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How fuzzy-trace theory predicts development of risky decision making, with novel extensions to culture and reward sensitivity

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ABSTRACT

Comprehensive meta-analyses of risky decision making in children, adolescents, and adults have revealed that age trends in disambiguated laboratory tasks confirmed fuzzy-trace theory's prediction that preference for risk decreases monotonically from childhood to adulthood. These findings are contrary to predictions of dual systems or neurobiological imbalance models. Assumptions about increasing developmental reliance on mental representations of the gist of risky options are essential to account for this developmental trend. However, dual systems theory appropriately emphasizes how cultural context changes behavioral manifestation of risk preferences across age and neurobiological imbalance models appropriately emphasize developmental changes in reward sensitivity. All of the major theories include the assumption of increasing behavioral inhibition. Here, we integrate these theoretical constructs—representation, cultural context, reward sensitivity, and behavioral inhibition—to provide a novel framework for understanding and improving risky decision making in youth. We also discuss the roles of critical tests, scientific falsification, disambiguating assessments of psychological and neurological processes, and the misuse of such concepts as ecological validity and reverse inference. We illustrate these concepts by extending fuzzy-trace theory to explain why youth are a major conduit of viral infections, including the virus that causes COVID-19. We conclude by encouraging behavioral scientists to embrace new ways of thinking about risky decision making that go beyond traditional stereotypes about adolescents and that go beyond conceptualizing ideal decision making as trading off degrees of risk and reward.

Introduction

Tremendous advancements have been made in understanding developmental trends in risky decision making over the past two decades. However, two major models of adolescent risk-taking, dual systems (DS; Steinberg, 2008) and neurobiological imbalance (NI; Casey, Getz, & Galvan, 2008; Casey, Galván, & Somerville, 2016), cannot account for the major trend observed in the most discerning studies: a decline in risk preference from childhood to adulthood (Defoe, Dubas, Figner, & Van Aken, 2015). We call these studies "discerning" because they control for multiple confounders commonly present in laboratory and field research. Developmental changes in mental representations integral to fuzzy-trace theory (FTT; Reyna & Brainerd, 2011) predict this trend, while also clarifying

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the role of reward sensitivity and behavioral inhibition in adolescent risky decision making.

In the following, we explain the major tenets of FTT, such as gist and verbatim mental representations and developmental changes in reliance on these representations. A brief discussion follows of key features of relevant laboratory tasks and the importance of using critical tests to allow for scientific falsification. Next, the important yet nuanced role of reward sensitivity and sensation seeking (distinct, yet related concepts) in FTT, and how this differs from DS and NI models, is discussed. Following that, we compare and evaluate the predictions of FTT and DS/NI models regarding risky decision making from childhood to adulthood. We conclude with a discussion of the important role culture plays in understanding risky decision making and differences in how DS/NI models and FTT characterize this role, along with implications of each of these models for a vivid contemporary example of risky decision making: COVID-19. As anticipated by theory, young people are a major vector for disease transmission of SARS-CoV-2, the virus that causes COVID-19, discussed below (Monod et al., 2021).

Fuzzy-trace theory

Fuzzy-trace theory (FTT) is a multi-process theory of cognition that captures how information is encoded, processed, and retrieved (Reyna & Brainerd, 2011). Information includes messages, media, outputs of risk models, and experiences with risk-related outcomes. Developmental differences in these processes, along with reward sensitivity[1] and inhibition, explain and predict adolescent risky decision making (Reyna, Wilhelms, McCormick, & Weldon, 2015). When faced with a decision, according to FTT, individuals simultaneously form different mental representations ranging from those that emphasize precise, verbatim details to those that focus on the least precise overall meaning, such as categorical gist (e.g., some money/no money; Reyna & Brainerd, 2011). Verbatim representations emphasize precise trade-offs, such as trading off degrees of risk for reward, which promotes risk-taking in most public-health contexts (e.g., Reyna et al., 2018; Reyna et al., 2011).

For example, a verbatim representation of the choice between $20 for sure or 1/3 chance of winning $60 and 2/3 of winning $0 would emphasize the details of the two options, such as the difference in reward magnitude. Of middling precision, ordinal gist captures relative tradeoffs between risk and reward (e.g., gaining more vs. less money) and is related to more risk-taking than is categorical gist (Mills, Reyna, & Estrada, 2008; Reyna, 2018), but only verbatim representations capture the degree to which amounts of reward trade off against amounts of risk. Categorical gist (the simplest gist representation) focuses on bottom-line differences between decision options (e.g., gaining money vs. gaining no money) which is generally protective against risk-taking in public-health contexts (e.g., Garavito, Reyna, DeTello, Landow, & Tarpinian, 2020; Reyna & Mills, 2014).

Gist representations depend on what a person knows, understands, and values, which are shaped by culture (Kahan, 2012; Reyna, 2012b). Thus, culture plays an important role in determining gist (McFall, 2015; Reyna, 2020a). Culture is used broadly here to include shared customs, practices, values, or beliefs among social groups that shape, amplify, or constrain expression of risk preferences (Wang, 2021). Specifically, retrieving pertinent values and applying them is an additional, critical step (beyond forming mental representations) in decision-making, representing a separate juncture where culture influences decision making.

As development progresses across age from childhood to adulthood, or with relevant experience or expertise, decision-making shifts from relying on more verbatim, precise mental representations to more meaningful, intuitive gist[2] (Kwak, Payne, Cohen, & Huettel, 2015; Reyna et al., 2011; Reyna, Chick, Corbin, & Hsia, 2014; Reyna & Lloyd, 2006). The accuracy of both types of representations improves from childhood to young adulthood; both are encoded, but reliance on gist increases (Brainerd, Reyna, & Ceci, 2008; Weldon, Corbin, Garavito, & Reyna, 2016). As with many developmental processes, these vary across individuals, with a minority of adults remaining at levels characteristic of younger individuals (e.g., Reyna et al., 2018).[3] The developmental shift in relative emphasis from verbatim (childhood) to gist (adulthood) representations, and how these representations interact with reward sensitivity and inhibition, predict and explain adolescent risky decision-making (Fig. 1). Indeed, predictions of developmental models of risky decision-making that do not incorporate assumptions about mental representations (e.g., Steinberg, 2008; Casey et al., 2008; Casey et al., 2016) diverge from observed patterns of risk preference in unconfounded laboratory tests (see Defoe et al., 2015).

Dual-process (e.g., Evans & Stanovich, 2013) and developmental theories assume that intuitive thinking is typically less sophisticated than more precise, analytical modes, but FTT uniquely emphasizes that increased reliance on intuitive gist representations is a hallmark of mature thinking. Therefore, in addition to explaining observed developmental patterns of risk preference, increased reliance on gist mental representations with age per FTT predicts paradoxical findings regarding developmental reversals (more biases

[1] As explained below, in our view reward sensitivity and sensation seeking overlap but are not identical. Sensation seeking scales are not "pure" measures of reward sensitivity (e.g., they can also tap novelty seeking) although they often group with behavioral activation and other motivational approach measures, and, thus, can index reward sensitivity (Reyna et al., 2011). References to "reward sensitivity" herein emphasize this idea of motivational approach, that rewards are more attractive.

[2] Reliance on gist is called "intuitive" because it is often unconscious and operates in a fuzzy, impressionistic manner (Abadie et al., 2013; Reyna, 2012a).

[3] A weighting function in Broniatowski and Reyna (2018) can be used to account for individual differences in preference for reliance on different forms of mental representation of risky options (see also Reyna and Brainerd (2011) for another model). Evidence for FTT-based neural substrates of individual differences in risky decision making can be found in Reyna et al. (2018) and Reyna and Huettel (2014).

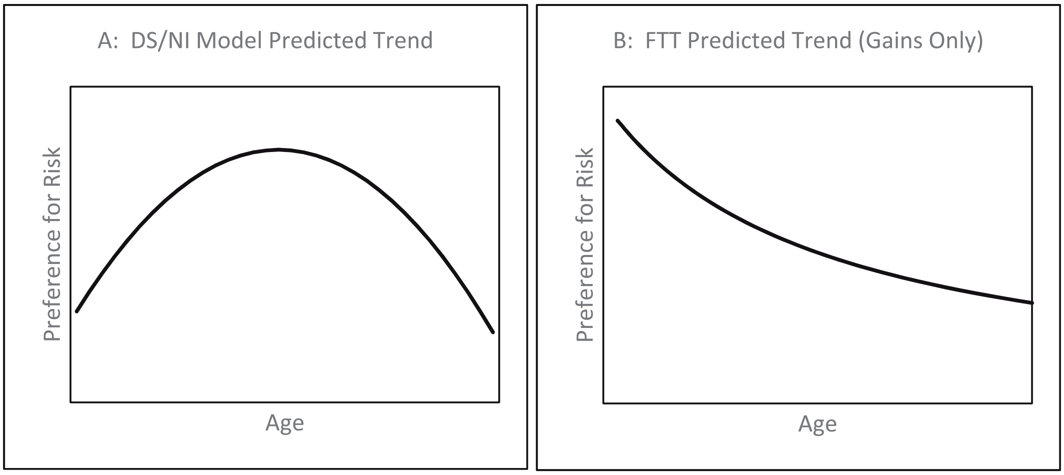

Fig. 1. Illustration of the main developmental predictions of DS/NI models and FTT for preference for risk. Predictions for DS/NI models appear in panel A on the left and predictions for FTT, for gains only, appear in panel B on the right. Studies typically involve individuals within the 10-to-30-years age range. For FTT, development is not based solely on age but also on experience. Further, individual differences, in addition to developmental differences, play an important role. For DS/NI (panel A), the shape of the trend for risk preference (i.e., curvilinear) is considered the same as that for real-life risk-taking. For FTT, risk preference (panel B) is a predictor of real-life risk-taking but not the only predictor. For FTT, risk preference declines with age, as shown in panel B and found in Defoe et al. (2015) meta-analyses. When theoretically motivated moderators were included, a childhood-to-adolescence decline was detected, as well as an adolescence-to-adulthood decline. FTT explains the peak in real-world risk-taking (usually during late adolescence/early adulthood) as the net result of risk preference, sensation seeking (which peaks during adolescence), and inhibition. (DS/NI and FTT acknowledge that risk opportunity also increases with age during this period.) The peak in sensation seeking (see Fig. 3 in Reyna et al., 2011) should not be confused with the peak in real-world risk-taking, and sensation seeking is not sufficient to predict real-world risk-taking by itself; FTT predictors account for additional unique variance in predicting real-world risk-taking.

in adults than children) including framing effects (discussed below), false memories, and moral biases[4] (donating *more* money, or candy, to one child in need compared to a group including that same child; Reyna & Brainerd, 2011; Kogut & Slovic, 2016; Fig. 2).

Testing developmental predictions: Disambiguating tasks is essential to reach correct conclusions

It is important to understand details of decision tasks to know whether and how adolescents' risky decision making differs from that of children or adults. Tasks providing clear tests of FTT's predictions have three critical features[5] (e.g., Reyna & Ellis, 1994; Reyna et al., 2011). First, expected values (EVs) of decision options are equal such that probabilities and outcomes trade off (e.g., $30 for sure [EV = $30] versus 1/2 chance of earning $60 and 1/2 chance of earning $0 [EV = 0.5 * $60 + 0.5 * 0 = $30]). Therefore, the gamble always offers the higher potential reward (or potential loss, in the loss frame). EV (processing verbatim numbers) contributes separately to preferences in parallel with contributions of gist (Broniatowski & Reyna, 2018; Reyna & Brainerd, 1994, 2011). Tasks that do not constrain EV as equal across decision options tap computational performance (e.g., knowledge and practice with multiplication) that also varies developmentally, which obscures developmental differences in risk preference (e.g., Weller, Levin, & Denburg, 2011). Thus, unequal value problems can make it more difficult to observe gist-based effects in choice data, though modeling reveals multiple forces at work (Broniatowski & Reyna, 2018).

Second, ideal tasks must include a categorical contrast between options (e.g., sure something vs. gamble with possibly nothing) to evaluate predictions.[6] According to FTT, increasing reliance on gist representations accounts for developmental differences in risk preference, but if options cannot be decomposed into simple categorical gist representations, respondents are forced to use more detailed levels of processing, thus obscuring the central developmental prediction of mature reliance on the simplest (categorical) gist. When two options both have the possibility of a zero outcome—two gambles—each boils down to "gaining something or gaining nothing," and choices must then be resolved using finer-grained distinctions. Thus, categorical gist is lawfully determined in FTT and

[4] The "singularity" effect, one child hurting evokes qualitative gist, and thus cues moral values more effectively (because such values are mentally represented categorically), but six children hurting elicits more fine-grained, proportionate responses; the latter becomes more of a math problem than a charity problem (e.g., Reyna, 2021).

[5] We do not mean that FTT does not apply to situations where these conditions are not met (e.g., FTT applies to the Allais paradox which does not involve equal expected values; Reyna & Brust-Renck, 2020) but simply that developmental tasks without these features generally fail to provide a diagnostic test of FTT's predictions.

[6] Decisions in the "gain frame" are typically meant in the literature when referring to developmental trends in risk preference (e.g., decisions involving winning rewards), but note that FTT makes unique developmental predictions for risky decision making that differ based on decision frame (i.e., gains vs. losses). See Fig. 2 and Reyna and Brainerd (2011) for more detail.

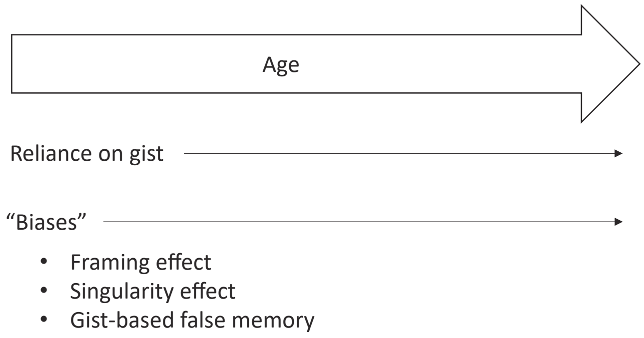

Fig. 2. Examples of developmental reversals explained by FTT. This figure illustrates that as age increases, so too does reliance on gist and, thus, specific cognitive biases. Young children engage in relatively more verbatim-style reasoning that conforms to traditional ideas of "rationality" in that preferences are consistent when options are quantitatively equivalent (no framing effect), whereas adults exhibit gist-based biases (framing effect). Emergence of gist-based biases is also illustrated in the singularity effect, which violates objective verbatim numbers (adults give more to one child than to many, but children give more to many than to one). Gist-based false memories also violate verbatim reality (adults remember gist-consistent events that did not happen; children remember more objectively; Reyna & Brainerd, 2011; Kogut & Slovic, 2016).

depends on the nature of options and their resulting gist (see Broniatowski & Reyna, 2018; Reyna, 2012a, for step-by-step instructions to derive gist). Hence, when a task provides a sure option wherein people can win/lose something, as opposed to possibly nothing in the gamble, categorical gist can be used and would differentiate older from younger participants.

Third, ideal tasks distinguish reward sensitivity from risk preference by varying the magnitude of rewards but holding constant the ratio of rewards in the gamble vs. sure option. Consider decisions involving small magnitudes (e.g., $5 for sure or 1/2 chance of $10 and 1/2 chance of $0) or large magnitudes (e.g., $150 for sure or 1/2 chance of $300 and 1/2 chance of $0). The risky reward is twice as much as the sure reward (1:2) but the dollar amount of the difference differs substantially ($5 vs. $150). Therefore, when adolescents prefer risky gains in the gain frame *only* when large reward magnitudes are at stake, this indicates a sensitivity to reward magnitude per se (e.g., getting $150 more compared to $5 more; Reyna et al., 2011).

Furthermore, tasks that conflate ambiguity and learning (as many experiential tasks do) usually cannot be decomposed in a meaningful way to test developmental predictions (cf. Osmont et al., 2017; see Edelson & Reyna, in press, for a more detailed discussion). These tasks tap known differences in learning rates across age, rendering results about preferences inconclusive. Separating risk preference from ambiguity in experimental tasks is important for testing theoretical predictions and because different developmental trajectories have been observed for attitudes towards risk vs. ambiguity (e.g., Tymula et al., 2012; Van den Bos & Hertwig, 2017). The representational architecture of FTT (not present in other models) facilitates ready application to decisions made under ambiguity: Reliance on gist is particularly useful precisely because of its fuzzy (vague) and "impressionistic" qualities–referred to as "rigorous sloppiness" (Argyris, 1988). According to von Neumann (1958, pp. 79–80), the imprecise nature of human thought makes it more robust to noise compared to the machine precision of computers (Reyna & Brainerd, 1992). Therefore, in the real world when decisions frequently involve ambiguity, gist is the kind of thinking that can be engaged in when details are unknown.

Some tasks also conflate risk and reward—one can only gain greater rewards if greater risks are taken—and thus cannot provide clear tests of theoretical predictions regarding risk preference. Thus, tasks such as the Stoplight (Chein et al., 2011), Iowa Gambling (IGT; Bechara, Damasio, Tranel, & Damasio, 1997), and Balloon Analogue Risk tasks (BART; Lejuez et al., 2002) assess several complex, interconnected factors that relate to maladaptive choices in everyday life, but, because they conflate ambiguity, risk, and reward, it is unclear what evidence of greater "risk-taking" on such tasks means. In addition, the BART and Stoplight tasks both involve patience or impulsivity, which adds another confound (Tymula, 2019). In contrast, tasks such as the Columbia Card Task (Figner et al. 2009), the modified Cups Task (Levin, Weller, Pederson, & Harshman, 2007), and the framing tasks (Reyna & Ellis, 1994; Reyna et al., 2011, described below) by design do not collapse over these important elements. Advancing understanding of adolescent risky decision making requires using unconfounded tasks that can provide critical tests of existing theories, especially when such theories diverge in predicting developmental patterns in preference for risk. Continued reliance on tasks that do not allow for these distinctions to be tested prevents scientific falsification.

Sometimes use of laboratory tasks that more closely resemble risk-taking in real life is promoted because of "ecological validity." However, ecological validity is about understanding and predicting real-life risk-taking,[7] not mimicking superficial or confounding features of real life (Edelson & Reyna, in press). The motivating problem of adolescent risky decision-making in real life is important, but what causes such behavior, or even what the developmental patterns actually are, cannot be determined without testing the underlying mechanisms, especially when tasks cannot provide critical tests of existing theories. Recent meta-analyses do provide such critical tests (Defoe et al., 2015) if examined with these factors in mind, showing that risk preference declines from childhood to

[7] Contrary to false assertions about ecological validity, laboratory choices do correlate with those in everyday life (though naturally not perfectly; e.g., see Parker & Fischhoff, 2005; Reyna et al., 2011; Lejuez et al., 2003; Verschoor, D'Exelle, & Perez-Viana, 2016; see also Sherman, Steinberg, & Chein, 2018).

adulthood, despite a “bump” in reward sensitivity in adolescence.

Implications for health decisions

Developmental differences in mental representations carry important implications for risky health decisions. Focusing on representations closer to the verbatim, as younger people are more likely to do, emphasizes trading off between dimensions of a decision, such as magnitudes of risk and reward. In many public health contexts, benefits are in fact high and risk is in fact low for a single act of risk-taking.[8] If the benefits are high and risk is low, a “rational” calculus weighs in favor of taking the risk (Reyna et al., 2015). In contrast, gist representations help insulate decision makers from risk-taking primarily by encouraging risk avoidance for rewards because they involve boiling down options to categorical contrasts—such as no risk versus some risk—the simplest gist. Reliance on gist tends to be adaptive in the sense that it facilitates making healthier choices (e.g., avoiding unsafe sex) because it incorporates context, meaning, and values into the decision making process (based on specific mechanistic principles; Reyna, 2012a, 2018). Whether avoiding risk is adaptive from an “evolutionary perspective” in the sense of propagating one’s genes is a separate question but perhaps not necessarily the most relevant one for navigating the challenges of modern society (Reyna & Farley, 2006). Unlike situations in which potential rewards are at stake, when the status quo is a sure bad situation (a loss frame), gist favors taking a risk. One reason categorical gist representations promote healthier choices is because they offer better cues for retrieval of core social and cultural values that are also stored in a gist form in long-term memory (Helm & Reyna, 2017; Mills et al., 2008; Reyna, 2020a; Reyna & Mills, 2014). Hence, gist-based decisions are more likely to reflect core health-promoting values (Fujita & Han, 2009).

Reward sensitivity and sensation seeking

The developmental shift in reliance on mental representations from verbatim-based to gist per FTT described above, in conjunction with heightened reward sensitivity during adolescence, accounts for a unique pattern of decision making. “Reward sensitivity” incorporates the idea of motivational approach towards and pleasure derived from rewarding stimuli, which can manifest as “sensation seeking” in the sense of goal-directed behavior (including risk-taking) to achieve such rewards (Steinberg et al., 2018; Zuckerman, 1994). Indeed, Reyna et al. (2011) found that a reward-sensitivity factor, on which measures of sensation seeking and behavioral approach loaded, accounted for unique variance in predicting sexual behavior and intentions. Sensation seeking also encompasses novelty seeking, or attraction to novel (unknown) exciting experiences (Romer et al., 2017). Therefore, although there is certainly some degree of overlap among these constructs, reward sensitivity is conceptually distinct from novelty/ambiguity seeking, risk-taking (engaging in behavior with potential negative outcomes, such as addiction, felony conviction, or serious physical injury), and risk preference (measured unambiguously in decision tasks with both equal EV and categorically different outcomes, e.g., Defoe et al., 2015; Reyna et al., 2011).

Sensation seeking and some measures of reward sensitivity have been shown to peak during adolescence (Galván, 2013; Khurana, Romer, Betancourt, & Hurt, 2018; Reyna et al., 2011; cf. Insel & Somerville, 2018; van Duijvenvoorde et al., 2014). While sensation seeking is often measured through self-report questionnaires, reward sensitivity is frequently studied in the context of neuroscientific studies (Shulman et al., 2016).[9] Important points to keep in mind regarding neural evidence of adolescent responsiveness to reward are that evidence from neuroimaging studies is prone to noise (e.g., motion in the scanner) and is largely correlational in that brain activation is associated with behavior rather than experimentally manipulating some factor and then observing the effect of that experimental variation on brain activation; the latter kind of causal experiments are much needed to understand brain functioning. Brain activation is also difficult to experimentally manipulate in the sense of turning it on and off (but see Figner et al., 2010).

Nevertheless, hypotheses about reward sensitivity are grounded in animal work allowing for experiments, and we do not mean to claim that neuroimaging is without value. Although caution should be used in making psychological inferences based on neural activity, Poldrack (2011) does not call for blanket admonishment of this approach but rather increasing scientific rigor. Moreover, the usual admonitions about reverse inference regarding reward sensitivity and other processes have important qualifications: (1) converging studies with disambiguated tasks that tap mechanisms and (2) evidence-based theoretical predictions, which change the prior probability of a finding and implicate specific mechanisms (Buckholtz et al., 2016).

Reward sensitivity also interacts with other key processes. Notably, adolescents are more likely than adults to exhibit reverse framing (risk seeking for gains and risk aversion for losses) especially when large (e.g., EV = $150) but not small (e.g., EV = $5) rewards are at stake (e.g., Reyna et al., 2011). According to FTT, reverse framing is the product of both a developmental peak in reward sensitivity and reliance on more precise (closer to verbatim than gist) mental representations of information. Reward-sensitive adolescents relying on more verbatim representations would be particularly attracted to risky options offering high rewards, and would trade off risk and reward. However, relying on categorical gist avoids trading off. Therefore, those reward-sensitive adolescents who rely more on gist representations should be less responsive to large rewards because their mental representations emphasize *qualitative*

[8] In general, the probability of pregnancy or contracting a sexually transmitted infection from a single act of unprotected sex or the probability of dying or incarceration from a single act of drunk driving are, in fact, low. However, this does not mean that these are good ideas but rational economic analyses can justify such choices.

[9] One might wonder whether the evidence of a peak in sensation seeking during adolescence results from a failure of self-report questionnaires to adequately include items that might apply to children or younger adolescents, but evidence suggest that this is false (e.g., Steinberg et al., 2008). Broader age ranges (e.g., children and adults) in examining such developmental trends would be helpful (e.g., Galván, 2017).

differences between decision options (something is better than nothing), rendering them less likely to succumb to high rewards. Adolescents who do not rely on gist representations might still avoid risk-taking—despite more precise processing—if risks outweigh rewards, thus favoring risk avoidance through a rational calculus.

Reverse framing in FTT concurs with mechanisms of reward sensitivity and/or sensation seeking in DS/NI theories (Casey et al., 2008; Steinberg, 2008; Steinberg et al., 2018), but research has shown that assuming reward sensitivity by itself contradicts developmental data. As research shows and FTT predicts, risk preference follows a different trajectory from reward sensitivity. While DS/NI models, as all traditional decision theories do, assume that individuals necessarily trade off along dimensions of risk and reward (e.g., Shulman et al., 2016), research demonstrates that mental representations that categorize outcomes qualitatively (as contrasted with trading off by degrees) play a dominant role in mature, healthy decision-making (e.g., Garavito et al., 2020; Reyna et al., 2011; Reyna & Mills, 2014).

One might hypothesize that differences in risk-taking can be explained *solely* by attitudes about ambiguity. That hypothesis is wrong because experiments with known probabilities and outcomes—no ambiguity—still show a decrease in risk preference from childhood to adulthood (see review by Defoe et al., 2015). That decrease has been clearly tied to separate measures of verbatim and gist processing—*controlling for sensation seeking*—which then predict risk-taking intentions and behavior (e.g., Reyna et al., 2011; Reyna & Farley, 2006). Thus, research shows that risk preference decreases across age while sensation-seeking increases and then decreases—and each contributes to risky intentions and behavior.

FTT and DS/NI models: Convergent and divergent predictions

As noted, reward sensitivity/sensation seeking plays an important role in the other major models of adolescent risky decision making, DS and NI models (Casey et al., 2008; Casey et al., 2016; Steinberg, 2008). These models both assume that heightened risk taking in adolescence compared to adulthood results from a developmental asymmetry in neural systems related to reward and cognitive control or inhibition. Cognitive control is thought to improve linearly with age, whereas reward sensitivity/sensation seeking is thought to peak during adolescence, creating imbalance between these mechanisms during adolescence, and thus rendering this age group susceptible to engaging in risky activities (Steinberg et al., 2018). Steinberg et al.'s DS approach emphasizes socioemotional rewards and peers in enhancing motivation to achieve rewards (Chein et al., 2011; Gardner & Steinberg, 2005; Shulman et al., 2016), whereas Casey et al. emphasize that dual processes interact in a complex manner throughout development (Casey et al., 2016). FTT incorporates these mechanisms.

As in DS and NI models, inhibition also plays an important role in FTT (Reyna & Brainerd, 2011).[10] All else equal, FTT predicts that lower levels of inhibition are associated with risky behavior (Reyna & Farley, 2006). However, FTT provides two mechanisms for inhibition: a cognitive route (not dissimilar to reinterpretation of motivating stimuli, e.g., thinking of a marshmallow as a cotton ball; Mischel & Shoda, 1995) and response inhibition, measured separately in FTT's models (e.g., the tendency to withhold an approach or "yes" response; Reyna et al., 2015). Research on FTT has shown that mathematical skills improve and computational processes are executed more efficiently (sometimes tapped in contemplative or deliberative tasks) from childhood to adulthood while metacognition (and associated inhibition) increases (i.e., impulsivity declines). While FTT acknowledges that sometimes risk-taking can be the product of acting without thinking –prompted by reward sensitivity and lack of inhibition –these assumptions are not sufficient (Reyna & Farley, 2006). Instead, mental representations explain a significant portion of adolescent risky decision making, beyond reward sensitivity and lack of inhibition. According to FTT, qualitative, gist-based intuition may help insulate adolescents from lower inhibitory control compared to adults because it can function to shift attention away from quantitative trading off between reward magnitudes, which may ultimately dampen the motivational pull of reward-magnitude sensitivity in adolescence. Thus, FTT provides inroads to overcoming developmental challenges involving motivation and inhibition (Reyna & Mills, 2014).

DS and NI models predict an adolescent-specific peak in risk-taking, that adolescents will take more risks than other age groups (Shulman et al., 2016; Fig. 1). According to these models, both lower rates of risk-taking among children compared to adolescents, and lower risk-taking among adults compared to adolescents should be expected. This is an important point on which FTT and DS/NI models diverge. FTT predicts that risk preference will be highest in childhood, will decline between childhood and adolescence, and decline again more subtly between adolescence and adulthood. These predictions follow from FTT when controlling for differences in numeracy, which is a distinct faculty and is correlated with age (and with missing school as risk takers are more likely to do). See Fig. 1 for a rough illustration of such developmental predictions. Note that for FTT, risk-taking is expected to decline less between adolescence and adulthood because as with many developmental processes, differences get smaller as age increases—but it is the only theory to account for declines in risk preference from early adolescence to middle/late adolescence (see below; Defoe et al., 2015; Defoe et al., 2019).

Although not the focus of this manuscript, it is worth noting that when it comes to older adults (age 65 and older), it is important to distinguish demands of the task (e.g., learning) from preference for risk. Reliance on verbatim mental representations decreases in old age, and failure to learn to the same degree in experiential tasks can masquerade as higher preference for risk because of known older-

[10] Standard dual-process theories assume that advanced thinking must be contemplative (or deliberative) as contrasted with less advanced acting without thinking ("thinking fast" i.e., impulsivity). FTT recognizes that contemplative or deliberative abilities increase from childhood to adulthood, including metacognitive monitoring (Broniatowski & Reyna, 2018) and inhibitory ability, discussed below. However, gist-based intuition also increases during the same developmental period, and gist processing is often not contemplative or deliberative, but, rather, is executed rapidly in familiar domains outside of conscious awareness.

age differences in verbatim memory in these types of tasks (e.g., Reyna & Brainerd, 2011; Samanez-Larkin & Knutson, 2014).

The following section discusses developmental trends in preference for risk in laboratory tasks, because risk-taking, as manifested behavior, is influenced by external factors such as opportunity (Gerrard, Gibbons, Houlihan, Stock, & Pomery, 2008) and therefore focusing only on such real-life trends is misleading (Reyna & Farley, 2006). As an aside, we should note that, because of this emphasis on laboratory tasks, one might think that FTT does not account for decision makers' arousal, but this is not the case. Rivers, Reyna, and Mills (2008) specifically incorporate research on arousal, which is associated with perceived rewards (or benefits) and also with failures of self-control (i.e., lack of inhibition), but reliance on gist can help to insulate decision makers against these influences. Importantly, arousal is distinct from valence (positive or negative) and discrete emotions (Rivers et al., 2008), as well as reward (although high rewards are often considered highly arousing). While it may be the case that many risky decisions in the real world involve all of these factors, to truly understand the mechanisms underlying adolescent risk-taking, these concepts must be distinguished both conceptually and through the use of unconfounded laboratory tasks. How "hot", "emotional," and "arousing" contexts influence the way that adolescents make decisions depends on how these features interact with cognitive representational processes that are now known to account for major developmental trends in risk-taking from childhood and adulthood (Defoe et al., 2015). While recent studies examine developmental trends in composite measures that combine several of these features (e.g., Icenogle et al., 2019) which provide important observations and insights,[11] we suggest a complementary approach: employing laboratory tasks that allow for critical tests of theories and show how context influences decision making.

Developmental trends in preference for risk: Empirical results

The meta-analyses conducted by Defoe et al. (2015) provided substantial clarity regarding developmental trends in risk-taking on laboratory tasks. Overall, results were largely consistent with FTT and at odds with dual systems models on critical tests of the theories, putting aside results that do not adjudicate one way or the other. Defoe et al. document an overall decline in risk preference from childhood to adolescence (when using a critical test: a disambiguated task), and again from adolescence to adulthood. The distinction between tasks that included a sure win (or not) was captured though the FTT moderator (Defoe et al., 2015). Specific results of the four separate meta-analyses are discussed in more detail below.

Do children differ from adolescents in risk preferences? A critical test of alternative theories

The first meta-analysis conducted by Defoe et al. (2015) compared children with early adolescents and did not find an age difference in "risk-taking" (risk preference), without testing the FTT or some DS/NI moderators. This result is contrary to DS and NI models which predict an increase in risk-taking between children and adolescents and does not bear on FTT either way. That is, FTT predicts a decrease in risk-taking from childhood to early adolescence because of an increased reliance on gist with age when options differ categorically (e.g., a sure win available), but this could not be tested. The second meta-analysis comparing children with adolescents overall, including the FTT moderator, found that risk-taking decreased from childhood to adolescence (as expected per our discussion above, no effect was observed when this moderator was not included). This finding lies in direct contrast to DS and NI models which predict the opposite trend for these age groups, but is in line with FTT's predictions.

Do early adolescents differ from late adolescents in risk preferences? Another critical test of alternative theories

The third meta-analysis tested the difference between early adolescents and mid-to-late adolescents and found that early adolescents take more risks than mid-to-late adolescents. This finding is again contrary to DS theory which predicts heightened risk-taking specific to mid-late adolescents—indeed this age range is when sensation seeking has been found to peak in some studies. In contrast, this finding is in line with FTT which predicts a decline in risk-taking with age from childhood to adulthood. The FTT moderator did not have additional explanatory power for this effect, but the finding is in line with FTT's predictions.

Do adolescents differ from adults in risk preferences? A final critical test of alterative theories

The fourth meta-analysis tested the difference between adolescents and adults and found that adolescents take more risks than adults. This finding is in line with both DS/NI models and FTT. Table 1 summarizes the results of the moderation analyses. Again, the FTT moderator was not significant but the overall result is in line with theoretical predictions. Again, null effects of the moderator can be speculated about (e.g., less power than overall analyses) but null effects are ultimately indeterminate.

Although Defoe et al. (2015) conducted separate meta-analyses to address risk preference from childhood to adulthood, a few

[11] Measures designed to tap responsiveness to heightened (socio-) emotional arousal ('hot' choices), which often co-occurs with risk taking in adolescents tend to reliably account for variance in self-reported risk taking. However, the seemingly 'cold', contemplative decisions tapped in laboratory tasks predict unique variance in highly arousing contexts of self-reported risk taking, such as using illicit drugs and sexual risk taking (e.g., Reyna & Farley, 2006). Arousal, emotion, and reward motivation interact with modes of thinking tapped in laboratory tasks (Rivers et al., 2008) and, surprisingly, many studies of adolescents have shown that risk taking is predicted as much or more by seemingly cold contemplation of risks and benefits in the laboratory outside of the context of arousal as by impulsivity in the context of arousal (see also Romer, Reyna, & Satterthwaite, 2017).

Table 1
Summary of Key Results from Meta-analyses in Defoe et al. (2015).

Meta-analysis	Ages (M years)	Effect size	Theoretically Motivated Moderators Tested	Summary
1A	Children (8.60) vs. Early adolescents (12.20)	$g = 0.04$ ($p = .68$)	Nonsignificant: Incentivized vs. nonincentivized tasks; time pressure vs. no time pressure; dynamic vs. static; experience-based vs. description-based *FTT moderators not tested.*	Children and early adolescents do not differ in level of risk taking in laboratory tasks (but FTT moderator not tested).
1B	Children (8.75) vs. Adolescents (14.87)	$g = -0.00$ ($p = .97$)	Nonsignificant: Immediate outcome feedback vs. delayed outcome feedback; gain gambles vs. mixed gambles; incentivized vs. nonincentivized tasks; time pressure vs. no time pressure; dynamic vs. static; experience-based vs. description-based. Significant: *sure win* vs. *no sure win* (FTT moderator; $b = -0.46$; $p = .02$)	Consistent with FTT, adolescents take fewer risks than children (when a sure win is available)
2	Early adolescents (12.23) vs. Mid-late adolescents (16.16)	$g = 0.15$ ($p = .01$)	Nonsignificant: Incentivized vs. nonincentivized tasks; time pressure vs. no time pressure; dynamic vs. static; experience-based vs. descriptive-based; *sure win* vs. *no sure win* (FTT moderator).	Early adolescents take more risks than mid-late adolescents, consistent with FTT but inconsistent with DS/NI.
3	Adolescent (14.87) vs. Adult (24.98)	$g = 0.37$ ($p < .01$)	Nonsignificant: Gain gambles vs. mixed gambles; incentivized vs. nonincentivized tasks; time pressure vs. no time pressure; dynamic vs. static; *sure win* vs. *no sure win*; sure neutral vs. no sure neutral (FTT moderators). Significant: Immediate outcome feedback vs. delayed outcome feedback ($b = 0.50$; $p = .01$) when tested in a univariate model (and the multivariate model was also significant but individual moderators were not).	Adolescents take more risks than adults, consistent with FTT and DS/NI

studies examining this entire age span were included although the tasks used would not allow for a critical test of FTT for the reasons explained above. An additional study examined behavior using the Cups tasks across a wide age range (Weller et al., 2011), although adolescents (ages 12–17) were not included in this study. Nevertheless, they found that risk-taking in the gain frame decreased steadily with age, which is consistent with predictions of FTT. In addition, a recent large cross-national study examined performance on tasks such as BART, Stoplight, and IGT from ages 10 to 30 (Duell et al., 2016; Duell et al., 2018; Icenogle et al., 2019; Steinberg et al., 2018) but the focus was not on risk preference per se but rather "sensation seeking," (composite score of self-reported sensation seeking and performance on the stoplight task and IGT), "risk-taking propensity" (performance on the stoplight task and BART), "self-reported risk preference" (composite of performance on the stoplight task and BART, and a risk perception scale) or "psychosocial maturity" (composite score including the stoplight task, BART, a measure of impulse control, and other behavioral measures). The use of these tasks does not allow for a critical test of FTT for the reasons explained above.

Thus, the metanalyses confirmed earlier studies (see also Kwak, Payne, Cohen, & Huettel, 2015). Reyna and Ellis (1994) conducted the first framing study in children (including 4-year old preschoolers to 11-year old early adolescents) presenting several problems that factorially varied risk and outcome. Reyna et al. (2011) used this same task to conduct the first examination of framing in adolescents (M = 15.5 years) compared to young adults (M = 19.7 years), discussed above, except that money was used as the outcome and the amounts were multiplied by a factor of five. These two studies demonstrate an increasing tendency towards standard framing (risk aversion for gains and risk seeking for losses) with age that depends on the magnitude of the outcomes. Focusing on the gain frame, as many risk studies do, results are in line with the overall trend observed by Defoe et al. (2015): an overall decline in risk preference from childhood to adulthood. According to FTT, increased reliance on gist with age in large part accounts for this trend, as discussed above.

Extensions to culture

According to the DS model, culture plays an important role in the behavioral manifestation of risk preference. For example, rates of cigarette smoking among teens vary dramatically across cultures, although underlying factors may not differ (Duell et al., 2018). According to this perspective, cross-national variability in risk-taking is assumed to result from differences in opportunities to take risks and contextual constraints on behavior such as social norms (e.g., drinking is illegal in some countries for all ages and hence lowers rates of reckless drinking among adolescents; Duell et al., 2018; Reyna & Farley, 2006). Using FTT as a framework, culture can be seen as playing a fundamental role in adolescent decision-making.

There are two main predictions about how culture influences decision making in FTT, which future research should test directly and quantitatively. First, culture shapes how individuals interpret the gist of a decision or situation (Reyna, 2020a; Reyna & Brainerd, 2011). Unlike gist, precise verbatim representations that capture the details of a decision (e.g., literal wording or numbers characterizing decision information) are not expected to vary based on culture, all else equal. Gist representations, however, are subjective. Based on the same facts, two people could come away with different gists because information is filtered through culture, personal beliefs, knowledge, and values—though values are represented distinctly from options—as individuals distill the underlying meaning of a situation (e.g., Wang, 2002). Second, even if two people have the same gist representations of a situation, how they decide ultimately comes down to their values (Fraenkel et al., 2016; Reyna, 2020a). Therefore, because culture can play an important role in

Table 2
Examples of Studies Applying FTT to Adolescent and Young Adult Risky Decision Making.

Authors (year)	Participants	Outcome	Select Results
Ajayi, Garavito, and Reyna (2021)	University (M = 19.79) and high school (M = 16.11) students	Intentions to report concussions	Gist processing, knowledge about concussions, and attitudes towards concussions mediated the relationship between SES and intentions to report concussions.
Brown, Nowlan, Taylor, and Morley (2013)	University students (M = 20.83)	Intentions to reduce drinking	Bounded estimates of risk (intended to tap gist mental representation) were stronger predictor of intentions to reduce drinking than unitary estimates (intended to tap verbatim mental representations).
Brust-Renck et al. (2017)	University students (M = 19.21)	Healthy behavior and intentions (e.g., nutrition, exercise)	FTT-informed curriculum was associated with mediators of health promoting behaviors including gist comprehension.
Cho, You, and Choi (2018)	Middle school students (M = 13.94)	Knowledge, attitudes, and intentions towards caffeine.	No significant difference in acquisition of gist knowledge between individuals in gist vs. verbatim condition (regarding graphics about caffeine consumption) was observed, but gist knowledge significantly related to higher attitudes and intentions towards caffeine control whereas verbatim knowledge did not.
Gamino et al. (2014)	Middle school students (M = 12.95)	Gist-based reasoning and fact recall	Participation in cognitive training program emphasizing understanding underlying meaning was associated with improvements in gist-based reasoning.
Garavito et al. (2020)	High school (M = 16.12) and college students (M = 19.82)	Intentions to report concussions symptoms	Gist-based thinking about risks and values predicted intention to report concussions in college students, and gist-based thinking about risks predicted intention to report in high schoolers.
Helm et al. (2018)	Adolescents (M = 13.93), college students (M = 19.62), and adults (M = 38.74)	Plea decisions	Developmental differences in reliance on gist representations, thus difficulty applying relevant values to decisions, rendered adolescents more likely to plead guilty to crimes they did not commit.
Kwak et al. (2015)	Adolescents (M = 13) and young adults (M = 22)	Risky gambling task	Adolescents were more likely to trade off outcomes and probabilities (tending toward verbatim compensatory processing) based on eye tracking, compared to young adults (tending toward noncompensatory gist), consistent with FTT (but contrary to other theories).
Mills et al. (2008)	Adolescents (M = 15.5)	Sexual behavior (“Have you ever had sex?”) and behavioral intentions to have sex	Verbatim and quantitative representations of risk related to more risk taking while gist representations of risk and values were related to less risk taking.
Mirman and Curry (2016)	Adolescents (17–18)	Racing behavior (“I raced other cars on the road when I was driving with my friends in the car in the past 1 month”)	Higher endorsement of gist principles about safe driving was associated with lower racing behavior.
O’Brien and Gormley (2016)	Adolescents and young adults (M = 19.7)	Perception of risky driving behavior	Risky driving behavior was negatively associated with a global risk measure but positively associated with specific risk measures.
Reyna et al. (2014)	Undergraduate students (M = 19.74), postcollege adults (M = 30.83), and intelligence professionals (M = 35.87)	Framing decision problems	Framing bias increased with development; older and more expert decision makers demonstrated stronger standard framing and greater confidence in decisions compared to undergraduates; experimental manipulations mimicked effects of development as predicted by FTT.
Reyna et al. (2013)	College students (M = 17.91 and 17.86)	Risky drinking	Endorsement of personal responsibility to obey drinking laws was associated with less risky drinking (and likelihood of drinking and amount of drinking).
Reyna and Ellis (1994)	Preschoolers (M = 4 yrs 8 mo), second graders (M = 8 yrs 0 mo), fifth graders (M = 11 yrs 1 mo)	Framing decision problems (spinner task)	Preschoolers did not show framing effects and generally chose the risky option. Second graders demonstrated reverse framing at the highest level of risk. Fifth graders showed standard framing for smaller outcomes and reverse framing for larger outcomes.
Reyna et al. (2011)	College students (M = 19.7) and adolescents (M = 15.5)	Framing decision problems and sexual behavior (“Have you ever had sex?”),	College students showed standard framing but adolescents showed reverse framing when outcomes were larger. Gist-based thinking

(*continued on next page*)

Table 2 (*continued*)

Authors (year)	Participants	Outcome	Select Results
		total number of sexual partners, and behavioral intentions to have sex.	predicted less risk taking, whereas verbatim-based thinking predicted more risk taking.
Reyna and Mills (2014)	Adolescents (14–19)	26 outcomes, including sexual behavior and behavioral intentions	Intervention with gist-based curriculum resulted in improvements on 17 outcome measures. Effects of gist-based curriculum were greater than an existing intervention with similar content (but lacking gist of risk) on 9 outcome measures. Effects of gist-based curriculum remained significantly higher than control for 12 outcomes after one year.
Reyna and Wilhelms (2017)	College students (M = 20.26)	Self-reported risk taking, substance use, and financial problems	Higher endorsement of categorical delay of gratification values (measured with DG-Gist scale) predicted lower problem behaviors independent of other variables such as sensation seeking and a quantitative measures of temporal discounting.
Voepel-Lewis et al. (2018)	Adolescents and young adults (M = 19.91 for previously used perception opioid; M = 19.4 for never used prescription opioid)	Willingness to misuse prescription opioids	Deliberative processing of risks and benefits—higher endorsement of pain-relief and lower perceptions of risks—predicted intentions to misuse in adolescents and young adults.
White et al. (2015)	Adolescents (M = 15.04) and young adults (M = 19.15)	Online risk taking behavior and behavioral intentions	Gist-based thinking negatively correlated with intentions to take online risks while verbatim-based thinking positively correlated with intentions.
White, Gummerum, and Hanoch (2018)	Adolescents (13–17) and young adults (18–24)	Framing decision questions (online gambling)	Adolescents engaged in less standard framing than young adults. Both age groups engaged in less standard framing for large compared to small rewards.

shaping values, it may influence decision making separately from its influence on the formation of gist representations (e.g., Kogut, Slovic, & Västfjäll, 2015; see also Reyna & Casillas, 2009).

For example, with respect to adolescent risky decision making, stronger endorsement of familismo and family obligation values have been linked with lower rates of risky behavior, including substance use and externalizing behavior, among samples of Mexican and Mexican-American youth (Germán et al., 2009; Cruz et al., 2018; Telzer, Fuligni, & Galván, 2016). Familismo values emphasize "centrality of the family unit" and incorporate family obligations to immediate as well as extended family—family above all (Germán et al., 2009). However, a relationship with risk-taking behaviors has not been observed with respect to family assistance (e.g., taking care of siblings; Telzer, Gonzales, & Fuligni, 2014) or explicitly didactic cultural socialization (e.g., encouraging reading about ethnicity; Qu, Galván, Fuligni, & Telzer, 2018). These results may highlight an important role for simple, relevant values in the link between culture and risk taking, and not all family values may be equally relevant.

There is some similarity between familismo values and gist principles that have been examined empirically (including "I have a responsibility to my parents/family to not have sex" and "Better not to have sex than hurt my parents/family"; Garavito et al., 2020; Mills et al., 2008; Reyna et al., 2011; Reyna & Mills, 2014). Evidence that higher endorsement of familismo/family obligation values correlates with lower risk-taking is consistent with FTT, such that agreement with gist principles (which often incorporate a sense of responsibility to family) relates to lower rates of risk-taking in a number of domains, including sexual intentions and behavior, intentions to report concussions, online risk-taking, healthy eating, and dangerous driving (Table 2; Brust-Renck et al., 2017; Mirman & Curry, 2016; White, Gummerum, & Hanoch, 2015).

In contrast to reliance on gist representations of a situation, which help cue relevant values in the decision-making process, reliance on verbatim representations makes it harder for adolescents to make decisions in accordance with their values, as illustrated in plea bargaining in which correlations between values and plea choices depended on verbatim/gist thinking (Helm & Reyna, 2017; Helm, Reyna, Franz, & Novick, 2018). Therefore, for adolescents occupying the transitional space in development moving from verbatim to gist-based representations of decisions, variation in the automaticity of accessing values as part of decision making is expected and the relationship between culture and decision making would be expected to vary accordingly.

Culture would still be expected to relate to decision making even of adolescents who rely more on verbatim processing, but the relationship would be one of memorized rules rather than decision making with intuitive insight. Gist-based adherence to values is internalized because it is based on meaning, as opposed to being externally controlled by laws and rules, as research has shown for adolescents adhering to the legal drinking age (Reyna et al., 2013). When adolescents rely predominately on gist representations, their mental representation of a situation will be shaped by their culture and reflect underlying understanding, and these adolescents will have an easier time cuing and implementing their values in making decisions. Although the potential for insight increases from childhood to adulthood, reliance on social stereotypes also increases (e.g., Davidson, 1995; Jacobs & Potenza, 1991; Morsanyi, Chiesi, Primi, & Szűcs, 2016) for a similar reason (i.e., increasing reliance on gist). A framework for understanding how such mental representations might develop and potential ways forward are discussed in Reyna (2020a).

A current example

A contemporary example helps highlight our key points: novel extensions of FTT to reward sensitivity and culture (Fig. 3). According to FTT, when faced with the decision of attending a non-socially distanced party during the ongoing pandemic or staying home for a virtual hang-out, for most adolescents and young adults, the chances of getting seriously ill from COVID-19 are far less than 50% for a single encounter and the perceived benefits of the in-person party are high (Fig. 3). Reward sensitivity likely favors going to the party ("I want to have fun"), however, adolescents who think that the gist of the party is categorically risky and that the hangout is categorically safe, and then apply the values that "No risk is better than some risk" and/or "I have responsibility to not hurt other people" would decide to stay home and use social media instead of partying with friends and risking getting sick or spreading a deadly virus. Cognitive reinterpretation together with applying such categorical values may lead to successful inhibition.

More generally, a healthy gist of COVID-19 decisions for young people is that, although the risks of hospitalization or death are small, they are real (non-negligible; Reyna, 2020b). Moreover, if young people engage repeatedly in risky behavior, when hundreds are testing positive, the odds will eventually "catch up to them" (i.e., the cumulative probability is categorical; Reyna, 2008). These concepts of categorical gist were effectively taught to adolescents in a large, randomized trial of health risk taking, while also providing specific probabilities and outcomes (Reyna & Mills, 2014). Scales have been developed that measure this kind of categorical gist thinking, including the gist of cumulative risk (i.e., that it becomes categorically certain with repeated risk-taking), and how it changes with specific instruction (Blalock & Reyna, 2016; Garavito et al., 2020). Thus, the kinds of gist-based predictions we have made for COVID-19 have been tested in such domains as HIV-AIDS transmission, concussion risks in sports, and other domains of risky decision-making (e.g., Brust-Renck et al., 2017; Mills, Reyna, & Estrada, 2008; Mirman & Curry, 2016; Reyna & Adam, 2003; White, Gummerum, & Hanoch, 2015). Table 2 provides a summary of examples of such studies. In short, according to FTT, to help people "get the gist" of decisions (e.g., what would deciding one way or another mean for them categorically; Reyna, 2020a), interventions should highlight the bottom-line meaning of the information they seek to convey by focusing on key, important main points and removing trivial literal details (distinctions without meaningful differences; Blalock & Reyna, 2016). Examples of questions one might ask in order to assess gist as can be found in Table 1 of Reyna (2018) and examples of categorical gist that relate to COVID-19 can be found in Fig. 3.

Informed by DS, Steinberg criticized college plans regarding in-person instruction for the Fall 2020 semester during the COVID-19 pandemic, calling them "so unrealistically optimistic that they border on delusional" (Steinberg, 2020). This skepticism is not necessarily misplaced — indeed there were many examples of COVID-19 outbreaks coinciding with the start of in-person college attendance (Watson, Hubler, Ivory, & Gebeloff, 2020). However, some university communities came together to make a hybrid

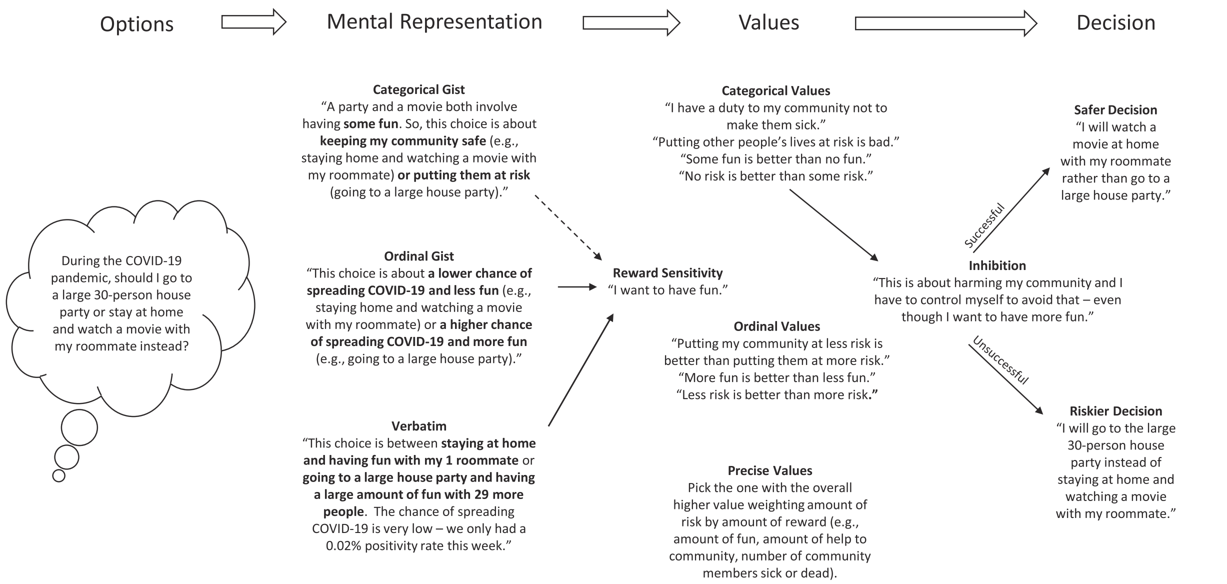

Fig. 3. Example of how FTT applies to risky decision making regarding COVID-19. Model of FTT that illustrates relationships among mental representations, values, reward, and inhibition, and how these components might relate to a contemporary example of risky decision making, COVID-19. Lines (indicating cuing) from categorical gist to categorical values, ordinal gist to ordinal values, and verbatim representation to precise values (and lines from each of these outputs to decisions), were omitted for simplicity but FTT assumes all three representations, their compatible values, and resulting preferences are processed for each decision. Inhibition highlighted here involves gist interpretation of the options that then elicits core social values – a cognitive route to inhibition beyond simply downregulating reward seeking. Other forms of inhibition include "white knuckling" or effortful self-control (e.g., Zayas, Mischel, & Pandey, 2014) and pre-commitment (e.g., Duckworth, Milkman, & Laibson, 2018). The dashed line from categorical gist to reward suggests that categorical gist representations might dampen the motivational pull of reward by backgrounding the kind of thinking that emphasizes trading off of magnitudes of risk and reward (e.g., verbatim tradeoffs).

instruction model work. As of October 27, 2020, operating with partial in-person instruction since Fall 2020, Cornell University reported a 0.02% positivity rate by week out of thousands of daily tests as part of a comprehensive surveillance program informed by multiple developmental perspectives, including FTT (Cornell University, 2020).[12] Several mitigating situational factors likely contributed to this success (e.g., secluded campus location, strong state-level precautionary measures, and low base rates of infection in surrounding areas). Nevertheless, whether the spread of COVID-19 is exacerbated or quelled ultimately comes down to what individuals decide to do (Reyna, 2020b).

According to DS/NI models, when college students are faced with decisions that offer the potential for highly valued rewards (especially social rewards), they may find themselves unable to control their behavior and end up engaging in risky activities, such as attending large gatherings without wearing masks (Steinberg, 2020; but see Telzer, Fuligni, Lieberman, & Galván, 2013). Ultimately, this view suggests that adolescents are universally predisposed to take risks, and absent sufficient cognitive control or social/cultural constraints, they will do so. While it is true that enhanced behavioral control measures adopted by the University (e.g., regulatory and legal constraints) likely played a role, perhaps it should not be surprising that young adults on college campuses (or older adults in general) could avoid some of the serious risks that might lead to high levels of community transmission if they understand and rely on gist representations such as "it only takes once to get COVID-19" and the health consequences are seen as real—potentially lethal and long-lasting, despite their small probabilities.[13] In addition, as we have discussed, decisions faced by young adults about risky decisions involving COVID-19 also likely draw on strong, shared social values among the student population about the importance of protecting all members of the community and of their personal responsibility to keep each other safe from infection. In a sense, these values can be thought of as part of the University's culture.

Conclusions

In summary, of the major models of adolescent risk-taking, FTT uniquely predicts and explains the observed decline in preference for risk from childhood through adulthood in laboratory tasks, which are important because they measure how risk preference changes developmentally without confounds that undercut conclusions. According to FTT, developmental differences in mental representations, shaped by culture, account for this trend, and also help clarify the role of reward sensitivity and inhibition in risky decision making. Further, culture plays an important role in shaping values that are better retrieved and implemented in decision-making through reliance on gist representations. To advance our understanding of developmental differences in risky decision making, greater emphasis should be placed on using unconfounded tasks that provide critical tests of existing theories.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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[12] As of March 22, 2021 the positivity rate by week was 0.16%.

[13] We do not mean to suggest that all adults will naturally avoid risk. Instead, our point is that it is not surprising that adults could get things right with respect to COVID if they rely on gist and core values.

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