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COMMENTARY

Models of Risky Choice Across Ages, Frames, and Individuals: The Fuzzy Frontier

Valerie F. Reyna

Department of Psychology, Human Neuroscience Institute, Cornell University

Huizenga and colleagues have made a major contribution to decision sciences by comparing formal models based on prospect, fuzzy-trace, and dual-process theories and a hybrid model. Building on surprising results predicted by fuzzy-trace theory (e.g., truncation and developmental reversal effects, framing biases emerge with development) and striking out in new directions that highlight probability among other issues, their approach inspires questions on the frontier of knowledge. Here I discuss some of those questions and clarify theoretical predictions.

Keywords: fuzzy-trace theory, prospect theory, framing effect, developmental reversal, truncation effect

Huizenga et al. (2023) provide a panoramic view of key issues: why people make risky decisions, why gains and losses differ, and how individual and developmental differences modulate these decisions. Moreover, they compare major theories of decision-making, cleverly formalizing them, and provide a bonus experiment that disentangles some confounds between probabilities and outcomes in prior work. The upshot of their impressive undertaking is that, considering decision makers from childhood through adulthood, combining the central construct of fuzzy-trace theory (FTT), namely, mental representations of the gist of decisions, along with probability of gains, explains most individual's preferences. Furthermore, they confirm that framing effects emerge with development as originally predicted by FTT (and observed), contrary to predictions of other developmental theories.

To illustrate, consider Figure 7 in Huizenga et al. (2023).[1] The lines for gains and losses overlap for the youngest age groups and gradually separate as age increases with losses eventually eliciting more risky choices than gains for adults (the framing effect).[2] Hence, as FTT predicts for gist-based biases, adults are more biased than children in that they distinguish gaining from losing even when these ultimately amount to the same net outcome. Younger age groups distinguished quantities on the x-axis (whether due to variation in risky-gain probabilities or to other quantities; Table 1).

Valerie F. Reyna https://orcid.org/0000-0003-2851-5797

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Valerie F. Reyna played lead role in conceptualization, writing of original draft and writing of review and editing.

Correspondence concerning this article should be addressed to Valerie F. Reyna, Department of Psychology, Human Neuroscience Institute, Cornell University, MVR G331, Ithaca, NY 14853, United States. Email: vr53@cornell.edu

[1] For details about which differences are significant, see Huizenga et al. (2023). Here, I describe effects in broad strokes due to limitations of space but for details about theoretical explanations, see Reyna et al., 2011; Reyna, Brainerd, et al., 2021. This is not an exhaustive list. I also refer to evidence that is cited in reviews of the literature, not just the literature review itself.

[2] In Huizenga et al. (2023), “gains” and “losses” refer to gain and loss frames (as gain frames also involved losses and vice versa); see Table 1. Note that some of the theories do not just apply narrowly to “framing effects” (differences between choices for options framed as gains and as losses) but also to decision-making for gains (e.g., rewards) and decision-making for losses. Therefore, I use the terms “gain” and “loss” in the text but provide detailed examples in Table 1 of how gain and loss framing are implemented in different studies.

Table 1
Examples of Keep-Lose and Some-None Framing Problems Across Probabilities

Problem information	Constant sure option keep-lose problems: Gain frame	Constant sure option keep-lose problems: Loss frame	Variable sure option keep-lose problems: Gain frame	Variable sure option keep-lose problems: Loss frame	Constant sure option some-none problems: Gain frame	Constant sure option some-none problems: Loss frame
Starting amount	30	30	50	50	n/a	120
Sure	6	−24	10	−40	30	−90
Unedited gamble	.2(30) + .8(−30)	.2(30) + .8(−30)	.2(50) + .8(−50)	.2(50) + .8(−50)	.25(120) + .75(0)	.75(−120) +.25(0)
EV of unedited gamble	6 − 24 = −18	6 − 24 = −18	10 − 40 = −30	10 − 40 = −30	30 + 0 = 30	−90 + 0 = −90
Net EV of unedited gamble	12	12	20	20	30	30
Edited gamble	.2(30) + .8(0)	.2(0) + .8(−30)	.2(50) + .8(0)	.2(0) + .8(−50)	Same as above; editing not needed	Same as above; editing not needed
Starting amount	15	15	50	50	n/a	90
Sure	6	−9	20	−30	30	−60
Unedited gamble	.4(15) + .6(−15)	.4(15) + .6(−15)	.4(50) + .6(−50)	.4(50) + .6(−50)	.33(90) + .67(0)	.67(−90) + .33 (0)
EV of unedited gamble	6 − 9 = −3	6 − 9 = −3	20 − 30 = −10	20 − 30 = −10	30 + 0 = 30	−60 + 0 = −60
Net EV of unedited gamble	12	12	40	40	30	30
Edited gamble	.4(15) + .6(0)	.4(0) + .6(−15)	.4(50) + .6(0)	.4(0) + .6(−50)	Same as above; editing not needed	Same as above; editing not needed
Starting amount	10	10	50	50	n/a	60
Sure	6	−4	30	−20	30	−30
Unedited gamble	.6(10) + .4(−10)	.6(10) + .4(−10)	.6(50) + .4(−50)	.6(50) + .4(−50)	.5(60) + .5(0)	.5(−60) + .5(0)
EV of unedited gamble	6 − 4 = 2	6 − 4 = 2	30 − 20 = 10	30 − 20 = 10	30 + 0 = 30	−30 + 0 = −30
Net EV of unedited gamble	12	12	60	60	30	30
Edited gamble	.6(10) + .4(0)	.6(0) + .4(−10)	.4(50) + .4(0)	.6(0) + .4(−50)	Same as above; editing not needed	Same as above; editing not needed

Note. EV = expected value (sum of the products of Probability × Outcome); PT = prospect theory. Edited gamble refers to substituting the zero part of the gamble for frame-inconsistent information in keep-lose problems, as assumed in De Martino et al. (2006, 2008) and Huizenga et al. (2023). De Martino et al.'s (2006, 2008) version of keep-lose problems appears to confound probability and outcome; probability is described as "percentage of total amount offered in the sure option" (2008, supplemental, p. 7): As shown above, as the gain probability in the gamble increases, so does the magnitude of the sure outcome. Huizenga et al., 2023, mitigate this confound by using constant sure outcomes. Huizenga et al. (2023) define "editing" as removing both starting amount and frame-inconsistent information. However, PT does not require editing out the zero part of a gamble because that multiplies out to be zero, not affecting choices. Constant sure option keep-lose problems are from Huizenga et al. (2023); variable sure option keep-lose problems are from De Martino et al. (2006, 2008); constant sure option some-none problems are from Reyna and Ellis, 1994 (see also Kühberger & Tanner, 2010; Reyna et al., 2011; Tversky & Kahneman, 1981). Exact probabilities, exact outcomes, and expected values are considered "verbatim" features because they capture literal content and automatic rote computations of that content (e.g., expected value is typically computed automatically in expected value problems early in childhood when physical quantities are displayed; see findings and literature reviewed in Reyna & Ellis, 1994; Reyna & Farley, 2006; Schlottmann, 2001).

That is, children's slopes in Figure 7 are relatively steep; their choices reflected quantitative differences but not qualitative gist (Edelson & Reyna, 2021; Reyna & Ellis, 1994; Reyna et al., 2011).

FTT assumes that children and adults use quantitative strategies in these problems but the simplest level of representation—categorical gist—dominates increasingly and produces framing differences as Huizenga et al. (2023) observed. One reason we know that quantitative processing occurs is that we can unmask it by removing categorical gist processing. (There is other evidence, too, including memory tests for quantitative information and decisions in unequal expected-value problems.) Deleting the zero part of the gamble (a truncation effect) eliminates framing effects because it eliminates the some-none categorical gist contrast—decision makers revert to their more precise quantitative representations (Reyna et al., in press).

A major contribution of Huizenga et al. (2023) is theory comparison. However, they apply the word "describe" to all theories regardless of whether they predict any directional effect, "predict" post hoc (observed effects are assumed), or explain why effects are observed (and, using those mechanisms, predict them). Each of these has different evidentiary weight in deciding whether a theory is true.

Specifically, Huizenga et al.'s (2023) Hybrid Model (HM) does not predict framing effects but, rather, HM incorporates FTT's prediction. Also, truncation effects that ruled in FTT and ruled out prospect theory (PT) are adopted (Reyna & Brainerd, 1991).[3] Huizenga et al. (2023) go beyond through formal modeling (see also Broniatowski & Reyna, 2018; Reyna & Brainerd, 2011; Swait & de Bekker-Grob, 2022) and by adding assumptions about probability of gains but HM does not predict the probability effect; it is mainly justified empirically.

Similarly, Huizenga et al. (2023) apply PT to developmental differences. However, as they acknowledge, PT does not predict anything about development. One can take PT's parameters and use them to describe developmental effects, as Huizenga et al. do. But PT's mechanisms do not explain whether or why developmental differences will be observed. In fact, plugging in PT's psychophysical explanations of framing (outcomes and/or probabilities are perceived nonlinearly just as light or sound are) produces the "explanation" that adults are less accurate perceivers of quantity than children, the opposite of developmental theories of number (Siegler & Braithwaite, 2017).

Space does not permit in-depth discussion of dual-process theories, but specific mechanisms differ from FTT (Reyna, Broniatowski, & Edelson, 2021). Huizenga et al.'s (2023) characterization of dual-processes theories may have useful intersections with attribute-framing models (e.g., Gamliel & Kreiner, 2020). Effects of attribute framing are related to, though distinct from, risky-choice framing (Reyna, Brainerd, et al., 2021; cf. Levin et al., 2002).

Huizenga et al. (2023) argue plausibly that keep-lose tasks draw on categorical gist. Categorical gist is the simplest gist of quantities, and thus the level that most adults lean on, according to the fuzzy-processing preference, an FTT principle tested extensively. Therefore, preferences in some-none framing tasks are explained in terms of mental representations involving choosing between gaining some versus either gaining some or none (some gain is preferred to no gain) and between losing some versus either losing some or losing none (losing none is preferred to losing some), producing framing effects. More precise levels of representation are also processed and contribute to preferences, subject to developmental/individual differences (Reyna & Brainerd, 2011; Reyna & Brust-Renck, 2020).

If keep and lose are represented categorically, FTT predicts framing effects because keeping some is better than either keeping some or losing some and losing some is worse than either keeping some or losing some. FTT's prediction also holds if the categorical gist reflects editing the valence-inconsistent part of the gamble (converting lose all to keep none when the sure option is keep and keep all to lose none when the sure option is lose; Reyna & Brainerd, 1991) because the options boil down to some-none gist contrasts as previously studied. Huizenga et al. (2023) and De Martino et al. (2006, 2008, p. 10748) make this editing assumption. However, De Martino et al.'s (2006, supplemental) probability effect went in the opposite direction of Huizenga et al.'s: Risky choice decreased as

[3] Not all of PT is disconfirmed; the reference-point explanation of gain-loss framing is retained and is crucial for all of our work. However, the psychophysical functions that produce the framing effect in PT—whether of outcomes or of probabilities—are disconfirmed by the truncation effect that deletes the zero part of the gamble (Kühberger & Tanner, 2010; Reyna, Brainerd, et al., 2021).

probability increased, likely due to confounds with outcome (Table 1; Kühberger et al., 1999).

Unconfounded from outcome, an effect of probability of gains has been observed in some-none tasks: Risky choices increased as gain probability increased for adolescents and adults (Figure 2 in Reyna & Ellis, 1994; Figure 1 in Reyna et al., 2011). Although Huizenga et al. (2023) define their probability effect as increasing framing effects with increasing risky gain probabilities, the empirical and theoretical question is, what was the effect of varying risky gain probabilities across studies and did it interact with frame? The answer is that opposite effects of varying probability have been observed and probability sometimes interacted with frame and sometimes did not interact. Willingness to tolerate risk (improbability) for rewards is an individual/developmental difference in FTT (Broniatowski & Reyna, 2018; Chang, Yen, & Duh, 2002; Reyna et al., 2011). Huizenga et al.'s (2023) results on probability should inspire new theoretical developments (see also DeKay et al., 2022) and greater attention to semantic and pragmatic factors (Mandel, 2023).

In sum, formal models are very valuable but models are mechanisms not just outputs. Huizenga et al. (2023) persuasively argue (and present evidence) for surprising developmental and individual-differences mechanisms and for critically re-examining theories of decision-making.

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