations, both in discounting and framing tasks, are not accounted for by other approaches. The choices themselves remain mathematically unchanged, regardless of where the hidden zero is added, and so are not easily explained through discounting functions applied to quantities being traded off (Magen et al., 2014). In decisions involving numbers, FTT assumes that both quantitative and qualitative processing occur in parallel, and effects of zero introduce qualitative distinctions. More specifically, highlighting categorical gist distinctions in these tasks changes how one interprets the options, which results in cognitive reframing and different choices (see also Zayas, Mischel, and Pandey, 2014).

Time preferences also have a social component that have to do with endorsing cultural values, such as self-denial in the present to achieve greater rewards in the future (Reyna and Wilhelms, 2016). Greater endorsement of such gist principles would be expected to better predict behaviors than exact trade-offs, as assessed in delay discounting tasks. This is because gist representations and associated gist principles capture how most people make decisions. These principles are also more general and can therefore be applied to more situations, as opposed to quantitative trade-offs such as "sacrifice X units of pleasure now to enjoy Y units of pleasure later." Therefore, FTT predicts that the gist of delay of gratification – sacrifice now, enjoy later – has greater predictive validity for problem behaviors in real-world settings than verbatim processing about quantitative trade-offs (i.e., problem behaviors can involve borrowing money to have fun rather than for necessities or drinking to excess).

Exploring this predictive validity, Reyna and Wilhelms (2016) compared a twelve-item scale (called DG-Gist) that evaluated individuals' agreement (using a five-point Likert scale ranging from "strongly disagree" to "strongly agree") with qualitative gist principles associated with DG (e.g., "Sacrifice now, enjoy later," and, "I spend money on having fun today and don't worry about tomorrow") to other measures of delay discounting and impulsivity. Having a lower score on DG-Gist signifies having a higher tendency to delay gratification. Reyna and Wilhelms investigated the convergent and divergent validity of DG-Gist along with other potentially related scales (e.g., spendthrift–tightwad, delay discounting, and Barratt impulsiveness). Correlations of these scales with DG-Gist were relatively low, and it also explained unique variance in predicting problem behaviors not accounted for by the other scales (e.g., overdrawing one's bank account). DG-Gist remained a significant predictor of financial and nonfinancial problem behaviors controlling for such dimensions as sensation seeking, cognitive reflection, delay discounting, and Barratt impulsivity. Thus, this simple, short scale outpredicted longer and more precise scales, including those that tap deliberation as posited in dual-process theories (e.g., Frederick, 2005). Furthermore, these findings across four studies provide support for FTT's explanations of economic and health decisions, incorporating mental representations of gist principles such as delay of gratification.

25.3.4 Developmental and Individual Differences

In combination, the aforementioned results provide critical tests of FTT and alternative theories, such as EU, PT, and dual-process theories, supporting predictions that gist-based and verbatim-based mental representations are reflected in the brain and behavior. According to FTT, representational reliance affects judgment and decision-making. Reliance on gist, as illustrated by the strength of the framing effect, grows developmentally (i.e., with age and expertise; Meschkow et al., in press; Reyna and Brainerd, 2011). A person at a later stage of development and expertise (e.g., an adult) is predicted to *rely* more on gist processing (as opposed to verbatim processing) than a person who is younger and has less expertise (e.g., an adolescent). More specifically, studies have shown that adults, more so than children, tend to rely on the simplest gist representation possible that is needed in order to decide on an action, which has been dubbed the "fuzzy-processing preference" (Reyna and Brainerd, 2008; Reyna et al., 2014; Reyna and Lloyd, 2006; Wilhelms, Corbin, and Reyna, 2015). Although children are less able to perform calculations, they tend to nevertheless focus more on literal details, and can make quantitative trade-offs of probabilities and outcomes if amounts are presented using concrete props when making decisions (Reyna, 1996; Reyna and Brainerd, 1994, 1995; Reyna and Ellis, 1994; Reyna and Lloyd, 2006; Reyna et al., 2011; Reyna et al., 2015b).

Adolescents, who are generally less developmentally advanced than adults but more advanced than children, are caught in between the two ends of the continuum and have more variability as a group (Reyna et al., 2011; Reyna and Farley, 2006; Mills et al., 2008). Research on adolescents incorporating eye tracking data also support FTT's predictions. This research suggests that adolescents obtained more information about options and used a more intensive analytical method to trade off quantities compared to adults (Kwak et al., 2015). Verbatim and gist processing both improve developmentally, including improvements in the ability to remember verbatim details and the gist of information, but the extent to which a person *relies* on each type of processing also shifts, from verbatim to gist, with age and expertise (Meschkow et al., in press; Mills et al., 2008; Reyna, 2012; Reyna and Lloyd, 2006).

Ironically, because young children are the most likely to rely on verbatim processing of probabilities and outcomes, "computing" something like expected value, they are the most likely to behave like rational economists. For example, they do not show framing effects, treating gains and equivalent losses

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similarly (e.g., Reyna and Ellis, 1994). Additional evidence shows that children are sensitive to differences in probabilities and outcomes and combine them roughly multiplicatively (as in expected-value type theories, such as EU theory and PT). They rely on the literal magnitudes of probability and outcome as they are presented. Experiments demonstrating these effects ensure that all probabilities and outcomes are represented with concrete props so that children can understand and remember them.

Adolescents are more sensitive to outcomes, such as rewards, than are children or adults (Reyna et al., 2011). Given that expected values are equal between options in many laboratory tasks, the gamble option will always include a larger possible reward than the sure reward in the opposite option. For example, harking back to our earlier example, $2,000 is larger than $1,000 in the gain frame, and conversely, the $1,000 sure loss in the loss frame is smaller than the $2,000 loss in the gamble. In addition to predicting and finding that framing biases increased from childhood to adulthood, FTT also predicted that adolescents should exhibit reverse framing when differences between outcomes are large (e.g., Reyna et al., 2011; Reyna and Farley, 2006). In reverse framing, a person has a higher preference for the gamble in the gain frame and for the sure option in the loss frame. Reverse framing implies that adolescents are relying more on the quantitative differences between outcomes and less on the simple qualitative gist of options, the latter producing the typical framing effect in adults (Chick and Reyna, 2012; Reyna et al., 2011).

Predictions of FTT allow the theory to explain phenomena in the literature that other theories are not able to account for, such as that framing effects and other gist-based biases become stronger as one ages (e.g., adults are more affected by the framing bias than children; Reyna and Ellis, 1994; Reyna et al., 2011). As a person gains experience and expertise in an area, the effects of framing biases also increase (Reyna et al., 2014). None of the developmental theories, including developmental versions of dual-process theory (Casey et al., 2008; Steinberg, 2008), predict that susceptibility to biases increase as one ages and gains expertise. This increase is classified as a developmental reversal because it reverses the usual expectation of developmental improvement. Because both gist and verbatim processing improve with age, this developmental reversal is not the product of adults or experts losing the ability to determine the expected value of their options (Corbin et al., 2015; Weller, Levin, and Denburg, 2011).

Despite the observations that reliance on gist-based processing increases with age and expertise, relying on gist increases vulnerability to specific cognitive biases (Adam and Reyna, 2005; Reyna et al., 2014). More traditional theories may categorize biases such as framing, and the susceptibility to these biases, as errors in decision-making. However, in FTT, susceptibility to many cognitive biases is the result of the developmental increases in reliance on the gist of information (e.g., Jacobs and Potenza, 1991). Aside from just framing, FTT also predicts that false memories will increase developmentally because, again, these phenomena are based on an increased reliance on gist processing (Brainerd, Reyna, and Ceci, 2008; De Neys, and Vanderputte, 2011; Reyna, 2004). Overall, children and adolescents are less susceptible to gist-based biases than adults, even when controlling for knowledge; verbatim processing impairs decision-making in regard to taking unnecessary risks but lessens the effects of cognitive biases (Reyna and Brainerd, 2011; Weldon et al., 2013).

One clarification that needs to be made, however, is that adults do have the ability to shift to more complex gist representations (and sometimes almost verbatim representations) in decisions that are unable to be made when relying on the simplest gist representation (Reyna, 2012). Imagine, as an example, a person deciding between two choices seen in the Allais paradox: a 11 percent chance of winning $1 million and an 89 percent chance of winning $0 versus a 10 percent chance of winning $5 million and a 90 percent chance of winning $0 (Reyna and Brainerd, 2011). In this instance, an adult would require a more complex representation because the simplest gist representation (e.g., *winning something* versus *winning nothing* in both options) would not provide an answer; options are indistinguishable because both have zeros. Instead, a more precise gist representation would provide the distinction necessary to make a decision (e.g., choosing between "winning less" versus "winning nothing" and "winning more" versus "winning nothing").

The developmental shifts that FTT predicts, and that are supported by the literature, also help to further the understanding of why adolescents (and novices) may be more logical and calculating at times, yet still have higher levels of risk taking. In a similar vein, adults and experts often have lower levels of risk taking for gains and tend to rely more on the gist of the situation (Reyna et al., 2014; Reyna and Lloyd, 2006). As an explanation for these developmental differences, reliance on gist representations and gist-based processing is the foundation for advanced processing and is gradually given precedence over time. This shift toward reliance on gist-based processing also creates a protective effect against unnecessary risks. The preference for gist and the use of gist principles, rather than verbatim processing, to aid in decision-making allows people to rely more on the basic understanding of the decision, which will often result in healthier choices (Chapman, Gamino, and Mudar, 2012; Reyna and Farley, 2006; Reyna and Mills, 2014; Reyna, Weldon, and McCormick, 2015a; Wilhelms, Reyna, Brust-Renck, Weldon, & Corbin, 2015). This is in part due to the nature of many risky scenarios. Often, the benefits of risk taking outweigh the risks. Therefore, verbatim-based decision-making, which results in trade-offs between the exact risks and rewards, favors the risky decisions objectively in more scenarios (Mills et al., 2008). In gist-based processing, which ignores specific details in favor of the bottom-line representation and general principles, these hazardous trade-offs are avoided.

A growing body of evidence suggests that gist and verbatim processing may be characterized by differences in underlying neural circuitry (Reyna et al., 2015b). Venkatraman et al. (2009) examined the neural mechanisms underlying a decision task in which three options were presented: selecting to maximize the probability of winning something (Pmax), minimize losses (Lmin), or maximize gains (Gmax). The authors presented participants with a series of trials. Each trial consisted of five possible outcomes and an associated probability of occurrence (e.g., a 25 percent chance of winning \$80, a 15 percent chance of winning \$40, a 20 percent chance of winning \$0, a 20 percent chance of losing \$35, and a 20 percent chance of losing \$75). Two alternatives for improving the gambles appeared on the screen, allowing the participant to choose between adding an amount of money (e.g., \$20) to one of two outcomes (e.g., to the \$0 or to the -\$75). The options presented represented one of three possible strategies: gains could be maximized by adding \$20 to the magnitude of the highest gain (Gmax); losses could be minimized by adding \$20 to the worst loss (Lmin); or the probability of winning anything at all could be maximized by adding \$20 to the zero dollar option (Pmax). The Gmax or Lmin strategies involve trading off risk and reward, a “verbatim-based” approach as discussed earlier. The Pmax (gist-based) strategy simplifies the gamble by removing the categorical possibility of winning nothing, clearly a prediction of FTT.

Venkatraman et al. (2009) observed increased activation in the posterior parietal cortex (PPC) and the dlPFC when participants chose the gist-based Pmax strategy. Increased activation in the vmPFC for Gmax choices was also present, as well as increased activation in the anterior insula for Lmin choices. Functional connectivity analyses showed that dmPFC connectivity varied as a function of strategy; there was increased connectivity with the dlPFC and PPC for gist-based (Pmax) simplifying choices, and increased connectivity with the anterior insula for verbatim-based compensatory choices (Gmax or Lmin). Further, cognitive control areas such as the dlPFC may be involved in advanced gist-based thinking (Venkatraman et al., 2009). The notion that gist processing would be associated with higher-level cognitive networks is inconsistent with traditional dual-processing accounts, which assume that intuitive thinking (e.g., as reflected in the simplifying noncompensatory Pmax strategy) is ontogenetically and phylogenetically less advanced (Casey et al., 2008; Evans and Stanovich, 2013). The results described in the preceding sections suggest that distinct neural circuitry underlies the use of gist versus verbatim strategies, consistent with FTT.

25.3.4.1 *Numeracy and Decision-Making*

In some areas of judgment and decision-making, such as medical decision-making, dual-process theorists have emphasized the knowledge of numbers and computation as the paradigmatic example of Type 2 thinking (for overviews, see Peters, 2012; Reyna et al., 2009). Objective numeracy is relevant to many judgments and decisions, but it can have ironic effects when that knowledge is applied by rote using verbatim thinking. For example, the “charity problem” presents a choice between three charitable institutions: one institution that will reduce deaths from a disease from 15,000 to 5,000 per year, a second that will reduce deaths from 160,000 to 145,000 per year, and a third that will reduce deaths from 290,000 to 270,000 per year (Peters, Slovic, and Vastfjall, 2008). The first institution reduces the greatest *proportion* of deaths, whereas the third institution reduces the greatest *absolute number* of deaths. People higher in numeracy tend to select the first institution, probably because they are automatically computing the proportions. People lower in numeracy typically opt for the institution that saves the largest number of lives. Thus, this is an example in which reliance on mindless computation may be beneficial for efficient calculation of proportions, but does not necessarily lead to selecting the best option that saves the greatest number of lives. Liberali et al. (2012) analyzed objective and subjective numeracy, as well as the Cognitive Reflection Test (Frederick, 2005), and found that participants who were more likely to reflect on their initial answers made fewer errors on questions that elicit an automatic (incorrect) answer (e.g., "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?" Liberali et al., 2012). People who used mindless computation came up with the incorrect answer "10 cents" – the automatic answer. However, if the ball costs 10 cents, then the bat would have to cost $1.10, and $1.10 + 0.10 equals a total cost of $1.20. Therefore, when people reflect on and censor their initial responses, they often recognize the error and derive the correct answer (that the ball costs $0.05).

The distinction in FTT between exact computation and approximate intuition of number maps roughly onto neural-based distinctions in numerical cognition (Nieder, 2016; Reyna and Brainerd, 1994, 2008). Neuroscience findings suggest that there are distinct circuits that underlie exact versus approximate number networks in the brain. For example, there is more left-angular gyrus activity for exact than for approximate calculation, perhaps because language-based areas may be involved in memory representations of exact numbers (DeHaene et al., 2003). The horizontal segment of the intraparietal sulcus (HIPS) is involved in approximate numerical estimation and comparing the magnitudes of two numbers (DeHaene et al., 2003, 2004). Furthermore, neurons in the prefrontal cortex (PFC) fire in response to a quantitative representation of zero (lack of stimulus), suggesting that there is a neural representation of "nothing" (Ramirez-Cardenas, Moskaleva, and Nieder, 2016). These recent findings may lend insight into the neural networks of observed framing behavior, namely the categorical comparisons that adults rely on when making a choice (e.g., "winning something" versus "winning nothing").

25.3.4.2 *Reward Responsivity and Decision-Making*

The decision to make a risky choice can also be explained in part by response to reward. For example, some researchers suggest that the reason that risk taking is more prevalent during the adolescent years is because of a greater sensitivity to reward during adolescence (Galvan, 2012). The neural circuitry of response to reward has been well established, consisting of dopamine pathways in the midbrain that project to the striatum. More specifically, the mesolimbic pathways project from the ventral tegmental area to the ventral striatum (nucleus accumbens) and vmPFC. The nigrostriatal pathways project from the substantia nigra to the dorsal striatum (caudate nucleus and putamen). Different parts of the striatum have been recognized as having different roles in the response to reward. The ventral striatum has been implicated in anticipation and evaluation of reward, whereas the dorsal striatum is involved in action selection and initiation by integrating cognitive, motivational, and emotional information (Balleine, Delgado, and Hikosaka, 2007; Diekhof et al., 2012; Hare, Camerer, and Rangel, 2009).

If a person wants or likes a particular reward, he or she may be more likely to take a risk to obtain that reward (or larger amounts of that reward). Neuroscientists have conducted quite a bit of animal research suggesting that there are differences in behavior and in the underlying neural systems that underlie liking versus wanting a reward (Berridge, 2007). For example, disrupting dopaminergic pathways in rodents impairs their motivation to obtain these rewards (wanting), but does not affect how much the animal enjoys the reward. (Liking was measured by orofacial reactions such as tongue protrusions; Pecina and Berridge, 2005.) The differences in wanting versus liking provide further evidence for the notion that these are distinct constructs that should be considered separately. FTT distinguishes effects of reward, and its developmental influence, from effects of representation (Reyna et al., 2011, 2015).

In economics, utility theory (and related theories) suggests that the subjective values of different types of rewards are all mapped onto the same reward value dimension (Samuelson, 1947). In parallel, findings in neuroscience suggest that there may be common neural areas that respond to different types of reward in the striatum and vmPFC (FitzGerald, Seymour, and Dolan, 2009; Kim, Shimojo, and O'Doherty, 2010). For example, Levy and Glimcher (2011) identified distinct areas of activation for different types of reward, also testing the common currency of reward hypothesis (the notion that the same neural circuits respond to different types of rewards; e.g., money versus a palatable food). The authors had participants make choices between sure and risky options for money, food, and water. They found that participants' choices for different reward types were correlated – that is, if a participant was more risk-averse for monetary choices, he or she tended to also be more risk-averse for choices about food or water. (See also the discussion of the DOSPERT risk-taking scale in Reyna and Huettel, 2014.) The authors observed similar areas of activation across reward types, including the vmPFC and striatum. Within the vmPFC, there were differences; they found distinct areas that showed increased activation only to money (posterior cingulate cortex), whereas the dorsal hypothalamic areas showed increased activation only to food (Levy and Glimcher, 2011). A meta-analysis conducted on fMRI studies of reward response supported the conclusion that the vmPFC and medial OFC have a neural signature common to different types of reward (Levy and Glimcher, 2012). Furthermore, Plassmann, O'Doherty, and Rangel (2007) found that the vmPFC/medial OFC signal increased as participants' willingness to pay for rewarding food items increased (see also Kable and Glimcher, 2007). Note that overall subjective value increases with reward, consistent with our earlier comments about these areas. Findings support the notion of a common currency of reward, and although the way people respond to one type of reward does not necessarily perfectly predict response to a different type of reward, they do tend to be correlated (Figner and Weber, 2011; Hanoch, Johnson, and Wilke, 2006; Weber, Blais, and Betz, 2002).

Individuals vary in reward response variables such as sensation seeking, suggesting that individual differences in reward response also explain some of the variance in risky choice. For example, people higher in sensation seeking take more risky choices than people lower in sensation seeking. Cservenka et al. (2013) had participants complete a modified version of the Wheel of Fortune decision-making task in which trials resulted in monetary wins or no wins. Cservenka et al. compared low versus high sensation seeking (SS) groups to understand how neural activation differed between groups in response to the reward outcome. The authors found that those high in SS had greater activation in the bilateral insula and prefrontal cortex than low SS for the Win > No Win contrast. Furthermore, those high in SS showed less activation for No Wins than low SS, indicating that high SS may not be as affected by negative consequences. The authors suggest that this may reflect a lower level of autonomic arousal that may put high SS in dangerous situations in which they are less sensitive to potential negative consequences (Cservenka et al., 2013).

FTT incorporates individual differences in sensitivity to outcomes, particularly rewards, but separates the effects of motivation to approach rewards from gist and verbatim modes of thinking. According to FTT, people higher in sensation seeking have a greater tendency to rely on verbatim processing for reasoning and decision-making, which leads to more computation of risks and rewards, and in turn, less or reverse framing (i.e., more risky choices for gains and fewer risky choices for losses; Reyna et al., 2011; Weldon et al., in press).

In addition to individual difference effects on decision-making, developmental differences in neural activation have also been observed. Adolescent decision-making is characterized by different patterns of brain activation than adult decision-making. Heightened reward sensitivity in adolescence has been associated with overdeveloped reward areas (e.g., ventral striatum) in relation to underdeveloped top-down control areas (PFC and ACC) in the developing brain (Casey, Jones, and Hare, 2008; Steinberg, 2008). According to FTT, increased reward sensitivity to gains along with greater emphasis on verbatim risk-reward trade-offs produces vulnerability to unhealthy risk taking (Reyna et al., 2011; Reyna et al., 2015b).

25.4 Conclusions and Future Directions

In this chapter, we review behavioral and brain evidence supporting FTT as an integrative framework to explain and predict decision-making and economic behavior. FTT incorporates both meaningful and rote representations of information into its predictions, with these representations falling on a spectrum with categorical gist (i.e., some versus none) on one end and precise, verbatim details (i.e., 50 percent chance of winning $2,000) on the other. This key representational aspect goes beyond nonlinear distortion of utilities or values, accounting for a wide range of phenomena in judgment and decision-making that are not fully accounted for by other theories, including false memories, framing effects, reverse framing, truncation effects on framing, sensation seeking and reward sensitivity, metacognitive monitoring and inhibition, hidden-zero effects on delay discounting, delay of gratification, and effects of numeracy. Additional effects, such as base-rate, conjunction, and disjunction effects, are reviewed elsewhere (e.g., Reyna and Brainerd, 2008).

Provided that hypotheses about cognitive strategies and causal mechanisms are tested, identifying the neural circuitry underlying reward sensitivity, subjective value, numeracy, risky choice, and mental representation can lend important insight into decision-making. Economists and psychologists are also becoming increasingly interested in neuroscience because of what can be learned about the neurobiological basis of unwise and irrational behavior, such as spending or borrowing more than one can afford. In this connection, intervention experiments provide additional tests of causal mechanisms and are aimed at reducing unwise and irrational behavior.

As examples, FTT's interventions in the health domain have demonstrated that gist-based processing leads to improved judgment and decision-making (Blalock and Reyna, 2016; Reyna et al., 2015a; Wolfe et al., 2015). Interventions that have involved gist-based training have been successful in improving decisions about sexual risk taking in adolescents (Reyna and Mills, 2014; Reyna et al., 2015a). A gist-based web tutoring system was effective in improving understanding about genetic testing and breast cancer risk (Wolfe et al., 2015). Another study demonstrated the efficacy of a gist-based decision tool in helping rheumatoid arthritis patients understand the risks and benefits of different treatment options (Fraenkel et al., 2012). Given the success of these interventions, it is encouraging that gist-based processing is a way of thinking that can be trained. The same theoretical principles could be applied to interventions to improve financial judgments and decision-making. By building on prior research in many areas, FTT provides a multifaceted approach that links cognition, personality, social, cultural, and neurobiological influences so that researchers can continue to learn more about judgment, decision-making, and neuro-economics.

25.5 References

Adam, M. B., and Reyna, V. F. (2005). Coherence and Correspondence Criteria for Rationality: Experts' Estimation of Risks of Sexually Transmitted Infections. *Journal of Behavioral Decision Making*, 18(3), 169–186. doi:10.1002/bdm.493.

Allais, M. (1953). Le comportement de l'homme rationnel devant le risque: Critique des postulats et axiomes de l'école américaine. *Econometrica*, 21, 503–546.

Balleine, B. W., Delgado, M. R., and Hikosaka, O. (2007). The Role of the Dorsal Striatum in Reward and Decision-Making. *Journal of Neuroscience*, 27(31), 8161–8165.

Bechara, A. (2005). Decision Making, Impulse Control and Loss of Willpower to Resist Drugs: A Neurocognitive Perspective. *Nature Neuroscience*, 8 (11), 1458–1463. doi: 10.1038/nn1584.

Berns, G. S., Laibson, D., and Loewenstein, G. (2007). Intertemporal Choice: Toward an Integrative Framework. *Trends in Cognitive Science*, 11, 482−488.

Berridge, K. C. (2007). The Debate over Dopamine's Role in Reward: The Case for Incentive Salience. *Psychopharmacology*, 191(3), 391–431.

Bickel, W. K., Jarmolowicz, D. P., Mueller, E. T., and Gatchalian, K. M. (2011). The Behavioral Economics and Neuroeconomics of Reinforcer Pathologies: Implications for Etiology and Treatment of Addiction. *Current Psychiatry Reports*, 13 (5), 406–415. doi: 10.1007/s11920-011-0215-1.

Blalock, S. J., and Reyna, V. F. (2016). Using Fuzzy-Trace Theory to Understand and Improve Health Judgments, Decisions, and Behaviors: A Literature Review. *Health Psychology*, 35(8), 781–792.

Brainerd, C. J., Reyna, V. F., and Ceci, S. J. (2008). Developmental Reversals in False Memory: A Review of Data and Theory. *Psychological Bulletin*, 134(3), 343–382.

Broniatowski, D. A., Klein, E. Y., and Reyna, V. F. (2015). Germs Are Germs, and Why Not Take a Risk?: Patients' Expectations for Prescribing Antibiotics in an Inner City Emergency Department. *Medical Decision Making*, 35, 60–67. doi: 10.1177/0272989X14553472.

Brown, J. W., and Braver, T. S. (2008). A Computational Model of Risk, Conflict, and Individual Difference Effects in the Anterior Cingulate Cortex. *Brain Research*, 1202, 99–108.

Casey, B. J., and Caudle, K. (2013). The Teenage Brain: Self-Control. *Current Directions in Psychological Science*, 22(2), 82–87. doi: 10.1177/0963721413480170.

Casey, B. J., Jones, R. M., and Hare, T. A. (2008). The Adolescent Brain. *Annals of the New York Academy of Sciences*, 1124(1), 111–126.

Chapman, S. B., Gamino, J. G., and Mudar, R. A. (2012). Higher-Order Strategic Gist Reasoning in Adolescence. In V. F. Reyna, S. Chapman, M. Dougherty, and J. Confrey (Eds.), *The Adolescent Brain: Learning, Reasoning, and Decision Making* (pp. 123–152). Washington, DC: American Psychological Association.

Chick, C. F., Reyna, V. F., and Corbin, J. C. (2016). Framing Effects Are Robust to Linguistic Disambiguation: A Critical Test of Contemporary Theory. *Journal of Experimental Psychology: Learning, Memory, and Cognition.* 42, 238–256.

Chick, C.F. and Reyna, V.F. (2012). A fuzzy-trace theory of adolescent risk-taking: Beyond self-control and sensation seeking. In V. F. Reyna, S. Chapman, M. Dougherty, and J. Confrey (Eds.), *The Adolescent Brain: Learning, Reasoning, and Decision Making* (pp. 379–428). Washington, DC: American Psychological Association.

Corbin, J. C., Reyna, V.F., Weldon, R.B., and Brainerd, C.J. (2015). How Reasoning, Judgment, and Decision Making Are Colored by Gist-Based Intuition: A

Fuzzy-Trace Theory Approach. *Journal of Applied Research in Memory and Cognition. Journal of Applied Research in Memory and Cognition*, 4, 344–355.

Cservenka, A., Herting, M. M., Seghete, K. L. M., Hudson, K. A., and Nagel, B. J. (2013). High and Low Sensation Seeking Adolescents Show Distinct Patterns of Brain Activity During Reward Processing. *Neuroimage*, 66, 184–193.

Defoe, I. N., Dubas, J. S., Figner, B., and Van Aken, M.A. (2014). A Meta-analysis on Age Differences in Risky Decision Making: Adolescents Versus Children and Adults. *Psychological Bulletin*, 141*(1)*, 48–84. doi: 10.1037/a0038088.

Dehaene, S., Molko, N., Cohen, L., and Wilson, A. J. (2004). Arithmetic and the Brain. *Current Opinion in Neurobiology*, 14(2), 218–224.

Dehaene, S., Piazza, M., Pinel, P., and Cohen, L. (2003). Three Parietal Circuits for Number Processing. *Cognitive Neuropsychology*, 20(3–6), 487–506.

Diekhof, E. K., Kaps, L., Falkai, P., and Gruber, O. (2012). The Role of the Human Ventral Striatum and the Medial Orbitofrontal Cortex in the Representation of Reward Magnitude: an Activation Likelihood Estimation Meta-analysis of Neuroimaging Studies of Passive Reward Expectancy and Outcome Processing. *Neuropsychologia*, 50(7), 1252–1266.

De Martino, B., Kumaran, D., Seymour, B., and Dolan, R. J. (2006). Frames, Biases, and Rational Decision-Making in the Human Brain. *Science*, 313(5787), 684–687.

De Neys, W., and Vanderputte, K. (2011). When Less Is Not Always More: Stereotype Knowledge and Reasoning Development. *Developmental Psychology*, 47(2), 432–441.

Doyle, J. R. (2013). Survey of Time Preference, Delay Discounting Models. *Judgment and Decision Making*, 8, 116–135.

Evans, J. S. B. T., and Stanovich, K. E. (2013). Dual-Process Theories of Higher Cognition: Advancing the Debate. *Perspectives on Psychological Science*, 8(3), 223–241. doi: 10.1177/1745691612460685.

Figner, B., and Weber, E.U. (2011). Who Takes Risks When and Why? Determinants of Risk Taking. *Current Directions in Psychological Science*, 20(4), 211–216. doi: 10.1177/0963721411415790.

Fischer, G. W., and Hawkins, S. A. (1993). Strategy Compatibility, Scale Compatibility, and the Prominence Effect. *Journal of Experimental Psychology: Human Perception and Performance*, 29,580–597.

Fitzgerald, T. H., Seymour, B., and Dolan, R. J. (2009). The Role of Human Orbitofrontal Cortex in Value Comparison for Incommensurable Objects. *Journal of Neuroscience*, 29, 8388–8395.

Fox, C. R., and Poldrack, R. A. (2009). Prospect Theory and the Brain. In P. W. Glimcher, C. F. Camerer, E. Fehr, and R. A. Poldrack (Eds.), *Neuroeconomics: Decision Making and the Brain* (pp. 145–173). London: Academic Press.

Fox, C. R., and Tannenbaum, D.(2011). The Elusive Search for Stable Risk Preferences. *Frontiers in Psychology*. Published online November 15, 2011. doi: 10.3389/fpsyg.2011.00298.

Fraenkel, L., Peters, E., Charpentier, P., Olsen, B., Errante, L., Schoen, R. T., and Reyna, V. (2012). Decision Tool to Improve the Quality of Care in Rheumatoid Arthritis. *Arthritis Care and Research*, 64(7), 977–985.

Frederick, S. (2005). Cognitive Reflection and Decision Making. *Journal of Economic Perspectives*, 19(4), 25–42.

Frederick, S., Loewenstein, G., and O'Donoghue, T. (2002). Time Discounting and Time Preference: A Critical Review. *Journal of Economic Literature*, 40, 351–401. doi: 10.1257/jel.40.2.351.

Fukukura, J., Ferguson, M. J., and Fujita, K. (2013). Psychological Distance Can Improve Decision Making Under Information Overload via Gist Memory. *Journal of Experimental Psychology: General*, 142(3), 658–665. doi: 10.1037/a0030730.

Galvan, A. (2012). Risky Behavior in Adolescents: The Role of the Developing Brain. In V. F. Reyna, S. B. Chapman, M. R. Dougherty, and J. Confrey (Eds.), *The Adolescent Brain: Learning, Reasoning, and Decision Making* (pp. 267–289). Washington, DC: American Psychological Association.

Gonzalez, C., Dana, J., Koshino, H., and Just, M. (2005). The Framing Effect and Risky Decisions: Examining Cognitive Functions with fMRI. *Journal of Economic Psychology*, 26(1), 1–20.

Glimcher, P. W., Camerer, C. F., Fehr, E., and Poldrack, R. A. (Eds.) (2009). *Neuroeconomics: Decision making and the Brain.* New York: Academic Press.

Green, L., Fry, A. F., and Myerson, J. (1994). Discounting of Delayed Rewards: A Life-Span Comparison. *Psychological Science*, 5(1), 33–36.

Green, L., Myerson, J., Lichtman, D., Rosen, S., & Fry, A. (1996). Temporal Discounting in Choice between Delayed Rewards: The Role of Age and Income. *Psychology and Aging*, 11(1), 79–84.

Hanoch, Y., Johnson, J. G., and Wilke, A. (2006). Domain Specificity in Experimental Measures and Participant Recruitment. *Psychological Science*, 17, 300–304.

Hare, T. A., Camerer, C. F., & Rangel, A. (2009). Self-Control in Decision-Making Involves Modulation of the vmPFC Valuation System. *Science*, 324, 646–648. doi: 10.1126/science1168450.

Jentsch, J. D., and Taylor, J. R. (1999). Impulsivity Resulting from Frontostriatal Dysfunction in Drug Abuse: Implications for the Control of Behavior by Reward-Related Stimuli. *Psychopharmacology*, 146, 373–390.

Kable, J. W., and Glimcher, P. W. (2007). The Neural Correlates of Subjective Value During Intertemporal Choice. *Nature Neuroscience*, 10, 1625–1633. doi: 10.1038/nn2007.

Kable, J. W., and Glimcher, P. W. (2010). An "as Soon as Possible" Effect in Human Intertemporal Decision Making: Behavioral Evidence and Neural Mechanisms. *Journal of Neurophysiology*, 103(5), 2513–2531. doi: 10.1152/jn.00177.2009.

Kable, J. W., and Levy, I. (2015). Neural Markers of Individual Differences in Decision-Making. *Current Opinion in Behavioral Sciences*, 5, 100–107. doi: 10.1016/j.cobeha.2015.08.004.

Kahneman, D. (2003). A Perspective on Judgment and Choice: Mapping Bounded Rationality. *American Psycholigist*, 58, 697–720.

Kahneman, D. (2011). *Thinking Fast and Slow.* London: Penguin.

Kahneman, D., and Tversky, A. (1979). Prospect Theory: An Analysis of Decision Under Risk. *Econometrica*, 47, 263–291. doi: 10.2307/1914185.

Kim, H, Shimojo, S., and O'Doherty, J. P. (2010). Overlapping Responses for the Expectation of Juice and Money Rewards in Human Ventromedial Prefrontal Cortex. *Cerebral Cortex*, 21, 769–776.

Kirby, K. N., (2009). One-Year Temporal Stability of Delay-Discount Rates. *Psychonomic Bulletin and Review*, 16, 457–462.

Koffarnus, M. N., Jarmolowicz, D. P., Mueller, E. T., and Bickel, W. K. (2013). Changing Delay Discounting in the Light of the Competing Neurobehavioral Decision Systems Theory: A Review. *Journal of Experimental Analysis of Behavior*, 99, 32–57. doi: 10.1002/jeab.2.

Kühberger, A., and Tanner, C. (2010). Risky Choice Framing: Task Versions and a Comparison of Prospect Theory and Fuzzy-Trace Theory. *Journal of Behavioral Decision Making*, 23(3), 314–329. doi: 10.1002/bdm.656.

Kurkela, K. A., and Dennis, N. A. (2016) Event-Related fMRI Studies of False Memories: An Activation Likelihood Estimation Meta-analysis. *Neuropsychologia*, 81, 149–167.

Kwak, Y., Payne, J. W., Cohen, A. L., and Huettel, S. A. (2015). The Rational Adolescent: Strategic Information Processing During Decision Making Revealed by Eye Tracking. *Cognitive Development*, 36, 20–30. doi: 10.1016/ j.cogdev.2015.08.001.

Levy, D. J., and Glimcher, P. W. (2011). Comparing Apples and Oranges: Using Reward-Specific and Reward-General Subjective Value Representation in the Brain. *Journal of Neuroscience*, 31, 14693–14707. doi: 10.1523/JNEUROSCI. 2218-11.2011.

Levy, D. J., and Glimcher, P. W. (2012). The Root of All Value: A Neural Common Currency for Choice. *Current Opinion in Neurobiology*, 22, 1027–1038. doi: 10.1016/ j.conb.2012.06.001.

Liberali, J. M., Reyna, V. F., Furlan, S., Stein, L. M., and Pardo, S. T. (2012). Individual Differences in Numeracy and Cognitive Reflection, with Implications for Biases and Fallacies in Probability Judgment. *Journal of Behavioral Decision Making*, 25(4), 361–381.

Lloyd, F. J., and Reyna, V. F. (2001). A Web Exercise in Evidence-Based Medicine Using Cognitive Theory. *Journal of General Internal Medicine*, 16(2), 94–99. doi: 10.1111/j.1525-1497.2001.00214.x.

Magen, E., Dweck, C. S., and Gross, J. J. (2008). The Hidden-Zero Effect: Representing a Single Choice as an Extended Sequence Reduces Impulsive Choice. *Psychological Science*, 19, 648–649. doi: 10.1111/j.1467-9280.2008.02137.x.

Magen, E., Kim, B., Dweck, C. S., Gross, J. J., McClure, S. M. (2014). Behavioral and Neural Correlates of Increased Self-Control in the Absence of Increased Willpower. *Proceedings of the National Academy of Sciences of the United States of America*, 111, 9786–9791. doi: 10.1073/pnas.1408991111.

McClure, S. M., Ericson, K. M., Laibson, D. I., Loewenstein, G., and Cohen, J. D. (2007). Time Discounting for Primary Rewards. *Journal of Neuroscience*, 27, 5796–5804.

Meade, C. S., Lowen, S. B., Maclean, R. R., Key, M. D., and Lukas, S. E. (2011). fMRI Brain Activation During a Delay Discounting Task in HIV-Positive Adults with and Without Cocaine Dependence. *Psychiatry Research*, 192 (3), 167–175. doi: 10.1016/j.pscychresns.2010.12.011.

Meschkow, A. S., Nolte, J., Garavito, D. M. N., Helm, R. K., Weldon, R. B., and Reyna, V. F. (in press). Risk Taking Across the Lifespan. In M. H. Bornstein (Ed.), *The SAGE Encyclopedia of Lifespan Human Development*.

Mills, B., Reyna, V. F., and Estrada, S. (2008). Explaining Contradictory Relations Between Risk Perception and Risk Taking. *Psychological Science*, 19(5), 429–433. doi: 10.1111/j.1467-9280.2008.02104.x.

Nieder, A. (2016). The Neuronal Code for Number. *Nature Reviews Neuroscience*, 17, 366–382.

Odum, A. L. (2011). Delay Discounting: Trait Variable? *Behavioural Processes*, 87, 1–9. doi: 10.1016/j.beproc.2011.02.007.

Ohmura, Y., Takahashi, T., Kitamura, N., and Wehr, P. (2006). Three-Month Stability of Delay and Probability Discounting Measures. *Experimental and Clinical Psychopharmacology*, 14 (3), 318–328. doi: 10.1037/1064-1297.14.3.318.

Peciña, S., and Berridge, K. C. (2005). Hedonic Hot Spot in Nucleus Accumbens Shell: Where Do μ-opioids Cause Increased Hedonic Impact of Sweetness? *Journal of Neuroscience*, 25(50), 11777–11786.

Peters, E. (2012). Beyond Comprehension: The Role of Numeracy in Judgments and Decisions. *Current Directions in Psychological Science*, 21(1), 31–35.

Peters, E., Slovic, P., Västfjäll, D., and Mertz, C. K. (2008). Intuitive Numbers Guide Decisions. *Judgment and Decision Making*, 3, 619–635.

Pfeifer, J. H., and Allen, N. B. (2012). Arrested Development? Reconsidering Dual-Systems Models of Brain Function in Adolescence and Disorders. *Trends in Cognitive Sciences*, 16, 322–329. doi: 10.1016/j.tics.2012.04.011.

Plassmann, H., O'Doherty, J., and Rangel, A. (2007). Orbitofrontal Cortex Encodes Willingness to Pay in Everyday Economic Transactions. *Journal of Neuroscience*, 27, 9984–9988. doi: 10.1523/JNEUROSCI.2131-07.2007.

Jacobs, J. E., and Potenza, M. (1991). The Use of Judgement Heuristics to Make Social and Object Decisions: A Developmental Perspective. *Child Development*, 62(1), 166–178.

Ramirez-Cardenas, A., Moskaleva, M., and Nieder, A. (2016). Neuronal Representation of Numerosity Zero in the Primate Parieto-Frontal Number Network. *Current Biology*, 26(10), 1285–1294.

Rangel, A., Camerer, C., and Montague, R. (2008). A Framework for Studying the Neurobiology of Value-Based Decision-Making. *Nature Reviews Neuroscience*, 9, 545–556.

Reyna, V. F. (1996). Conceptions of Memory Development with Implications for Reasoning and Decision Making. *Annals of Child Development*, 12, 87–118.

Reyna, V. F. (2004). How People Make Decisions That Involve Risk. *Current Directions in Psychological Science*, 13(2), 60–66. doi: 10.1111/j.0963-7214.2004.00275.x.

Reyna, V. F. (2008). A Theory of Medical Decision Making and health: Fuzzy-trace theory. *Medical Decision Making*, 28, 850–865.

Reyna, V. F. (2011). Across the Lifespan. In B. Fischhoff, N. T. Brewer, and J. S. Downs, (Eds.), *Communicating Risks and Benefits: An Evidence-Based User's Guide* (pp. 111–119). Washington, DC: U.S. Department of Health and Human Services, Food and Drug Administration. Retrieved from www.fda.gov/ScienceResearch/SpecialTopics/RiskCommunication/default.htm

Reyna, V. F. (2012). A New Intuitionism: Meaning, Memory, and Development in Fuzzy-Trace Theory. *Judgment and Decision Making*, 7(3), 332–359.

Reyna, V. F., and Adam, M. B. (2003). Fuzzy-trace theory, risk communication, and product labeling in sexually transmitted diseases. *Risk Analysis*, 23, 325–342.

Reyna, V. F., and Brainerd, C.J. (1991). Fuzzy-Trace Theory and Framing Effects in Choice: Gist Extraction, Truncation, and Conversion. *Journal of Behavior and Decision Making*, 4(4), 249–262. doi: 10.1002/bdm.3960040403.

Reyna, V. F., and Brainerd, C. J. (1994). The Origins of Probability Judgment: A Review of Data and Theories. In G. Wright and P. Ayton (Eds.), *Subjective Probability* (pp. 239–272). New York: Wiley.

Reyna, V. F., and Brainerd, C. J. (1995). Fuzzy-Trace Theory: An Interim Synthesis. *Learning and Individual Differences*, *7(1)*, 1–75. doi: 10.1016/1041–6080(95)90031–4.

Reyna, V. F., and Brainerd, C. J. (2008). Numeracy, Ratio Bias, and Denominator Neglect in Judgments of Risk and Probability. *Learning and Individual Differences*, 18(1), 89–107. doi: 10.1016/j.lindif.2007.03.011.

Reyna, V. F., and Brainerd, C. J. (2011). Dual Processes in Decision Making and Developmental Neuroscience: A Fuzzy-Trace Model. *Developmental Review*, 31, 180–206. doi: 10.1016/j.dr.2011.07.004.

Reyna, V. F., Chick, C. F., Corbin, J. C., and Hsia, A. N. (2014). Developmental Reversals in Risky Decision Making: Intelligence Agents Show Larger Decision Biases than College Students. *Psychological Science*, 25(1), 76–84. doi: 10.1177/0956797613497022.

Reyna, V. F., Corbin, J. C., Weldon, R. B., and Brainerd, C. J. (2016). How Fuzzy-Trace Theory Predicts True and False Memories for Words and Sentences. *Journal of Applied Research in Memory and Cognition*. 5(1), 1–9. doi: 10.1016/j.jarmac.2015.12.003.

Reyna, V. F., and Ellis, S. C. (1994). Fuzzy-Trace Theory and Framing Effects in Children's Risky Decision Making. *Psychological Science*, 5, 275–279. doi: 10.1111/j.1467–9280.1994.tb00625.x.

Reyna, V. F., Estrada, S. M., DeMarinis, J. A., Myers, R. M., Stanisz, J. M., and Mills, B. A. (2011). Neurobiological and Memory Models of Risky Decision Making in Adolescents Versus Young Adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 37(5), 1125–1142. doi: 10.1037/a0023943.

Reyna, V. F., and Farley, F. (2006). Risk and Rationality in Adolescent Decision Making. *Psychological Science in the Public Interest*, 7(1), 1–44. doi: 10.1111/j.1529-1006.2006.00026.x.

Reyna, V. F., and Huettel, S. A. (2014). Reward, Representation, and Impulsivity: A Theoretical Framework for the Neuroscience of Risky Decision Making. In V. F. Reyna and V. Zayas (Eds.), *The Neuroscience of Risky Decision Making* (pp. 11–42). Washington, DC: American Psychological Association.

Reyna, V. F., and Lloyd, F. J. (2006). Physician Decision Making and Cardiac Risk: Effects of Knowledge, Risk Perception, Risk Tolerance, and Fuzzy Processing. *Journal of Experimental Psychology: Applied*, 12(3), 179–195. doi: 10.1037/1076-898X.12.3.179.

Reyna, V. F., and Mills, B. A. (2007). Interference Processes in Fuzzy-Trace Theory: Aging, Alzheimer's Disease, and Development. In D. Gorfein and C. MacLeod (Eds.), *Inhibition in Cognition* (pp. 185–210). Washington, DC: APA Press.

Reyna, V. F., and Mills, B. A. (2014). Theoretically Motivated Interventions for Reducing Sexual Risk Taking in Adolescence: A Randomized Controlled Experiment Applying Fuzzy-Trace Theory. *Journal of Experimental Psychology: General*, 143(4), 1627–1648. doi: 10.1037/a0036717.

Reyna, V. F., Nelson, W. L., Han, P. K., and Dieckmann, N. F. (2009). How Numeracy Influences Risk Comprehension and Medical Decision Making. *Psychological Bulletin*, 135(6), 943–973.

Reyna, V. F., Weldon, R. B., and McCormick, M. J. (2015a). Educating Intuition: Reducing Risky Decisions Using Fuzzy-Trace Theory. *Current Directions in Psychological Science*, 24(5), 392–398. doi: 10.1177/0963721415588081.

Reyna, V. F., Wilhelms, E. A., McCormick, M. J., and Weldon, R. B. (2015b). Development of Risky Decision Making: Fuzzy-Trace Theory and Neurobiological Perspectives. *Child Development Perspectives*, 9(2), 122–127. doi: 10.1111/cdep.12117.

Reyna, V. F., and Wilhelms, E. A. (2016). The Gist of Delay of Gratification: Understanding and Predicting Problem Behaviors. *Journal of Behavioral Decision Making*. Published online 10 AUG 2016. doi: 10.1002/bdm.1977.

Reynolds, B., and Schiffbauer, R. (2005). Delay of Gratification and Delay Discounting: A Unifying Feedback Model of Delay-Related Impulsive Behavior. *Psychological Record*, 55, 439–460.

Rivers, S. E., Reyna, V. F., and Mills, B. (2008). Risk Taking Under the Influence: A Fuzzy-Trace Theory of Emotion in Adolescence. *Developmental Review*, 28(1), 107–144.

Roiser, J. P., De Martino, B., Tan, G. C., Kumaran, D., Seymour, B., Wood, N. W., and Dolan, R. J. (2009). A Genetically Mediated Bias in Decision Making Driven by Failure of Amygdala Control. *Journal of Neuroscience*, 29(18), 5985–5991.

Samuelson, P. A. (1947). Foundations of Economic Analysis. *Science and Society*, 13(1), 93–95.

Savage, Leonard J. (1954). *The Foundations of Statistics*. New York: Wiley.

Simpson, C. A., and Vuchinich, R. E. (2000). Reliability of a Measure of Temporal Discounting. *Psychological Records*, 50 (1), 3–16.

Stanovich, K. E., and West, R. F. (2008). On the Relative Independence of Thinking Biases and Cognitive Ability. *Journal of Personality and Social Psychology*, 94(4), 672–695. doi: 10.1037/0022-3514.94.4.672.

Steinberg, L. (2008). A Social Neuroscience Perspective on Adolescent Risk Taking. *Developmental Review*, 28(1), 78–106. doi: 10.1111/j.1467-8721.2007.00475.x.

Tversky, A., and Kahneman, D. (1986). Rational Choice and the Framing of Decisions. *Journal of Business*, 59(4), S251–S278.

Venkatraman, V., Payne, J. W., Bettman, J. R., Luce, M. F., and Huettel, S. A. (2009). Separate Neural Mechanisms Underlie Choices and Strategic Preferences in Risky Decision Making. *Neuron*, 62, 593–602. doi: 10.1016/j.neuron.2009.04.007.

Von Neumann, J., and Morgenstern, O. (1944). *Theory of Games and Economic Behavior*. Princeton, NJ: Princeton University Press.

Weber, E. U., Blais, A.-R., and Betz, E. (2002). A Domain-Specific Risk-Attitude Scale: Measuring Risk Perceptions and Risk Behaviors. *Journal of Behavioral Decision Making*, 15, 263–290. doi: 10.1002/bdm.414.

Weldon, R. B., Corbin, J. C., Garavito, D. M. N., and Reyna, V. F. (in press). The Gist Is Sophisticated Yet Simple: Fuzzy-Trace Theory's Developmental Approach to Individual Differences in Judgment and Decision Making. In M. Toplak and J. Weller (Eds.), *Individual Differences in Judgment and Decision Making from a Developmental Context.*

Weldon, R. B., Corbin, J. C., and Reyna, V. F. (2013). Gist Processing in Judgment and Decision Making: Developmental Reversals Predicted by Fuzzy-Trace Theory. In H. Markovits (Ed.), *The Developmental Psychology of Reasoning and Decision-Making* (pp. 36–62). New York: Psychology Press.

Weller, J. A., Levin, I. P., and Denburg, N. L. (2011). Trajectory of Risky Decision Making for Potential Gains and Losses from Ages 5 to 85. *Journal of Behavioral Decision Making*, 24, 331–344. doi: 10.1002/bdm.690.

Wertheimer, M. (1938). Gestalt Theory. In W. D. Ellis (Ed.), *A Source Book of Gestalt Psychology* (pp. 1–11). London: Kegan Paul, Trench, Trubner.

Wilhelms, E. A., Corbin, J. C., and Reyna, V. F. (2015), Gist Memory in Reasoning and Decision Making. In A. Feeney and V. Thompson (Eds.), *Reasoning as Memory* (pp. 93–109). New York: Psychology Press.

Wilhelms, E. A., Helm, R. K., Setton, R. A.,and Reyna, V. F. (2014). Fuzzy Trace Theory Explains Paradoxical Dissociations in Affective Forecasting. In Wilhelms, E. A., and Reyna, V. F. (Ed.), *Neuroeconomics, Judgment, and Decision Making* (pp. 49–73), New York: Psychology Press.

Wilhelms, E. A., Reyna, V. F., Brust-Renck, P.G., Weldon, R. B., and Corbin, J. C. (2015). Gist Representations and Communications of Risks about HIV-AIDS: A Fuzzy-Trace Theory Approach. *Current HIV Research*, 13(5), 399–407. doi: 10.2174/1570162X13666150511142748.

Wolfe, C. R., Reyna, V. F., Widmer, C. L., Cedillos, E. M., Fisher, C. R., Brust-Renck, P. G., and Weil, A. M. (2015). Efficacy of a Web-Based Intelligent Tutoring System for Communicating Genetic Risk of Breast Cancer: A Fuzzy-Trace Theory Approach. *Medical Decision Making*, 35(1), 46–59.

Yechiam, E., and Telpaz, A. (2013). Losses Induce Consistency in Risk Taking Even Without Loss Aversion. *Journal of Behavioral Decision Making*, 26(1), 31–40.

Zayas, V., Mischel, W., and Pandey, G. (2014). Mind and Brain in Delay of Gratification. In V. F. Reyna and V. Zayas (Eds.), *The Neuroscience of Risky Decision Making* (pp. 145–176). Washington, DC: American Psychological Association.

Zheng, H., Wang, X. T., and Zhu, L. (2010). Framing Effects: Behavioral Dynamics and Neural Basis. *Neuropsychologia*, 48(11), 3198–3204.