Risk Matters Less When Options Are Apples-to-Oranges:

The Translate-and-Accommodate Model

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We pre-registered all studies and report all measures, conditions, and exclusions. Preregistrations, experimental materials, data, and analysis code are available at Weingarten, Rottenstreich, & Wu (2026).

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Abstract

Risk aversion for moderate-likelihood gains is perhaps the best-known stylized fact from decision research. Though studies documenting it have focused on decisions involving money, such behavior is presumed to prevail very generally, across diverse domains. We investigate the validity of this generalization by contrasting two types of decisions. In unimodal choices, outcomes are “apples-to-apples.” Consider choosing between sure and uncertain monetary payoffs, or between sure receipt of a product and a chance at several units of it. In crossmodal choices, outcomes are “apples-to-oranges.” Consider choosing between sure receipt of one product and uncertain receipt of a disparate product. We observe two patterns by which risk matters less crossmodally, contrary to straightforward generalizations. First, relative to unimodal preferences involving actuarially fair risky options, corresponding crossmodal preferences exhibit less risk aversion. Second, crossmodal preferences vary less across risk levels: as the likelihood and subjective value of a risky option’s outcomes become increasingly unfavorable (favorable), people do not exhibit as much additional distaste (appetite) for it. These patterns of insensitivity engender an interaction: relative to unimodal settings, crossmodal settings yield less aversion to unfavorable and fair risk but more aversion to favorable risk. To explain this interaction, we present the translate-and-accommodate (TAA) model, in which unimodal preferences follow standard accounts, but crossmodal preferences reflect different processes of (i) deterministic translation and (ii) risk accommodation. The TAA model also explains the uncertainty effect and related patterns of seemingly bizarre, dominated choices.

Keywords: risk aversion, uncertainty, decision making, unimodal preferences, crossmodal preferences

Public Significance Statement: Most important decisions involve risk, with the consequences dependent on uncertainties such as the state of the economy or whether a used car will be reliable. Our studies indicate that risk has less impact on people’s choices when available options are “apples-to-oranges” (e.g., keep money in a savings account versus use it to purchase the used car) rather than “apples-to-apples” (e.g., keep money in that savings account or invest it in stocks whose value could go up or down depending on how the economy fares).

> … the study of decision making under risk has focused on … monetary outcomes and specified probabilities, in the hope that these simple problems will reveal basic attitudes toward risk and value.
>
> Kahneman & Tversky (1984)

Decisions under risk and uncertainty pervade myriad aspects of life. Yet, as the quote above suggests, much research has concentrated on a single, special type of decision, involving money and explicit probabilities (Mosteller & Nogee, 1951; Lopes, 1983; Goldstein & Weber, 1995; Hastie, 2001; Moscati, 2018). Experimental and theoretical tractability have encouraged a focus on such "simple problems," under the assumption that patterns observed with them obtain very broadly, across diverse types of decisions (Rettinger & Hastie, 2001; Keren & Wu, 2015; Shiffrin, 2022; Frey & Fischer, 2025).

Consider cornerstone findings of risk aversion. Generations of empirical work have examined binary choices between sure cash amounts and risky gambles that offer a moderate probability of a cash gain.[1] In these "simple problems," people tend to select sure things over gambles of equal or even somewhat greater expected value. They only select a gamble if it has meaningfully greater expected value. They are risk averse.[2] In turn, it is often assumed that across many real-world domains, people facing positive, moderate-likelihood options will similarly show distaste for fair risk and for less favorable risk and have appetite only for highly favorable risk (see Fox et al., 2015; Wu et al., 2004). As Kahneman and Tversky (1979) suggested, "(t)he prevalence of risk aversion is perhaps the best-known generalization" about decision making.

Is this generalization – robust risk aversion across diverse real-world domains – sensible? Do simple problems involving money and specified probabilities indeed reveal

[1] Some early empirical work used non-monetary outcomes. For example, Preston & Baratta (1948) examined gambles over points redeemable for candy, cigarettes, and cigars. Moscati (2018, footnote 9) provides examples of studies that had LP records, books, and cigarettes as outcomes.

[2] The opposite pattern, risk-seeking, is usually observed for small probability gains, as well as for moderate and large probability losses (Kahneman & Tversky, 1979; Tversky & Kahneman, 1992).

basic attitudes? Or, less affirmatively, how might cornerstone findings from these simple problems best be qualified when extended to other settings?

To address such questions, we expand on the standard experimental approach. The choices we examine still involve positive outcomes and specified probabilities. However, within these bounds, we contrast two types of decisions. We ask if there is a systematic divergence in risk preferences across what Cubitt, McDonald, and Read (2018) term unimodal and crossmodal settings (Arroyos-Calvera et al., 2024; Martin et al., 2016; Read et al., 2023; DeJarnette, 2022).

In unimodal settings, potential outcomes are "apples-to-apples." Monetary choices, such as a decision between $10 for sure and a 50-50 chance of $20 or nothing, are a canonical example. Here, potential outcomes vary in magnitude and likelihood but not otherwise. Or consider selecting between one guaranteed unit of an item and the possibility of either two or zero units of the same item; here, too, potential consequences vary in magnitude and likelihood but not otherwise. While the foregoing examples involve quantitative differences, unimodal choices can involve qualitative differences.[3] Consider selecting between a guaranteed unit of a store-brand product and uncertain receipt of a name-brand alternative.

In crossmodal settings, potential outcomes are "apples-to-oranges." Consider choosing between a sure $10 and a chance at two or zero units of some item, or between sure receipt of an item and uncertain receipt of a very different item.

Many real-world decisions may be perceived as unimodal, whereas many others may be perceived as crossmodal. Suppose a young parent has built up some savings and wishes to invest the money in a college fund. An ensuing choice among investment opportunities would arguably be seen as unimodal, with all potential outcomes monetary and varying only

[3] Quantitative information need not be presented numerically. It may be presented verbally or visually, as when small, medium, and large servings of ice cream are labeled as such or pictured on a menu. Chang et al. (2024) show that presenting information numerically leads people to place greater weight on it.

in likelihood and magnitude. The parent may, for instance, compare bond funds, and their lower but steadier expected returns, to equity funds, and their higher but more volatile expected returns. Or suppose that instead of investing the money, the same parent wishes to spend it on a family vacation. A choice among travel plans, for instance pitting a familiar, pleasant resort destination against an unfamiliar alternative that has limited reviews and thus could be either spectacular or spectacularly awful, may also be seen as unimodal. Finally, in contrast to funds-only and travel-only choices, suppose the parent mulls whether to invest in a college fund or take a family vacation. This choice may be viewed as crossmodal.[4]

We document two patterns by which risk matters less crossmodally. First, relative to unimodal preferences for actuarially fair risky options, corresponding crossmodal preferences exhibit less risk aversion. Second, crossmodal preferences vary less across risk levels. That is, as the likelihood or subjective value of a risky option's outcomes becomes increasingly unfavorable, people do not exhibit as much additional distaste for that option; and, as these parameters of a risky option become increasingly favorable, people do not exhibit as much appetite for it. Together, the two patterns of insensitivity engender an interaction: Given fair or unfavorable risk, crossmodal settings exhibit *less* risk aversion than unimodal settings. Yet, given favorable risk, crossmodal settings exhibit *more* risk aversion. This interaction may be contrasted with a uniform shift, from greater unimodal to lesser crossmodal risk aversion at all risk levels, a possibility which has been raised by previous research (e.g., Arroyos-Calvera et al., 2024; Martin et al., 2016; Read et al., 2023; DeJarnette, 2022).

In the college funds and family vacations context, risk mattering less crossmodally implies that funds-only and travel-only choices will be relatively sensitive to risk parameters, whereas the choice between investing for college and going on vacation will be less sensitive.

[4] As we discuss later, many choices are not inherently unimodal or crossmodal and, depending on circumstances and the individual decision maker, may be perceived either way. However, we assume some choices are apt to be perceived as unimodal and others as crossmodal. For convenience, in what follows we refer to these choices as unimodal and crossmodal, without reference to perceptions.

When selecting funds, a person may focus on bonds' steady, lower returns and equities' volatile, higher returns. When booking a trip, a person may focus on one destination being a known, satisfying quantity and the other being uncertain and possibly spectacular or spectacularly awful. In these and other apples-to-apples settings, choices may therefore boil down to a balancing of upside versus downside risk. However, in apples-to-oranges settings, it is possible to focus on other considerations. For instance, when pondering whether to place savings in a college fund or spend them on a family trip, a person may ask themselves something along the lines of whether it's best to prioritize financial responsibility or seize a rare opportunity for family bonding. Answers to this sort of question need not touch on risk (Johnson, 1988; 1989; Trope & Liberman, 2000; 2010). Our claim is not that risk is ignored in crossmodal decisions or that it completely governs unimodal ones. Rather, we propose a relative hypothesis, that risk matters less crossmodally.

A well-known scenario concerning intransitivity of indifference suggests a parallel intuition and may thus be instructive. This scenario was first articulated by Leonard Savage and subsequently discussed in various renditions by many authors, including Luce and Suppes (pp. 334-335, 1965), Restle (pp. 62-63, 1961), Tversky (pp. 283-284, 1969), and Read, McDonald, and Cubitt (p. 3, 2023). We present our own rendition of it: Suppose a person is indifferent between investing in a particular equities fund and spending the money on a family vacation to Barbados. If offered a Barbados vacation with an upgraded hotel room, the person will clearly prefer this option over the original Barbados vacation. Yet, the individual may well be indifferent between investing in the college fund and the upgraded Barbados option. What might explain this pattern? A person making the apples-to-apples, original-versus-upgraded Barbados choice will necessarily focus on the upgraded room. In contrast, a person making either of the two possible apples-to-oranges, Barbados-to-equities choices, may ask themselves something along the lines of is it better to prioritize financial responsibility or opportunities for family bonding. Thus, while we should not expect apple-to-oranges decisions to engender complete insensitivity to room upgrades, they may well engender relative insensitivity to them. The claim of lesser crossmodal sensitivity to risk parameters, such as likelihood and magnitude, is analogous.

We attribute lesser crossmodal sensitivity to mental processes of "translation" between options' outcomes. Comparing an investment to a vacation requires translating between disparate outcomes, financial returns and a trip. Comparing one investment to another, like bond and equities funds, does not require translation in the same way. Nor does comparing one trip to another. More broadly, it seems clear that making crossmodal decisions requires reconciling disparate outcomes in a way that making unimodal decisions does not. As we will detail and capture in a mathematical model, psychologically plausible assumptions about translation and its implications can account for crossmodal insensitivity.

Our theorizing about translation and unimodal-crossmodal differences draws on five streams of research: (i) work by Cubitt, McDonald, & Read (2018) and Read, McDonald, & Cubbitt (2023) which initially focused on intertemporal choice and later considered risky decision making; (ii) analyses of incommensurability and incomparability in both choice (Walasek & Brown, 2024; Sher, Müller-Trede, & McKenzie, 2025) and similarity (Shepard, 1964); (iii) studies of judgment given alignable versus non-alignable differences (Gourville & Soman, 2005; Markman & Medin, 1995; Medin et al., 1995; Slovic & MacPhillamy, 1975); (iv) classic results on anchoring and adjustment (Tversky & Kahneman, 1974; Chapman & Johnson, 1999; Mussweiler & Strack, 1999; Epley & Gilovich, 2006); and (v) findings of affect-driven probability distortion or neglect (Pachur et al., 2014; Pachur, Suter, & Hertwig, 2017; Rottenstreich & Hsee, 2001; Suter, Pachur, & Hertwig, 2016; see also McGraw et al., 2010).

We next discuss the first four streams and offer a translate-and-accommodate model (TAA) of decision under risk that leverages insights from each of them. By this model, unimodal preferences follow standard accounts, but crossmodal preferences are constructed differently, via processes of (i) deterministic inter-option translation and (ii) risk accommodation. After presenting the model, we set the stage for new studies by discussing the close relationship between risk mattering less crossmodally and the phenomenon of affect-driven probability distortion or neglect, which also concerns patterns of insensitivity. Our studies (six studies appear in the main text; two additional studies appear in the Supplemental Material (SM)) consistently reveal the interaction by which risk matters less crossmodally and corroborate the translate-and-accommodate model. They cannot be adequately explained by several alternative accounts, including two ubiquitous influences on decision making, preference intensity and noisy mental processes (Bhatia & Loomes, 2017; Costello & Watts, 2014; Enke & Graeber, 2023; Erev et al., 1994; Hutchinson et al., 2000; Loomes, 2015; Johnson & Busemeyer, 2005; Regenwetter & Davis-Stober, 2012).

After presenting our data, we show that translation processes can also explain the "uncertainty effect," by which a risky option is valued below its lowest possible outcome; that is, a risky option is valued below a sure thing it dominates (Gneezy, List, & Wu, 2006; Simonsohn, 2009; Moon & Nelson, 2020; Newman & Mochon, 2012; Wang, Fang, & Keller, 2013; Yang, Vosgerau, & Loewenstein, 2013). Standard theories of decision making cannot accommodate such behavior. Indeed, from the perspective of standard accounts, such behavior is outlandish: it seems to reflect indefensibly pronounced risk aversion. Our translate-and-accommodate model makes sense of the uncertainty effect. The model indicates that the effect may not stem from egregious risk aversion per se but is instead rooted in a mundane source: rough translation across disparate options. That is, translation which blurs or obscures the distinctions between crossmodal outcomes. Thus, in line with existing findings, our model implies that the uncertainty effect cannot arise with unimodal choices but can arise with crossmodal choices. The model further shows that rough translation can help account for other patterns of seemingly bizarre, dominated preferences, including the reverse uncertainty effect, by which a risky option is valued above its best possible outcome (Goldsmith & Amir, 2010; Shen, Fishbach, & Hsee, 2015). We conclude the paper by discussing potential directions for future research.

Four Antecedent Research Streams and the Translate-and-Accommodate (TAA) Model

Cubitt et al. (2018) introduced the unimodal-crossmodal distinction in the domain of intertemporal choice. Their unimodal settings pit immediate receipt of an item against a 60-day wait for the same item. Their crossmodal settings pit immediate receipt of an item against a 60-day wait for a different item. In line with standard results from the intertemporal choice literature, which has almost exclusively used unimodal stimuli, Cubitt et al.'s study yielded substantial unimodal impatience (Ainslie, 1975; Frederick et al., 2002). Yet, it also yielded little crossmodal impatience. To illustrate, the median participant required about $5 to accept delivery of a Lamy fountain pen in 60 days rather than immediately and about $4 to accept the same delay of a Godiva chocolate box. Unimodal impatience could thus be indexed at a total of $9. On the other hand, the median participant required less than $1 to receive the Lamy pen in 60 days rather than the Godiva box immediately and less than $1 to receive the Godiva later rather than the Lamy now. Crossmodal impatience could thus be indexed at only $2. In sum, Cubitt et al. observed that marked impatience, a landmark stylized fact from unimodal research, was substantially tempered crossmodally.

To explain this finding, Cubitt et al. suggested that the impact of any attribute, including delay, is "inversely related to the number of attributes that differ between options" (p. 882). That is, delay matters more unimodally, where the paucity of distinctions between options leads people to focus on it. In contrast, delay matters less crossmodally, where it is just one of a relative multitude of distinctions between options. By this argument, when a person mulls a Lamy pen now versus later, delivery time is the sole differentiator and therefore salient. However, when a person considers a Lamy pen now versus Godiva chocolates later, there are additional bases for preference, namely the differences between the items themselves, so that delivery time recedes in priority. In sum, Cubitt et al. proposed that crossmodal settings can dilute reactions to delay. Read et al. (2023) extended this dilution-based argument to risky choice, suggesting that crossmodal settings dilute reactions to risk parameters.

Our hypothesized translation processes expand on the argument put forth by Cubitt et al. and Read et al. These processes operate in part by diluting reactions to risk and in part via a quite different channel. As we detail below, the inclusion of both channels allows for the interaction we observe for risky choice – crossmodal preferences that are less averse to fair and unfavorable risk but more averse to favorable risk – rather than only a uniform shift toward lesser crossmodal risk aversion at all levels of risk. In their insightful work, Read et al. (2023) drew on dilution to suggest a uniform shift. Based on an analysis of potential reference points, Martin et al. (2016) also suggested a uniform shift, as did DeJarnette (2022).

To fully flesh out how translation can engender insensitivity to risk parameters, we present a formal model of unimodal and crossmodal preference. Here, we elaborate the model for settings in which unimodal outcomes only differ quantitatively, while crossmodal outcomes differ both quantitatively and qualitatively. In the SM, Part 1, we provide a comprehensive mathematical treatment of the model, including derivation of sufficient conditions for translation to engender the empirical patterns we document.[5]

[5] In the SM, we also elaborate the model for settings in which unimodal outcomes only differ quantitatively, while crossmodal outcomes only differ qualitatively.

To motivate the model, consider a crossmodal decision which pits a gamble offering either two or zero Godiva chocolates against a single sure Lamy pen. Also consider a unimodal, chocolate-only decision which pits the same Godiva gamble against a single sure Godiva chocolate. The crossmodal choice requires translating between chocolates and pens. For instance, one might mull whether the upside of two chocolates is an advantage over a single pen. Making the unimodal choice does not require translation in the same way. For instance, assuming more is better, it is obvious that two chocolates are better than one.

For simplicity, we restrict attention to choices between sure things and binary gambles and to non-negative outcomes. Let X and Y denote categorically distinct dimensions or products, such as Lamy pens and Godiva chocolates. Let (s_x, s_y) be the bundle offering sure quantities s_x of X and s_y of Y. Let $[x^*, x_*; y^*, y_*]$ denote the gamble offering quantities $x^* \geq x_*$ of X and $y^* \geq y_*$ of Y, with bundle (x^*, y^*) obtaining with probability p, and (x_*, y_*) obtaining with the complementary probability. In a unimodal choice, either $x^* = x_* = s_x = 0$ or $y^* = y_* = s_y = 0$. In a crossmodal choice, if $s_x > 0$, then $y^* > y_* > 0$, and if $s_y > 0$, then $x^* > x_* > 0$.[6]

We start with a classical formulation and then tweak it to incorporate translation and its implications. To begin, suppose

$$[x^*, x_*; y^*, y_*] \succ (s_x, s_y) \Leftrightarrow$$

$$f_x(x^*) + g_x(x_*) + f_y(y^*) + g_y(y_*) > f_x(s_x) + g_x(s_x) + f_y(s_y) + g_y(s_y). \quad (1)$$

[6] We exclude instances in which (x^*, y_*) is received in one state and (x_*, y^*) is received in the other. In such instances, each state produces the better outcome for one attribute and the worse outcome for the other, and hence accounts of multi-attribute risk aversion are needed (Richard, 1975; von Winterfeldt, 1980). Such accounts consider whether people prefer extreme or moderate outcomes across attributes.

This representation, which leaves outcome probabilities implicit, is very general. It includes expected utility (let $f_x(x^*) = pu_x(x^*)$ and $g_x(x_*) = (1-p)u_x(x_*)$, etc.) and cumulative prospect theory (let $f_x(x^*) = \pi(p)u_x(x^*)$ and $g_x(x_*) = (1-\pi(p))u_x(x_*)$, etc.).[7]

Without loss of generality, set $f_y(0) = g_y(0) = f_x(0) = g_x(0) = 0$. Then, for unimodal choices involving dimension X (and thus, $y^* = y_* = s_y = 0$),

$$[x^*, x_*; 0,0] \succ (s_x, 0) \Leftrightarrow f_x(x^*) + g_x(x_*) > f_x(s_x) + g_x(s_x). \tag{2}$$

Similarly, for crossmodal choices such that $x^* = x_* = s_y = 0$,

$$[0,0; y^*, y_*] \succ (s_x, 0) \Leftrightarrow f_y(y^*) + g_y(y_*) > f_x(s_x) + g_x(s_x). \tag{3}$$

We next rewrite Equations (2) and (3) in terms of the gamble's "advantages" and "disadvantages" compared to the sure thing (Shafir, Osherson, & Smith, 1993; Tversky, 1969; Tversky & Simonson, 1993):

$$[x^*, x_*; 0,0] \succ (s_x, 0) \Leftrightarrow [f_x(x^*) - f_x(s_x)] - [g_x(s_x) - g_x(x_*)] > 0. \tag{4}$$

This expression interprets choice of the gamble in terms of a balance of "upside risk," $f_x(x^*) - f_x(s_x)$, versus "downside risk," $g_x(s_x) - g_x(x_*)$. Similarly, for crossmodal choices:

$$[0,0; y^*, y_*] \succ (s_x, 0) \Leftrightarrow \left[f_y(y^*) - f_x(s_x)\right] - \left[g_x(s_x) - g_y(y_*)\right] > 0. \tag{5}$$

From a purely mathematical standpoint, Equations (2) and (3) are transparently equivalent to Equations (4) and (5). Nevertheless, each pair suggests a distinct decision strategy (Payne, Bettman, & Johnson, 1988; Svenson, 1979). Equations (4) and (5) stress between-option comparisons: That people consider available options' relative advantages and disadvantages – the ways in which each alternative is better or worse than others – and select the option with the best combination of these. Between-option strategies are instantiated by

[7] Original (Kahneman & Tversky, 1979) and cumulative prospect theory (Tversky & Kahneman, 1992) coincide for two-outcome gambles and thus are both special cases of (1). Birnbaum's TAX and RAM models (e.g., Birnbaum, 1997; Birnbaum & McIntosh, 1996) reduce to prospect theory for two-outcome gambles and thus are also special cases. However, some notable models are not special cases, e.g., weighted utility (Chew & MacCrimmon, 1983; Dekel, 1986).

many influential accounts, including regret theory (Bell, 1982; Loomes & Sugden, 1982; Mellers et al., 1997), salience theory (Bordalo et al., 2012), and sequential sampling frameworks (Bhatia, 2014; Busemeyer & Townsend, 1993). On the other hand, Equations (2) and (3) stress alternative-by-alternative processing: That each option is evaluated via a process that at some stage focuses exclusively on it and effectively ignores other available options. Then, after all options have been evaluated, the best-evaluated option is selected. Alternative-by-alternative strategies are implicitly assumed by many other influential accounts, including expected utility, prospect theory (Kahneman & Tversky, 1979) and transfer of attention exchange (TAX) (Birnbaum, 2008).

To the extent that alternative-by-alternative strategies imply equivalent evaluations of a given option no matter what other options are available – in particular, whether those options are apples-to-apples or apples-to-oranges – these strategies do not readily mesh with a unimodal/crossmodal divergence. In contrast, between-options strategies do. The comparisons of one option with another may vary, depending on whether they are apple-to-apples or apples-to-oranges.[8] For this reason, we work with Equation (4) as a representation of unimodal preferences and Equation (5) as a representation of crossmodal preferences; in what follows, we tweak the latter to show how translation and its implications can make risk matter less crossmodally.

As written, Equation (5) makes the weighing of upside versus downside risk explicit but leaves between-options translation implicit. We thus further rewrite the equation so that both processes are explicit. To do so, we rearrange terms as follows:

[8] We later discuss this point with greater precision, by contrasting our data with predictions based on axioms of substitution and independence. These axioms may be thought of as sufficient conditions for alternative-by-alternative processing (Raiffa, 1968; Samuelson, 1952; Savage, 1954; Tversky & Russo, 1969). Relatedly, alternative-by-alternative approaches are consistent with the Independence of Irrelative Alternatives Axiom (IIA) (Luce & Raiffa, 1957), which requires that the evaluation of any alternative not vary as a function of other available alternatives. Our model does not adhere to IIA.

$$[0,0;y^*,y_*] \succ (s_x,0) \Leftrightarrow \left[\left(f_y(y^*)+g_y(y^*)\right)-\left(f_x(s_x)+g_x(s_x)\right)\right]$$

$$+\left[\left(f_y(y_*)+g_y(y_*)\right)-\left(f_x(s_x)+g_x(s_x)\right)\right]$$

$$-\left[\left(g_y(y^*)-g_x(s_x)\right)+\left(f_y(y_*)-f_x(s_x)\right)\right]>0. \quad (6)$$

In Equation (6), the first bracketed term to the right of the arrows compares sure receipt of y^* to sure receipt of s_x, while the second compares sure receipt of y_* to sure receipt of s_x. Together, these terms constitute a riskless translation. They compare y^* and y_* to s_x, as if all of them were available with certainty. When these two deterministic comparisons terms are in total positive, the gamble outcomes are on average better than the sure thing; when they are in total negative, the gamble outcomes are on average worse than the sure thing. However, y^* and y_* do not obtain with certainty, and it is necessary to accommodate for the likelihood of getting one rather than the other. The third bracketed term corrects for risk in this way, by revising the sure comparisons in line with the likelihood of receiving either the upside y^* or downside y_*, rather than s_x.

The psychological interpretations of crossmodal preference construction suggested by Equations (5) and (6) are vastly different. Suppose the dimensions X and Y refer to Lamy pens and Godiva chocolates, respectively. According to Equation (5), a person who chooses between a sure amount of Lamy pens and a Godiva gamble compares the upside quantity of chocolates to the pens, compares the downside quantity of chocolates to the pens, and determines which comparison beats the other. This is a replica of the unimodal process envisioned by Equation (4), except for two products rather than one.

In contrast, Equation (6) is consistent with the person comparing the quantity of pens to the quantities of chocolates – as if all of these were available risklessly – and in addition making allowance for the chocolate gamble's risk (Gneezy, List, & Wu, 2006). It is as if people ask something along the lines of "how do I feel about the chocolates versus pens?"

and modify their assessment to reflect the chocolate's risk. Or, in the college funds vs. vacation scenario, people might consider how they feel about, say, financial responsibility versus family bonding opportunities and modify their evaluation to accommodate the attendant risks. This approach to crossmodal preference construction, which we dub *translate-and-accommodate* or TAA, departs from the unimodal process envisioned by Equation (4). The translation is deterministic and separate from the weighing of risk.

There are three broad reasons why crossmodal preferences constructed via translation-and-accommodation may yield insensitivity to risk parameters, such as the quantities and probabilities of available outcomes. First, some things are lost in translation. Distinctions are often blurred or obscured. The logic of Savage's scenario concerning preference indifference, which we discussed in terms of Barbados vacations, room upgrades, and equities college funds, can be applied to illustrate rough translation. Someone who is indifferent between 1 pen and 1 chocolate, and who unsurprisingly prefers 2 pens to 1 pen, may nevertheless be indifferent between 2 pens and 1 chocolate. That is, distinctions which are keenly appreciated unimodally, such as between 2 versus 1 pens, may have less impact crossmodally. Insensitivity to risk will ensue from low resolution of crossmodal comparisons, because if someone does not have a sharp sense of how they feel about pens versus chocolates, then it will not matter much how many pens or chocolates an option may yield nor the likelihood with which it may do so.

The possibility of crude rather than nuanced translation is buttressed by findings from other areas of psychology. For example, Shepard (1964) studied similarity judgment. He presented participants with a circle that had a single marked radius. It was designated as the standard and paired with a sequence of circles designated as variants. At one end of the sequence was a variant that matched the standard in size but not radial angle. At the other end was a variant that matched it in radial angle but not size. The intervening variants all differed from the standard on both dimensions. The participants' task was to select the variant which seemed most similar to the standard. Many participants selected one of the end-variants, which matched the standard on a single dimension. That they did not select intervening variants that differed from the standard along both dimensions suggests difficulties with translating between dimensions or, put more succinctly, crude rather than nuanced judgment.

The assertion that translation can dull preferences is related to a thesis offered by Walasek & Brown (2024; see also Sher, Müller-Trede, & McKenzie, 2025). They argue that there is no common currency of subjective value, that many options are thus incomparable, and that in constructing crossmodal choices, people thus do not – indeed cannot – make tradeoffs. How, then, do people choose crossmodally? Walasek and Brown suggest that rather than computing tradeoffs – which can be fine-grained – people often invoke rank-based and lexicographic approaches – which are relatively crude, insensitive assessments. Our argument here is not as stark as Walasek and Brown's but parallel in spirit: because crossmodal preferences entail translation, and translation often blurs or obscures distinctions, crossmodal preferences will often show insensitivity to many parameters, including outcome quantities and outcome values (and room upgrades).

A second reason why translation-and-accommodation may engender insensitivity follows from the very need to translate not the content or output of translation. If translation is an additional mental operation that arises crossmodally but not unimodally, it may sap attention from risk accommodation; or it may render the relevant processing effortful and error-prone, thereby reducing confidence and diminishing impact (Payne, Bettman, & Johnson, 1988; 1993; Slovic, Griffin, & Tversky, 1990; Pachur, Hertwig, & Wolkewitz, 2014; Suter, Pachur, & Hertwig, 2016). This will also leave crossmodal preferences prone to insensitivity to risk parameters (and room upgrades).

A third reason that translation-and-accommodation may yield insensitivity to risk is closely related to the second. Translation may sometimes be primary: people may begin by translating and then accommodate risk by adjusting from this self-generated anchor. But adjustments from an initial anchor are often incomplete (Tversky & Kahneman, 1974; Chapman & Johnson, 1999; Jacowitz & Kahneman, 1995; Mussweiler & Strack, 1999; Epley & Gilovich, 2001, 2006; Lewis, Gaertig, & Simmons, 2019; Lee & Morewedge, 2022).

Patterns of insensitivity that likely reflect a combination of rough translation, inattention, distortion, and insufficient adjustment have been documented in studies of alignable versus non-alignable differences (Gourville & Soman, 2005; Markman & Medin, 1995; Medin, Goldstone, & Markman, 1995). Slovic and MacPhillamy (1974) had participants judge which of two students was likely to have a higher GPA. Participants showed decent sensitivity to scores on an aptitude test both students had taken (an alignable difference). They showed marked insensitivity to scores on aptitude tests taken by one student but not the other (non-alignable differences), presumably because comparing across tests entailed translating between them.

In light of the foregoing discussion, we generalize Equation (6) to capture rough translation as well as inattention, distortion, and insufficient adjustment. To get at the former, we posit that the translation terms (to reiterate, the first two bracketed terms to the right-hand of the arrows) do not receive full weight. Instead, they receive weight $0 \leq \tau \leq 1$, where τ is mnemonic for translation. Inserting τ into the model dulls distinctions between outcomes, so that translation captures the direction of someone's leanings but blunts their magnitude.

To get at inattention, distortion, and insufficient adjustment, we similarly posit that the risk accommodation term (the last bracketed term on the right-hand side) does not receive full weight. It instead receives weight $0 \leq \alpha \leq 1$, where α is mnemonic for accommodation.

The smaller is α, the less uncertainty is factored into preferences. This is Read, McDonald, and Cubitt's (2023) observation that crossmodal preferences may dilute reactions to risk.

We thus arrive at the following representation of crossmodal preferences:

$$[0,0; y^*, y_*] \succ (s_x, 0) \Leftrightarrow \tau\left[\left(f_y(y^*) + g_y(y^*)\right) - \left(f_x(s_x) + g_x(s_x)\right)\right]$$

$$+\tau\left[\left(f_y(y_*) + g_y(y_*)\right) - \left(f_x(s_x) + g_x(s_x)\right)\right]$$

$$-\alpha\left[\left(g_y(y^*) - g_x(s_x)\right) + \left(f_y(y_*) - f_x(s_x)\right)\right] > 0, \quad (7)$$

where τ indexes translation and α indexes accommodation.

All together we have a dual model, with unimodal preferences represented by Equation (4) and crossmodal translation-and-accommodation preferences by Equation (7). When $\tau = \alpha = 1$, (7) parallels (4). In the SM (see Part 1, Claims 1 and 2), we show that, given $2\tau - 1 < \alpha < 2\tau$, Equation (7) can yield lesser crossmodal sensitivity to available outcomes and their likelihoods, lesser crossmodal aversion to actuarially fair and unfavorable risk, and greater crossmodal aversion to actuarially favorable risk. Stated differently, if translation is at least somewhat rough and risk accommodation is diluted neither very little nor very much, then the model can account for the interaction by which risk matters less crossmodally.

An Example of TAA

It is useful to graphically illustrate a specific implementation of the translate-and-accommodate model. To do so, we simplify and set $f_x = f_y$ and $g_x = g_y$ and thus suppress the subscripts on f and g. We follow prospect theory, setting $f(z) = \pi(p)v(z)$ and $g(z) = (1 - \pi(p))v(z)$, where $\pi(p)$ is a probability weighting function reflecting subcertainty, $\pi(.5) < .5$, with $\pi(.5) = .40$ and $v(z) = z^{.7}$.

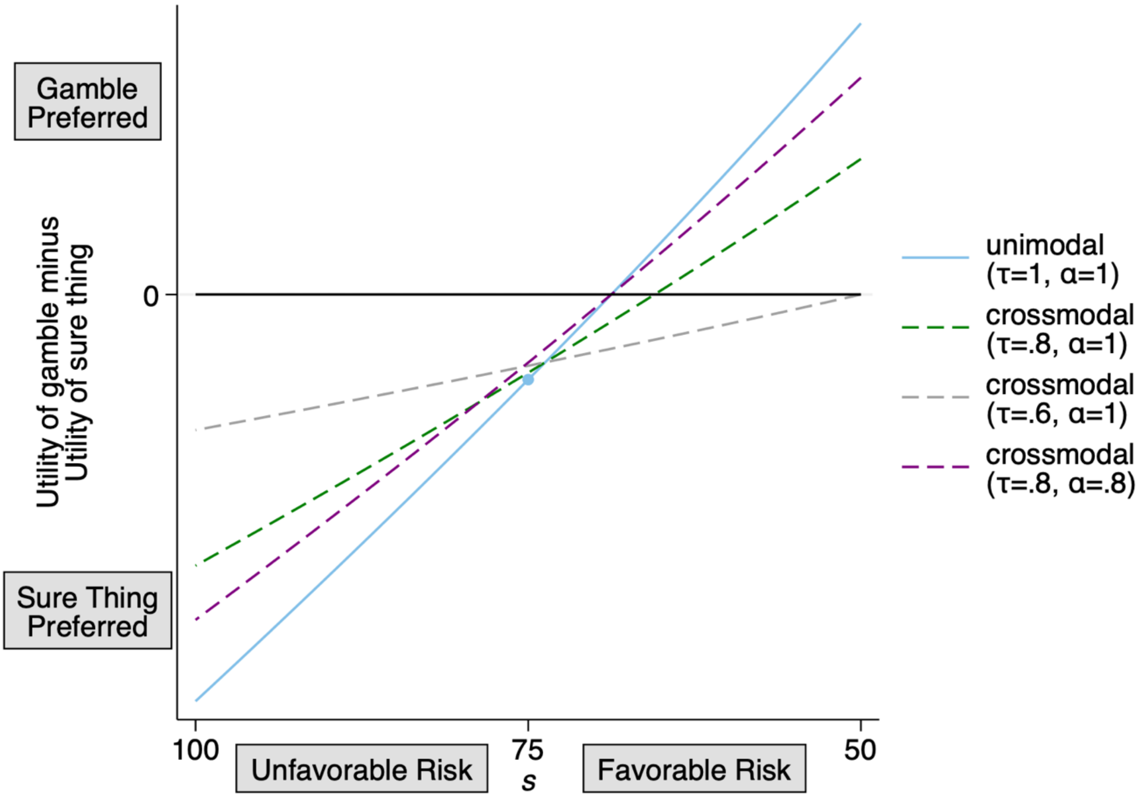

Figure 1. Unimodal (Equation (4)) and crossmodal (Equation (7)) preferences between an even chance gamble offering outcomes 50 and 100 and a sure alternative, $50 \leq s \leq 100$, for different roughness of translation (τ), and extent of risk accommodation (α).

Given this set-up, Figure 1 depicts preferences between an even chance gamble offering the outcomes 50 and 100 and a sure alternative, s. Along the horizontal axis, s varies in descending order, from 100 on the left to 50 on the right. Values of s between 100 and 75 render the gamble "unfavorable risk," while values between 75 and 50 render the gamble "favorable risk." The vertical axis captures the utility of the gamble minus the utility of the sure thing. Positive values of this relative utility measure reflect preference for the gamble, zero reflects indifference, and negative values reflect preference for the sure thing. The light blue line plots unimodal preferences, corresponding to Equation (4) and thus paralleling $\tau = \alpha = 1$. The green, grey, and purple dashed lines plot crossmodal preferences, corresponding to Equation (7), for different τ and α.

All four lines slope up, implying increasing preference for the gamble as its risk becomes more favorable (that is, as the sure alternative, s, becomes worse). The figure also reveals the two patterns of insensitivity by which risk matters less crossmodally. First, at the actuarially fair risk level $s = 75$, all four lines are in the negative domain, implying risk aversion; however, the crossmodal lines are all somewhat higher than the light blue line, implying less crossmodal aversion to fair risk. Second, the slopes of the crossmodal lines are shallower than that of the light blue line, indicating that crossmodal preferences are less sensitive to changes in the prevailing risk level. Indeed, all three crossmodal lines yield a crossover interaction by which there is less crossmodal risk aversion for unfavorable risk (large s) and more crossmodal risk aversion for favorable risk (small s).

The green and grey lines each set risk accommodation at $\alpha = 1$, but they differ in terms of translation. The green line reflects a relatively minor loss of acuity, $\tau = .8$, while the grey line reflects a more severe loss of acuity, $\tau = .6$. Accordingly, the grey line's slope is shallower: with rougher translation, risk matters even less crossmodally.

Meanwhile, the green and purple lines both set roughness of translation at $\tau = .8$. But whereas the green line reflects "full" risk accommodation, $\alpha = 1$, the purple dashed line reflects more modest risk accommodation, $\alpha = .7$. Reducing α yields preferences that are closer to indifferent between the crossmodal gamble and the actuarially fair sure thing, $s = 75$. Thus, α controls the level of risk aversion with comparatively more risk aversion for higher α and comparatively more risk seeking for lower α.

Taking Stock

To summarize, we have presented a translate-and-accommodate (TAA) model that expands on standard accounts of risky choice. It assumes a between-options decision strategy and distinguishes between unimodal and crossmodal preference construction. Consistent with standard approaches, it interprets unimodal preference construction in terms of a single process that may be characterized as upside versus downside risk comparison. In contrast, it characterizes crossmodal preference construction in terms of separate processes of deterministic between-options translation and risk accommodation. The essence of the model is that when people decide between sure apples and uncertain oranges (and are able to pursue a between-options decision strategy), they evaluate how they feel about apples versus oranges and in addition make some allowance for the attendant risk. In contrast, when they decide between sure and uncertain apples, they are apt to focus on the attendant risk.

Affect-Driven Insensitivity to Probability

The notion that risk matters less crossmodally is closely related to the phenomenon of affect-driven probability distortion or neglect, by which people show less sensitivity to variation in the likelihood of affect-rich than affect-poor outcomes. Work by Pachur, Hertwig, and Wolkowitz (2014) illustrates this phenomenon and the paradigms developed to study it (see also Pachur & Galesic, 2013; Suter, Pachur & Hertwig, 2016; Pachur, Suter, & Hertwig, 2017). These authors had participants consider gambles that offered a specified probability of receiving either a cash payoff or a luxury amenity as an add-on to a hotel stay (e.g., free cocktails or an upgrade to a room with a balcony). Participants also rated how happy they would be with a given cash amount or amenity. These affect ratings varied substantially within both the set of monetary payoffs and the set of hotel amenities. Yet, on the whole cash was affect-poor, while amenities were affect-rich. Choices between cash gambles were relatively sensitive to the probabilities of the payoffs, while choices between amenity gambles were relatively insensitive to the probabilities of the amenities. Moreover, within each kind of choice, greater affect-richness was associated with more pronounced insensitivity. Similar findings have been widely-replicated (Frank & Pachur, 2025; von Helversen, Coppin, & Scheibehenne, 2020; Petrova, Traczyk, & Garcia-Retamero, 2019;

Rosati & Hare, 2016; see also McGraw, Shafir, & Todorov, 2010; Rottenstreich & Hsee, 2001; Sunstein, 2003).[9]

Both affect-influenced responses to probability and risk mattering less crossmodally concern diversity in risk attitudes that depends on the nature of available outcomes. Our work thus owes a critical debt to research on affect-influenced responses to probability. It builds on this research in several ways.

To begin with, our work draws on the methods of that research. Note that choices between hotel amenities are crossmodal. For instance, cocktails and a balcony may be perceived as apples-to-oranges. Thus, while contrasts such as those of monetary and hotel amenity choices may be affect-poor versus affect-rich, they may also be unimodal versus crossmodal. Indeed, by our translate-and-accommodate model, hotel amenity gambles may yield insensitivity to probability because people, for example, ask themselves whether they prefer cocktails or a balcony and modify their answer to accommodate risk.

While research on affect-influenced responses to probability has not attempted to disentangle affect and modality, we implement designs that do so. The studies we present in the main text use common household products, such as bottles of detergent and plastic food containers, to formulate both unimodal and crossmodal "simple problems." Unimodal choice problems are of the form of s bottles of detergent for sure versus probability p of h bottles and $1-p$ of l bottles. Another example would be s food containers for sure versus p chance at h food containers and $1-p$ chance at l food containers. Crossmodal choice problems mix products: for instance, s bottles of detergent for sure versus h or l food containers, or s food containers for sure versus h or l bottles of detergent. By having participants encounter the

[9] Some details of the findings varied across investigations. For instance, Suter, Pachur, and Hertwig (2016) observed that in addition to yielding less sensitivity to variations in probability, affect-richness elevated the attractiveness of any positive outcome gamble. But interestingly, while insensitivity seems robust, not all studies yield greater elevation (e.g., Rottenstreich & Hsee, 2001).

very same outcomes unimodally and crossmodally, these studies can isolate an impact of choice modality that is independent of affect.

We term risk "fair" if $s = ph + (1-p)l$, in other words, if the unimodal gamble under consideration is actuarially fair relative to its sure alternative. Risk is "unfavorable" if $s > ph + (1-p)l$ and "favorable" if $s < ph + (1-p)l$. Across diverse values of the parameters s, p, h, and l, we consistently observe the interaction by which risk matters less crossmodally: crossmodal preferences are less averse to fair and unfavorable gambles but more averse to sufficiently favorable gambles.

Our work also builds on research concerning affect-driven probability distortion or neglect by examining a superset of its variables. That research has focused on differential responses to variation in p and $1-p$. It has not considered variation in s, h, and l. In contrast, the interaction we observe concerns the risk level prevailing for a choice – per the previous paragraph, how the riskiness of a gamble is related to the available sure alternative. This risk level depends on both the outcome likelihoods and outcome values of both the gamble and sure thing and is a function of all the parameters $p, 1-p, s, h,$ and l. In the SM (see Part 1, Claim 6), we show that the same restrictions on τ and α that we discussed earlier, $2\tau - 1 < \alpha < 2\tau$, generate less crossmodal sensitivity to p and $1-p$.

Most of our studies keep probabilities constant and manipulate outcome values to vary risk levels; a few manipulate probabilities to vary risk levels. To reiterate, the results are consistent across these manipulations. Thus, even if affect-driven probability distortion or neglect were attributable to crossmodality rather than (or in addition to) affect-richness, it alone cannot fully account for our results. Indeed, there are cases in which probability distortion or neglect and risk mattering less engender opposing predictions.[10]

[10] Suppose risk levels are held constant as likelihoods and outcome values are changed. Let gambles offering a small probability of a positive payoff be pit against sure things relative to which they constitute sufficiently favorable risk. That is, let p be small, $l = 0$, and $ph > s$ to a meaningful degree. Probability distortion or

Concomitantly, preference construction via translation-and-accommodation is distinct from any of the psychological processes that have been proposed to underlie affect-driven reactions to probability. It is not about differential sensitivity to any particular type of outcome (say affect-rich) versus any other (say affect-poor). It is about lesser sensitivity given two types of outcomes (i.e., crossmodally) rather than a single type (i.e., unimodally).

To sum up, affect-driven probability distortion or neglect and risk mattering less crossmodally are fundamentally connected. Both reveal sensitivity to risk parameters that depends on the nature of available outcomes. Nevertheless, the phenomenon of risk mattering less crossmodally is distinct in several ways. It concerns a larger set of relevant parameters. It highlights differential sensitivity when disparate outcomes are considered together not greater sensitivity to some outcomes than others. Accordingly, it points to a novel translation-and-accommodation form of preference construction.

Simple Problems Involving Common Household Products

We now present the series of studies that use common household products to formulate both unimodal and crossmodal "simple problems." We invoke the term "simple problems" in the spirit of the Kahneman and Tversky (1984) epigraph: our hope is that these very basic decisions can reveal key aspects of attitudes toward risk and value.

We pre-registered every study and report all measures, conditions, and exclusions. Pre-registrations, experimental materials, data, and analysis code are available at https://osf.io/3728x/?view_only=a79ba611d9a54c06a06d52380c5304e4. All studies were approved by Institutional Review Boards at UC San Diego (141690XX, "Assessment of

neglect imply that gambles will be more popular crossmodally than unimodally, because of insensitivity to the smallness of the likelihood of winning. However, risk mattering less crossmodally predicts that gambles will less popular crossmodally, because the favorable risk level will not matter as much crossmodally.

Uncertain Outcomes”), the University of Southern California (UP-24-00613, “Risky Sure Things”), and Arizona State University (#12708, “Risky Sure Things”).

We provide details of Study 1a. Subsequent studies in the series (Studies 1b – 1f) are variations on it that we present succinctly.

Method

Every study in the series concerned binary choices between a sure thing and a two-outcome gamble. Study 1a focused on even-chance gambles instantiated as coins flips. It implemented a 2 (Type of Decision: Unimodal versus Crossmodal) × 2 (Risk Level: Fair versus Favorable) × 3 (Product Pair) × 2 (Sure Product) entirely within-participant design.

In unimodal conditions, the sure thing and gamble involved the same product. For example, the study included the following pair of choices:

- 2 bottles of Tide detergent vs. a coin flip for either 3 or 1 bottles
- 2 Oxo food containers vs. a coin flip for either 3 or 1 containers

In crossmodal conditions, the coupling of sure things and gambles was switched, so that options pitted against one another involved different products. For example, the study also included the following pair of choices:

- 2 bottles of Tide vs. a coin flip for either 3 or 1 Oxo containers
- 2 Oxo containers vs. a coin flip for either 3 or 1 bottles of Tide

The Risk Level factor manipulated the number of units offered by each option. The choices listed above, pitting 2-unit sure things against prospects offering 1 or 3 units (“2 vs. 3/1”) are from the fair risk condition. The favorable risk condition pitted 1-unit sure things against gambles offering 3 or 0 units (“1 vs. 3/0”). The study thus also included the following unimodal choices,

- 1 bottle of Tide vs. a coin flip for either 3 or 0 bottles
- 1 Oxo container vs. a coin flip for either 3 or 0 containers

as well as these crossmodal choices,

- 1 bottle of Tide vs. a coin flip for either 3 or 0 Oxo containers
- 1 Oxo container vs. a coin flip for either 3 or 0 bottles of Tide

Table 1 lists all three Product Pairs in the study. The final factor, Sure Product, arises because at every Type of Decision × Risk Level combination (unimodal-fair, unimodal-favorable, crossmodal-fair, crossmodal-favorable), each product pair yielded two choices. For instance, the Tide-Oxo pair yielded a choice involving a Tide sure thing and a choice involving an Oxo sure thing.

	Product Pairs	Choices and their Risk Levels (Unfavorable, Fair, or Favorable)
Study 1a	Tide Detergent Oxo Containers Duracell AA Batteries HP Printer Paper Brawny Paper Towels SkinnyPop Popcorn	2 units for sure vs. 50-50 chance at 3/1 units (*Fair*) 1 unit for sure vs. 50-50 chance at 3/0 units (*Favorable Risk*)
Studies 1b – 1d	Tide Detergent Oxo Containers Duracell AA Batteries Brawny Paper Towels Solimo Disinfecting Wipes Colgate Toothpaste Travel-Sized Purell Scotch Tape	<u>Study 1b:</u> 2 units for sure vs. 50-50 chance at 4/0 units (*Fair*) 1 unit for sure vs. 50-50 chance at 4/0 units (*Favorable*) <u>Study 1c:</u> 3 units for sure vs. 50-50 chance at 4/0 units (*Unfavorable*) 1 unit for sure vs. 50-50 chance at 4/0 units (*Favorable*) <u>Study 1d:</u> 2 units for sure vs. 50-50 chance at 3/0 units (*Unfavorable*) 2 units for sure vs. 50-50 chance at 5/1 units (*Favorable*)
Studies 1e – 1f	Tide Detergent Oxo Containers Duracell AA Batteries Brawny Paper Towels Solimo Disinfecting Wipes Colgate Toothpaste	<u>Study 1e:</u> 1 unit for sure vs. 25-75 chance at 3/0 units (*Unfavorable*) 1 unit for sure vs. 75-25 chance at 3/0 units (*Favorable*) <u>Study 1f:</u> 1 unit for sure vs. 90-10 chance at 3/0 units (*Unfavorable*) 1 unit for sure vs. 10-90 chance at 3/0 units (*Favorable*)

Table 1. Stimuli in Studies 1a – 1f. Choices pitted a sure thing against a two-outcome gamble. In unimodal conditions, these options offered the specified units of the same product. In crossmodal conditions, they offered the specified units of different products.

It is useful to contrast the null hypothesis of no systematic unimodal-crossmodal divergence with the hypothesis that translation-and-accommodation causes risk to matter less crossmodally. The null hypothesis is rooted in classic axioms of independence and substitution (Raiffa, 1968; Samuelson, 1952; Savage, 1954; Tversky & Russo, 1969). For our purposes, such axioms formalize the requirement that the evaluation of any option should not be influenced by the alternative placed alongside it. Suppose for illustration's sake that a sure Tide option and a sure Oxo option are deemed equally attractive. Suppose further that, in unimodal choice, a person prefers a Tide gamble over the sure Tide option and an Oxo gamble over the sure Oxo option. Then, under the classic axioms, switching the gambles to generate Tide versus Oxo crossmodal decisions must not change preferences. That is, a person who prefers the gambles unimodally must prefer them crossmodally as well. As we detail below, it follows that the percentage of participants selecting the fair Tide gamble plus the percentage selecting the fair Oxo gamble should be statistically equivalent unimodally versus crossmodally. Likewise, the sum of the percentages selecting the favorable Tide and Oxo gambles should be equivalent unimodally versus crossmodally.

The hypothesis that risk matters less crossmodally runs contrary to the principles captured by independence and substitution. Under translation-and-accommodation, a gamble is evaluated differently depending on whether the sure alternative is similar or dissimilar. For example, in the Tide and Oxo example, unimodal preferences for the gambles over the sure things do *not* require that corresponding crossmodal choices also yield a preference for the gambles. Instead, we predict a particular Type of Decision × Risk Level interaction. Lesser crossmodal aversion to fair risk implies that fair gambles will be more popular crossmodally, and lesser crossmodal variation further suggests that sufficiently favorable gambles will be less popular crossmodally. Thus, we expect that the average percentage of participants selecting the fair Tide gamble and fair Oxo gamble will be greater crossmodally, while the average percentage selecting the favorable gambles will be smaller crossmodally.

Participants

We recruited 300 participants at a university lab in the U.S. (M_{age} = 20.7, 50% female). They completed the study remotely in exchange for course credit. After pre-registered exclusions, we arrived at a final sample of 259. Eight participants were excluded for technical reasons, as their browser or device was incompatible with our materials; 27 failed a pre-registered attention check; six violated dominance, as we explain below.

Materials and Procedure

The study (as well as all other studies) was implemented via Qualtrics. The opening instructions included two example choices: a unimodal choice involving Godiva chocolates and a crossmodal choice pitting the same chocolates against a Brita water pitcher. The chocolates and water pitcher were not part of the three product pairs listed in Table 1 and were not used in the core of the study. Full instructions as well as screenshots of unimodal and crossmodal choices are found in the SM, Part 2, Sec. 1.1.

Because each product pair spawned eight choices (2 Types of Decision × 2 Risk Levels × 2 Sure Products) and there were three pairs, the study included 24 "target" decisions. It also included 12 "distractor" decisions. Every participant completed all 36 decisions, in a randomized order, with the left-right placement of the sure thing randomly determined for each decision.

We included distractors to increase the variety of decisions presented, which we hoped would make it less likely that participants would routinize their responses. The distractors involved various quantities of sure thing and gamble outcomes, in combinations that always departed from those of the target decisions. Like the introductory examples, they concerned products that were not part of the three pairs listed in Table 1 (the distractor products are listed in the SM, Part 3).

The distractors also enabled checks for dominance violations. For instance, one distractor pitted a single sure ream of paper against a gamble offering either three reams or nothing. Another pitted two sure reams against the same gamble. Anyone who selected the gamble over two reams but not a single ream violated stochastic dominance or monotonicity (Fishburn, 1970). Six participants revealed such inconsistencies, and per our pre-registration, were excluded from our analyses.

After making all their decisions, participants responded to attention and comprehension checks and provided demographic information.

Results

Panel 1a of Figure 2 displays the results aggregated over the three product pairs. In accord with risk mattering less crossmodally, fair gambles were more popular crossmodally ($M_C = .426$ vs. $M_U = .331$) ($z = 4.86, p < .001$, repeated measures logit), but favorable gambles were less popular crossmodally ($M_C = .425$ vs. $M_U = .494$) ($z = 4.44, p < .001$, repeated measures logit).

We motivate our statistical tests by considering the axioms of independence and substitution within a probabilistic choice framework. For a given level of risk, fair or favorable, denote the two sure things and two gambles from any product pair by ST_1, ST_2, G_1 and G_2. The associated decisions yield four choice percentages, $\Pr(G_i \succ ST_j)$, which are unimodal if $i = j$ and crossmodal otherwise. A common assumption used to model probabilistic choice is *simple scalability* (Tversky & Russo, 1969), which here implies that $\Pr(G_i \succ ST_j) = f\left(U(G_i), U(ST_j)\right)$, for some f that is increasing in $U(G_i)$ and decreasing in $U(ST_j)$. Simple scalability can be thought of as a stochastic version of substitution, with choice percentages invariant to substitutions of equally attractive options.

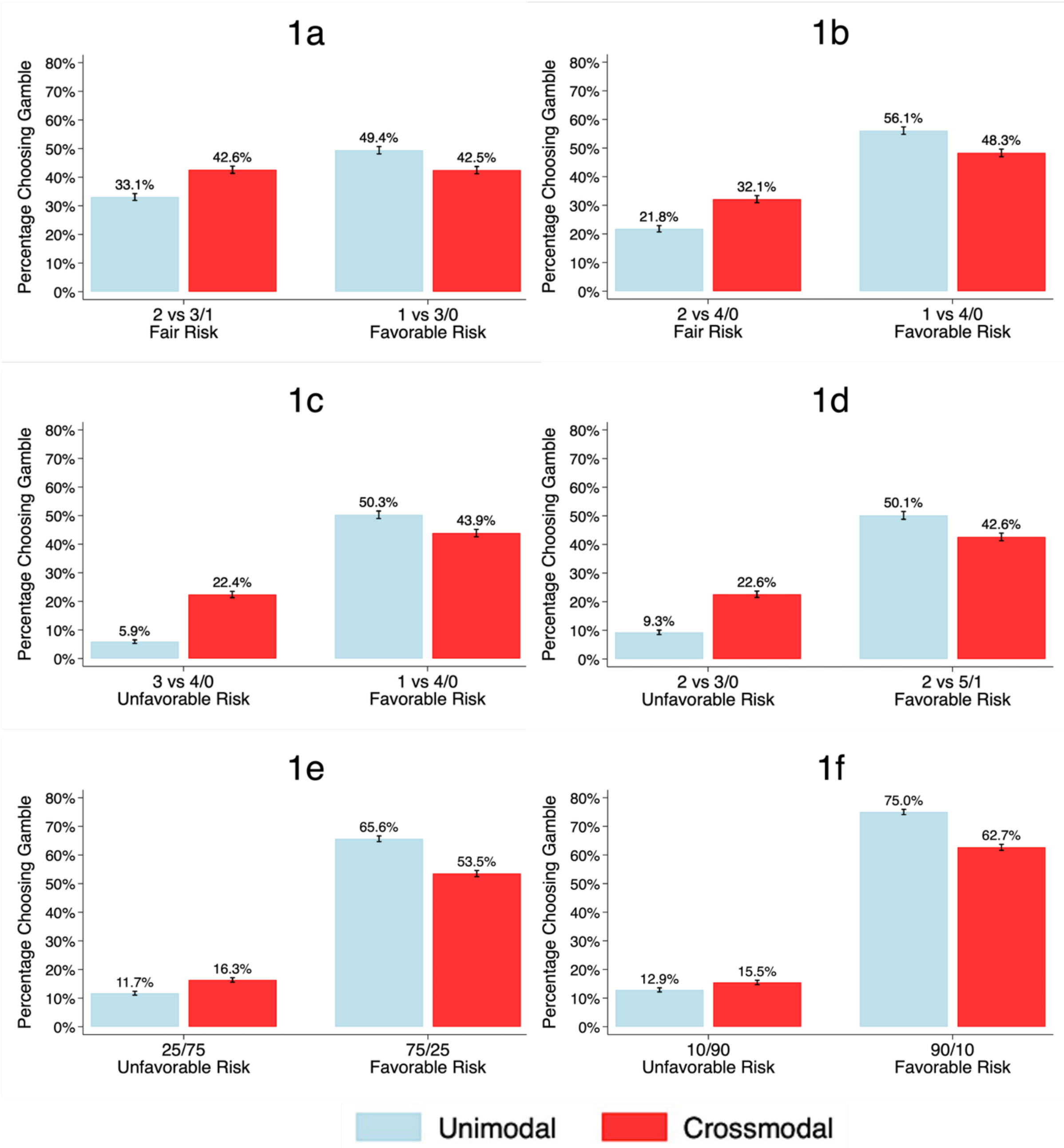

Figure 2. Results from Studies 1a – 1f, aggregated over product pairs. Bars show the percentage of participants choosing the gamble over the sure thing, as a function of decision type (unimodal or crossmodal) and risk level. Studies 1a through 1d involve 50-50 gambles. For instance, the fair risk condition of Study 1a involves sure things composed of 2 units of the relevant good and gambles offering an equal chance at 3 or 1 units. Studies 1e and 1f involves 25/75 and 10/90 probabilities, respectively; in those studies sure things offer 1 unit and gambles offer a chance at either 3 or 0 units. Error bars indicate +/- 1 standard error.

A standard form, sometimes termed the strong utility or Fechnerian utility model (Luce & Suppes, 1965), $\Pr\left(G_i \succ ST_j\right) = f\left(U(G_i) - U\left(ST_j\right)\right)$, is often instantiated in the logit functional, $\Pr(G_i \succ ST_j) = \frac{1}{1+\exp\left(U(G_i)-U(ST_j)\right)}$.[11] The logit form imposes considerable constraints on the choice percentages. Defining $\beta_{ij} = \ln\left(\frac{\Pr(G_i \succ ST_j)}{1-\Pr(G_i \succ ST_j)}\right)$, it requires $\beta_{11} + \beta_{22} = \beta_{12} + \beta_{21}$. That is, on a log odds scale, the sum of the proportion of participants selecting the product 1 gamble and the proportion selecting the product 2 gamble should be the same unimodally and crossmodally.

The statistical tests we next present employ logistic regressions. Related tests that rely on different parametric assumptions, probit regression or a linear probability model yield identical conclusions (see the SM, Part 4), as does a non-parametric, ordinal test we detail after Studies 1b – 1f. We also find similar results for mixed-effects models of the type Judd, Westfall, and Kenny (2012) advocate (see the SM, Part 4).

Let $C_{i,j,k,l}$ represent choice of the gamble (1) or sure thing (0). Here $i = \{1,2,3\}$ indexes product pairs; $j = \{1,2\}$ indicates whether product 1 or 2 of a pair is the sure thing; $k = \{U, C\}$ indicates the type of decision; and $l = \{fair, favorable\}$ indicates the level of risk. To assess our predictions, we conducted binary logistic regressions, separately for fair and favorable gambles, with a set of dummy variables, $DUM_{i,j,k,l}$, for all i, j, k, l, and with $\beta_{i,j,k,l}$ the corresponding regression coefficients. We specified the regressions with no intercept, clustering standard errors at the participant level to control for subject effects. To test whether fair gambles are more popular crossmodally, we conducted a post-regression Wald test on the null hypothesis that the sum of the coefficients for the unimodal conditions equals the sum of the coefficients for the crossmodal conditions, $\sum_{i=1}^{3}\sum_{j=1}^{2}\beta_{i,j,U,fair} = \sum_{i=1}^{3}\sum_{j=1}^{2}\beta_{i,j,C,fair}$. Similarly, to test that favorable gambles are less popular crossmodally, we implemented a Wald test on the regression coefficients:

[11] The original presentation of Savage's scenario from the introduction was used to illustrate potential problems with the "strong utility" model. See, for example, Restle (1961, pp. 62-63, 68).

$\sum_{i=1}^{3}\sum_{j=1}^{2}\beta_{i,j,U,favorable} = \sum_{i=1}^{3}\sum_{j=1}^{2}\beta_{i,j,C,favorable}$. These tests support the prediction that fair gambles are more popular crossmodally ($\chi^2(1) = 21.14, p < .001$), while favorable gambles are more popular unimodally ($\chi^2(1) = 21.49, p < .001$). The same pattern obtains for tests conducted at the product pair level (all $p < .05$). See the SM (Part 4), for more details.

Not surprisingly, the interaction in Figure 2 was highly significant. Our statistical test examined whether the difference between the sum of crossmodal coefficients and the sum of unimodal coefficients was distinct for fair gambles, $\sum_{i=1}^{3}\sum_{j=1}^{2}(\beta_{i,j,U,fair} - \beta_{i,j,C,fair})$, versus favorable gambles, $\sum_{i=1}^{3}\sum_{j=1}^{2}(\beta_{i,j,U,favorable} - \beta_{i,j,C,favorable})$. This test was significant at the aggregate level ($\chi^2(1) = 66.20, p < .001$) and for every product pair (all $p < .001$).

In sum, Study 1a corroborates the interaction by which risk matters less crossmodally, which we have attributed to translation-and-accommodation. Before discussing alternative explanations, we present Studies 1b – 1f, which conceptually replicate Study 1 with different risk parameters. Studies 1b – 1d continue to examine even chance gambles instantiated as coin flips, but with different outcome quantities. As a group, they consider unfavorable, fair, and favorable risk. Studies 1e and 1f examine gambles with uneven probabilities. Rather than varying risk level by manipulating outcome quantities, these studies manipulate outcome probability and look for crossmodal insensitivity to this manipulation, much as existing research has looked for affect-rich insensitivity to it.

Additional Simple Problems: Studies 1b – 1f

Each of these studies implemented an entirely within-participants design that paralleled Study 1a. The specific product pairs varied somewhat across studies (see Table 1), as did the number of example and distractor choices, and the nature of the participant pool (Table 2 shows that some studies were run at university labs and others online). To reiterate, Studies 1b – 1d followed Study 1a in using 50-50 gambles. However, Studies 1e – 1f employed different probabilities, 25/75 for Study 1e and 10/90 for Study 1f. For example, the unfavorable risk conditions in Study 1e pit gambles offering a 25% chance of the superior outcome (3 units of the relevant product) and a 75% chance of the inferior outcome (0 units) against the sure thing (1 unit); in favorable risk conditions, gambles offered the reverse probabilities. Full methodological details of each study are in the SM (see, Part 3).

The results were highly consistent across studies. Replicating Study 1a, and in line with risk mattering less because of translation-and-accommodation, every study yielded the predicted interaction. As Figure 2 and Table 2 show, fair and unfavorable prospects were significantly more popular crossmodally, whereas favorable prospects were significantly less popular (see the SM, Part 4 for analyses at the level of product pairs). Table 2 summarizes tests that employ the logit regressions outlined for Study 1a. As before, tests that rely on different parametric assumptions, probit regression, a linear probability model, or a mixed-effect regression model, generate identical conclusions (see the SM, Part 4).

	Participant Pool	Number of Participants (post-exclusions)	Hypothesis: fair and unfavorable gambles more popular crossmodally	Hypothesis: favorable gambles less popular crossmodally	Interaction
1a	University	259	21.14	21.49	66.20
1b	mTurk	179	18.43	18.51	43.03
1c	mTurk	178	89.71	14.08	106.50
1d	University	171	53.64	15.30	82.71
1e	Prolific	392	18.47	73.85	73.93

Table 2. Summary of Studies 1a – 1f. All test statistics are $\chi^2(1)$ and significant at $p < .001$.

Because Studies 1a – 1d all depart from work on affect-driven responses to probability by manipulating outcome quantities rather than probabilities, it is useful to consider a statistical analysis that concentrates on just these studies. Focusing on this quartet of data sets, the predicted interaction is supported by a conservative ordinal analysis at the level of product pairs that makes no parametric assumptions (as in, for example, logistic regression). Simple scalability is equivalent to a stochastic independence axiom, $\Pr(x \succ z) > \Pr(y \succ z)$ if and only if $\Pr(x \succ w) > \Pr(y \succ w)$ for all x, y, w, z (Tversky & Russo, 1969). Studies 1a – 1d include a total of 15 product pairs. Under the null hypothesis, only 6.25% of all pairs should violate this axiom by chance. However, in our data, 7 pairs show a violation by which fair and unfavorable prospects are more popular crossmodally while favorable prospects are less popular crossmodally.[12] This is significant by a binomial test ($z = 4.17, p < .0001$; for more details, see the SM (Table S4.1g).

Discussion

In "simple problems" concerning common household products, risk matters less when outcomes differ qualitatively. Preferences show an interaction: less aversion to fair and unfavorable crossmodal risk as well as less acceptance of crossmodal favorable risk. This interaction arises whether risk level is manipulated via outcome quantity (Studies 1a – 1d) or outcome likelihood (Studies 1e – 1f). To account for these patterns, we suggest that crossmodal preference construction may proceed via between-options translation and concomitant risk accommodation. Our TAA model captures how these psychological processes can diminish risk sensitivity.

[12] To explicate, for Study 1d, Pair 3, let ST_B be 2 units of Purell and ST_T be 2 units of Scotch Tape. Let UG_P (UG_S) be an unfavorable gamble that offers 0 or 3 units of Purell (Scotch Tape). Let FG_P and FG_S be corresponding favorable gambles that offer 5 or 1 units. Then we see a violation of stochastic independence (and hence simple scalability) for the unfavorable gambles, $\Pr(UG_P \succ ST_P) = .111 < \Pr(UG_P \succ ST_S) = .304$, but $\Pr(UG_S \succ ST_P) = .181 > \Pr(UG_S \succ ST_S) = .094$. We also see a violation of stochastic independence for the favorable gambles: $\Pr(FG_P \succ ST_P) = .550 > \Pr(FG_P \succ ST_S) = .450$ but $\Pr(FG_S \succ ST_P) = .374 < \Pr(FG_S \succ ST_S) = .439$. Under the null hypothesis, each of these violations occurs 25% by chance, so the overall ordinal pattern involving all four inequalities exhibited in Study 1d, Pair 4 has probability 6.25%.

That manipulations of outcome quantity and likelihood both engender relative crossmodal insensitivity corroborates the hypothesis that any risk parameter matters less crossmodally – and highlights connections between our work and research on affect-driven probability distortion and neglect. While the present studies isolate an influence of choice modality that is independent of affect, it would be interesting to know if affect-richness either adds to this influence or interacts with it. Perhaps risk matters much less when options both differ qualitatively and are affect-rich rather than affect-poor.

We next compare our results and translation-and-accommodation explanation to the data and argument put forward by Martin et al. (2016). Then, we discuss how two ubiquitous influences on decision making, preference intensity and noisy decision processes, may contribute to our results but cannot fully account for them.

Martin et al. also studied risky preferences and called for caution in generalizing from research involving monetary outcomes. Their experiments contrasted monetary choices with choices about different experiences, including vacations and movie watching. Because the experiences were disparate, in our parlance, Martin et al. contrasted unimodal monetary choices with crossmodal experience choices. However, Martin et al. did not distinguish between risk levels, as we have. Instead, in several experiments, they collapsed across all decisions concerning positive outcomes. They found that, overall, there were more choices of positive experience gambles than positive monetary gambles. Given this main effect, they highlighted the possibility of a uniform shift, lesser crossmodal than unimodal risk aversion.

To account for this uniform shift, Martin et al. offered an argument based on potential reference points. They proposed that many non-monetary outcomes, including experiences and consumer products, are often evaluated from superior reference points, such as the best option in the relevant category. Relative to inferior reference points, which lead outcomes to be coded as gains, superior reference points, which lead outcomes to be coded as losses, are known to push preferences away from risk aversion toward risk seeking (Kahneman & Tversky, 1984; Kahneman & Tversky, 1979).

By investigating different risk levels, we have observed a unimodal/crossmodal × risk level interaction rather than a uniform shift. Interestingly, however, each of our initial studies shows evidence of Martin et al.'s main effect. Study 1c is most relevant in this regard because it includes favorable and unfavorable risks that are symmetric: it pits 4/0 gambles against 1-unit and 3-unit sure things. Despite this symmetry, collapsing across the two levels of risk, gambles are selected in 33.1% of crossmodal choices and only 28.1% of unimodal choices ($z = 4.81, p < .001$, repeated measures logit). This instance of Martin et al.'s main effect alongside the interaction we document arises because in our studies, relative to unimodal preferences, crossmodal preferences attenuate avoidance of unfavorable risk more than they attenuate attraction to favorable risk (see Figure 2's summary of Study 1c).

Accordingly, we note that Martin et al.'s superior reference point argument cannot fully account for our results. Because superior reference points promote risk seeking, they fit with our observation of lesser crossmodal distaste for fair and unfavorable risk but not our observation of lesser crossmodal appetite for favorable risk.

Preference Intensity and Noisy Processes

Two ubiquitous influences on decision making, preference intensity and noisy processes, likely contribute to our results but also cannot fully explain them. Preference intensity refers to the degree to which a person values some item more than another item. For the product pairs in our studies, the cross-participant heterogeneity in this variable will include people who have much more interest in one product than the other (see, e.g., Hutchinson et al., 2000). These participants' markedly intense preferences will bias crossmodal choice proportions toward 50%. To see why, consider individuals who value

Tide detergent so much more than Oxo containers that they select any offered Tide option, be it a sure thing or gamble, over any offered Oxo option, be it a sure thing or gamble. These individuals will select the gamble in 50% of the crossmodal Tide versus Oxo choices we offer them. They will do so no matter what the risk level happens to be. Because the same logic applies to individuals who value Oxo containers much more than Tide detergent, it follows that markedly intense preferences will bias crossmodal choice proportions to 50%.

A bias toward 50% likely contributes to the lesser crossmodal aversion to fair and unfavorable gambles we observe. In every study we have presented, the percentage selecting such gambles is closer to 50% crossmodally than unimodally. However, a bias toward 50% does not readily match with the lesser crossmodal popularity of favorable gambles found in any of the studies manipulating outcome quantity. In Studies 1a and 1c, the percentage selecting these gambles is *further* from 50% crossmodally than unimodally. Meanwhile, both Studies 1b and 1d yield a straddling pattern – the crossmodal percentage is somewhat below 50% and the unimodal percentage somewhat above 50% – and are thus not strongly indicative of a bias toward 50%.

Though a bias toward 50% cannot fully account for our results, it may help explain why the extent to which crossmodal preferences are less averse to unfavorable risk is more pronounced than the extent to which they are more averse to favorable risk. In other words, given our methodology, this bias may play a role in generating the main effect highlighted by Martin et al., more overall choices of crossmodal than unimodal prospects.

Finally, to directly assess the impact of markedly intense preferences, we conducted versions of our analyses that dropped all participants who chose the same product from a pair across all crossmodal decisions. For example, for Study 1a and the product pair involving Tide and Oxo, we dropped all participants who chose the Tide option in each of the four crossmodal choices involving Tide and Oxo, as well as all participants who chose the Oxo option in each of these choices. The hypothesis that risk matters less crossmodally largely holds up in these restricted analyses: among the quartet of studies that manipulate outcome quantity, the predicted interaction remains significant in Studies 1a, 1c, and 1d though not 1b (see the SM, Part 4, Table S4.1h for details).

Noisy processes play an important role in decision making (Bhatia & Loomes, 2017; Loomes, 2015). For instance, it is possible that unimodal and crossmodal preferences diverge in part because the construction of crossmodal preferences is more complex and therefore more variable. Crossmodal preferences might be conceptualized as a convex combination of relevant unimodal processes and a random component. The random component could engender regressive patterns (see, e.g., Erev et al., 1994). As just discussed, regression toward 50% does not entirely fit with our results. However, well-known paradigms allow for regression to other values and can thereby reproduce our data. In drift diffusion models (Busemeyer & Johnson, 2004; Fudenberg et al., 2020), decision makers can have some initial inclination or predisposition to select each option (sure thing or gamble), and a final preference then emerges after a stochastic evolution from these starting values (Zhao et al., 2020; Desai & Krajbich, 2021). Predispositions tantamount to approximately a forty percent aggregate probability of selecting gambles are consistent with the behavior we observe. Though such predispositions may seem ad hoc, they of course cannot be ruled out by the paradigm used in Studies 1a – 1f.

In studies we present in the SM (Part 2), we implement designs that allow us to further assess the influence of crossmodal noise, preference intensity, and superior reference points. These studies also build on Studies 1a – 1f by examining an important setting: where crossmodal outcomes differ only qualitatively and not quantitatively. The results consistently show that risk matters less in a manner that gives rise to an interaction: crossmodal preferences exhibit less distaste for fair and unfavorable risk but also less appetite for favorable risk. They indicate that this behavior fits well with translation-and-accommodation, and whereas other psychological mechanisms likely contribute, none of them fits well with the entirety of the data.

Balancing Risk vs. Translation-and-Accommodation: Explaining the Uncertainty Effect

The TAA model offers a novel explanation of the "uncertainty effect," by which people sometimes value a gamble less than its worst possible outcome. Gneezy, List, and Wu (2006) provided the initial demonstration of this effect. They had college students indicate their willingness to pay (WTP) for a $50 gift certificate that could be used for a limited time at a campus bookstore, a similar $100 gift certificate, and a 50-50 chance at either gift certificate. WTPs for the gamble were lower than for the $50 gift certificate. Such behavior has since been widely reported (Simonsohn, 2009; Moon & Nelson, 2020; Newman & Mochon, 2012; Wang, Fang, & Keller, 2013; Yang, Vosgerau, & Loewenstein, 2013).

The uncertainty effect cannot be reconciled with expected utility, prospect theory, and most other standard accounts. Per Equation (4), these accounts at least implicitly view risky preference construction as a process of balancing risks. They thus impose an internality constraint: a gamble's subjective value must lie between those of its best and worst possible realizations. Indeed, from standard perspectives, the uncertainty effect seems bizarre. It appears to reflect implausibly pronounced risk aversion. Some authors have thus questioned whether studies reporting the effect reveal actual preferences or factors like participant error or confusion (Keren & Willemsen, 2009; Rydval, Ortmann, Prokosheva, & Hertwig, 2009).

Our model makes sense of the uncertainty effect. Rather than egregious risk aversion per se, it sees the effect as emanating from an arguably mundane source: low resolution translation, i.e., relatively low τ. Furthermore, it sees the effect as more likely, not less likely, as risk accommodation becomes more standard, i.e., with higher α.

Before laying out the TAA explanation of the uncertainty effect, it is useful to first illustrate the notions of balancing and an internality constraint. Consider someone providing a WTP for the gamble in Gneezy, List, and Wu's study. One possible balancing operation would have the individual mentally assign a cash value to the \$50 gift certificate, say \$25, likewise assign a cash value to the \$100 gift certificate, say \$40, and then price an equal probability of receiving \$25 or \$40 by forging a compromise between these figures. As long as people assign the same cash value to any gift certificate whether it is sure or uncertain, balancing operations of this sort satisfy internality and rule out the uncertainty effect.

Gneezy, List, and Wu thus speculated that the uncertainty effect arises when preferences are constructed not by balancing but by what may be termed composition-and-adjustment. For example, to establish a WTP for the gift certificate gamble, a person might compose the potential \$50 and \$100 outcomes and code the gamble as a "\$75 gift certificate with risk." They might then assign a cash value to a \$75 gift certificate, say \$35, and next reduce this amount to account for the risk. Note that while internality emerges as an obvious constraint in the course of a balancing operation, it does not do so during composition-and-adjustment. A reduction from \$35 might thus go to, say, \$20, and thereby yield a lower WTP for the gamble than for the \$50 gift certificate.

From the perspective of TAA, assigning a cash value to a bookstore gift certificate constitutes translation from "gift certificate currency" to "regular money." There are, moreover, parallels between composition and deterministic comparison as well as between adjustment and risk accommodation. Accordingly, in the SM (Part 1, Claim 8), we show that under TAA, for any given α, there is a cutoff τ below which the uncertainty effect materializes. The cutoff is

$$\tau < \alpha \left[\frac{g(z^*)-g(z_*)}{g(z^*)-g(z_*)+f(z^*)-f(z_*)}\right], \tag{8}$$

where we have suppressed the subscripts on f and g and denoted the best and worst possible outcomes by z^* and z_*, respectively. In the SM (Part 1), we show that aversion to fair unimodal risk implies that the bracketed term in Equation (8) is greater than ½. It follows that there exist τ and α pairs which satisfy both Equation (8) and $2\tau - 1 < \alpha < 2\tau$. In other words, the uncertainty effect can co-exist with our findings that risk matters less.

To unpack the relevant intuition, imagine a person making a direct choice between the gift certificate gamble and sure receipt of a cash amount they deem just as attractive as the \$50 gift certificate.[13] First, if translation is rough, then, deterministic comparisons of the gamble outcomes and sure cash alternative will not advantage the gamble very much. By construction, the comparison of the \$50 gift certificate and sure cash is a tie. In turn, rough translation implies that the comparison of the \$100 gift certificate and sure cash will be relatively close.[14]

Second, risk accommodation must nevertheless downgrade the gamble to account for the chance its upside (the \$100 gift certificate rather than sure cash) does not obtain. Ordinarily, risk accommodation must also upgrade the gamble for the chance its downside does not obtain. However, there is no downside here (since the \$50 gift certificate and sure alternative are equated). Therefore, risk accommodation can only drag down the gamble.

Finally, because internality does not emerge as a constraint, if deterministic comparisons do not advantage the gamble very much, dragging down the gamble to accommodate risk can render it less attractive than the sure thing. In this way, the uncertainty effect can materialize given sufficiently rough translation (relatively low τ) in tandem with sufficient risk accommodation (relatively high α). Notably, the effect does not

[13] Most demonstrations of the uncertainty effect involve pricing measures, like WTP. However, some involve direct choice; see, for example, Gneezy, List, and Wu's Section IV.
[14] Consistent with rough translation of deterministic comparisons, in Gneezy, List, and Wu's study median WTPs for the sure \$50 and sure \$100 gift certificates were not too different, equal to \$25 and \$40, respectively.

require drastic risk aversion per se. Rather, as we will further elaborate, it can materialize if sufficient accommodation is made for merely commonplace degrees of risk aversion.

Wang, Feng, & Keller (2013) studied the uncertainty effect and reported a counterintuitive finding consistent with our model's explanation. They observed a robust uncertainty effect in a baseline condition. However, imposing cognitive load eliminated it. We suggest that Wang et al.'s load manipulation impaired risk accommodation (i.e., lowering α) more than it influenced translation (i.e., not much changing τ). This suggestion fits with risk accommodation proceeding in part as an effortful adjustment from the anchor of deterministic translation. Seminal studies have established that load often stymies effortful adjustments (Gilbert, 2002; Trope, 1986; Epley & Gilovich, 2006).

It is worth mulling how low-resolution translation paired with relatively standard risk accommodation would manifest in real-world choices. Returning to the introductory decision about investing in an equities college fund or spending the money on a family vacation, consider a parent who does not conclude much when comparing financial responsibility and family bonding. This parent may nevertheless respond to the risk of an equities college fund. Or consider the household product gambles in our studies. A participant may not extract much from comparing 2 units of some product to 3 and 1 units of another. But they may nevertheless respond to the risk of the 3/1 gamble.

Characterizing the uncertainty effect as rooted in rough translation paired with reasonable risk accommodation implies a critical bound on it. In line with existing findings, the effect should not emerge in unimodal tasks, for instance when participants provide WTPs for a gamble offering purely monetary prizes, like $50 and $100, and should be confined to crossmodal tasks.

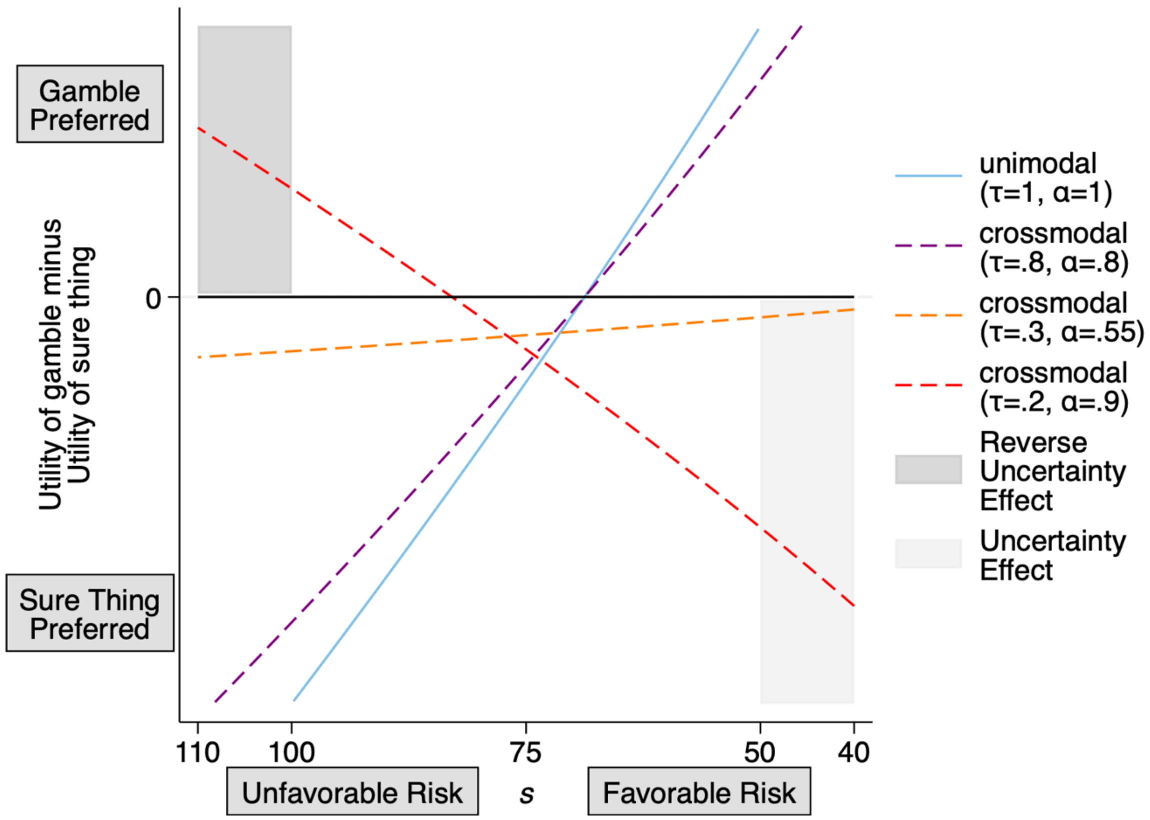

Figure 3. The figure illustrates how combination of τ and α can produce both an uncertainty effect and a reverse uncertainty effect. The plot examines unimodal (Equation (4)) and crossmodal (Equation (7)) preferences as a function of a sure thing that varies from 40 to 110. For crossmodal preferences, the purple and orange lines exhibit risk mattering less crossmodally in the form of a crossover interaction. The orange line also exhibits an uncertainty effect, a crossmodal preference for the sure thing, $s < 50$, over the stochastically dominating gamble. The red line produced by $\tau = .2$ and $\alpha = .9$ reflects inverted crossmodal preferences: the gamble is increasingly preferred as the sure alternative improves. This line yields both an uncertainty effect and a reverse uncertainty effect, a crossmodal preference for the gamble over the stochastically dominating sure thing, $s > 100$. Note: The figure assumes the parametric specification, $f(z) = .4z^{.7}$ and $g(z) = .6z^{.7}$.

Figure 3 elaborates several aspects of our model's explanation of the uncertainty effect. Like Figure 1, it plots the extent of preference between an even chance gamble whose outcomes are 50 and 100 and a sure alternative, s. Positive values on the vertical axis reflect preference for the gamble, while negative values reflect preference for the sure thing. Expanding on Figure 1's horizontal axis, the present figure allows the sure thing, s, to vary from a high of 110, which exceeds the gamble's superior outcome of 100, to a low of 40, which is less than the gamble's inferior outcome of 50. In other words, Figure 3 includes sure things that are not internal to the gamble outcomes.

As before, the figure assumes prospect theory, $f(z) = \pi(p)v(z)$ and $g(z) = (1 - \pi(p))v(z)$, with weighting function $\pi(p)$ such that $\pi(.5) = .4$. Because this prospect theory specification instantiates a commonplace degree of risk aversion, sufficiently high α then means that much weight is placed on entirely normal risk attitudes.[15]

The figure also includes two new grey regions. We start with the right-hand, lighter grey region, which marks instances in which the uncertainty effect obtains. In this region, sure things worse than 50 are preferred over the gamble. The light blue line capturing unimodal preferences and the purple line representing crossmodal preferences with $\tau = .8$ and $\alpha = .8$ are redisplayed from Figure 1. Neither of them intersects the right-hand, lighter-grey region, and thus neither of them produces an uncertainty effect. In contrast, the orange line corresponding to $\tau = .3$ and $\alpha = .55$ intersects that region, indicating a preference for the sure thing over the gamble when $s < 50$. Thus, while both the purple and orange lines exhibit risk mattering less crossmodally (they are less steep than the unimodal light blue line and below it at $s = 75$), only the orange line yields the uncertainty effect. By our model, the uncertainty effect arises when there is sufficiently rough translation ($\tau = .3$) coupled with sufficient risk aversion ($\alpha = .55$).[16]

Directionally Inverted Preferences and the Reverse Uncertainty Effect

So far, we have analyzed the translate-and-accommodate model as defined by Equations (4) and (7) and, in addition, given the bounds $2\tau - 1 < \alpha < 2\tau$. The left-hand bound requires that translation not be too rough; the right-hand bound requires that there be a

[15] Prospect theory for positive outcomes provides two channels for risk aversion. First, $v(x)$ is typically concave. Second, $\pi(p)$ is usually subcertain, $\pi(.5) < .5$, so that the higher outcome is weighted less than the lower outcome. Setting $\pi(.5) = .4$ approximates many estimates from the literature. With $w = .4$, $\alpha > \frac{\tau}{1-w} = \frac{5\tau}{3}$ is needed for the uncertainty effect and $\alpha > \frac{\tau}{1-w} = 2.5\tau$ is needed for the reverse effect.

[16] The pair $\tau = .3$ and $\alpha = .55$ satisfies the inequality required to produce risk mattering less, $2\tau - 1 < \alpha < 2\tau$, as well as Equation (8), which reduces to $\tau > .6\alpha$ under our parametric assumptions.

decent extent of risk accommodation. The purple, and orange crossmodal lines in Figure 3 satisfy both bounds (as does the unimodal light blue line). However, the red line with $\tau = .2$ and $\alpha = .9$ does not. Here, translation is extremely rough relative to risk accommodation, producing crossmodal preferences that are *inverted*: a gamble becomes more attractive as its sure alternative improves. Thus, in contrast to the other lines, the red line slopes down.

Like the uncertainty effect, directionally inverted crossmodal preferences seem bizarre. Attributing such preferences to error or confusion may thus seem natural (and will sometimes be correct). However, our model makes sense of why such preferences may arise. When translation is extremely rough, deterministic comparisons all but fail to distinguish the available outcomes, allowing risk accommodation to become the driver of preference. Imagine a parent who extracts practically nothing from comparing financial responsibility to family bonding. But suppose that individual nevertheless responds to risk. To see why preferences can invert in such circumstances, recall that risk accommodation downgrades gambles for their upside perhaps not obtaining and upgrades them for their downside perhaps not obtaining. But as sure things improve, downgrades become smaller and upgrades become larger. The constraint $\alpha < 2\tau$ does not allow substantial upgrades to trump deterministic comparison, but that is what happens when $2\tau < \alpha$.

Given $\alpha > 2\tau$ and inverted preferences, our model also allows for a "reverse uncertainty effect": a gamble may be preferred to a sure thing that is equal or superior to the gamble's best possible realization. Because they impose internality, standard models of risky choice do not allow for the reverse uncertainty effect, just as they do not allow for the original uncertainty effect. From the perspective of standard accounts, both effects are bizarre, reflecting implausibly pronounced risk seeking and implausibly pronounced risk aversion, respectively.

Yet, like the original uncertainty effect, the reverse effect has been documented experimentally, albeit less pervasively. Shen, Fishbach, and Hsee (2015; see also Goldmsith & Amir, 2010) asked participants to drink a large volume of water over a short time in exchange for either a sure \$2 reward or a reward that was equally likely to be \$2 or \$1. A greater percentage of participants drank the water when offered the uncertain reward. In line with the TAA model, it seems plausible that deterministic translations between \$2 and the drinking task are all but equivalent to those between \$1 and this task, but that the risk of the uncertain reward nevertheless registers with participants.

Accordingly, in the SM (Part 1, Claim 9), we show that for any given α, there is a cutoff τ below which a reverse uncertainty effect materializes. The cutoff is nearly identical to Equation (8), but inverts the fraction:

$$\tau < \alpha \left[\frac{g(z^*) - g(z_*) + f(z^*) - f(z_*)}{g(z^*) - g(z_*)}\right]. \quad (9)$$

The left-hand, darker grey region of Figure 3 marks instances of the reverse uncertainty effect. The orange line, with the quite rough translation, $\tau = .3$, does not enter this region and therefore does not yield a reverse uncertainty effect. However, the red line, with the even rougher translation, $\tau = .2$, does.

Putting It All Together: Risk Matters Less, the Uncertainty Effect, and the Reverse Uncertainty Effect

Figure 4 shows how different (τ, α) pairs in the unit square, some which adhere to $2\tau - 1 < \alpha < 2\tau$ and some which do not, can allow for combinations of: risk mattering less crossmodally, the uncertainty effect (UE), and the reverse uncertainty effect (RUE). Like Figures 1 and 3, it assumes a 50-50 gamble and prospect theory, with $\pi(.5) = .4$.

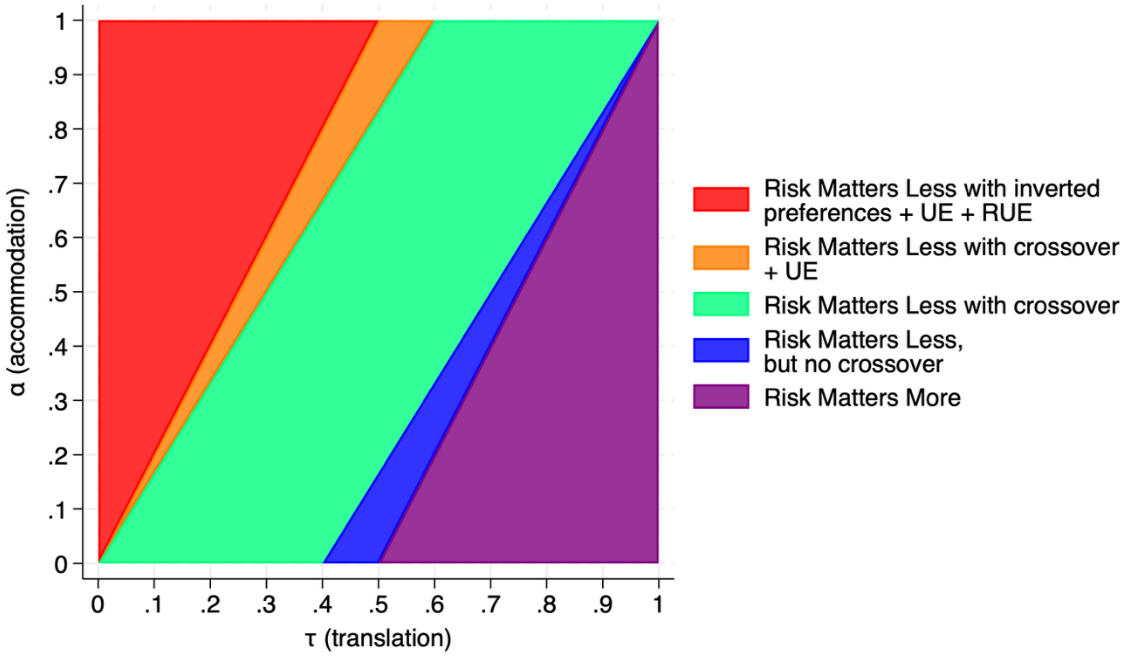

Figure 4. How various combinations of τ and α produce different preference patterns. Note: The figure assumes the parametric specification, $f(z) = .4z^{.7}$ and $g(z) = .6z^{.7}$.

The figure distinguishes five regions:

Green: This region is consistent with less crossmodal sensitivity to risk in the form of a crossover interaction. However, it does not permit an uncertainty effect nor a reverse uncertainty effect.

Orange: This region is consistent with less crossmodal sensitivity in the form of a crossover interaction. Moreover, it permits an uncertainty effect. But it does not permit a reverse uncertainty effect.

Red: This region allows for less crossmodal sensitivity, an uncertainty effect, and a reverse uncertainty effect. However, it also produces inverted preferences by which a gamble become relatively more attractive as the sure thing improves.

Blue: This region is consistent with less crossmodal sensitivity. However, it does not produce a crossover interaction. Contrary to our data, but in line with data from Martin et al. (2016), this region yields a main effect by which crossmodal preferences are always less risk averse than unimodal preferences. In addition, this region does not permit an uncertainty effect nor a reverse uncertainty effect.

Purple: This region is inconsistent with our empirical results. It produces crossmodal preferences in which risk matters *more* crossmodally not less.

Several intriguing predictions that follow from the translate-and-accommodate model are captured by the figure. First, the TAA model sees risk mattering less crossmodally as a common phenomenon. The area spanned by the green, orange, and blue regions is large.

Second, TAA allows for the simultaneous existence of risk mattering less crossmodally and the uncertainty effect. This is the orange region.

Third, TAA links the prevalence of the uncertainty effect to the probability weighting function. To reiterate, Figure 4 assumes $\pi(.5) = .4$, consistent with aversion to actuarially fair unimodal risk. If it instead assumed $\pi(.5) = .5$, consistent with risk neutrality, the orange region would disappear: there would be no possibility of risk mattering less crossmodally co-existing with the uncertainty effect. On the other hand, if $\pi(.5)$ were pushed lower, say $\pi(.5) = .2$, the orange region would increase in size. Finally, if $\pi(.5) > .5$, consistent with risk-seeking, the orange region would yield risk mattering less and the reverse uncertainty effect but not the uncertainty effect.[17]

Fourth, TAA provides a reason for why the uncertainty effect appears to more robust than the reverse uncertainty effect. The right-hand side of Equations (8) and (9) are governed by whether $g(z^*) - g(z_*)$ is larger than $f(z^*) - f(z_*)$. Risk aversion for fair, unimodal, 50-50 gambles implies $f(z^*) - f(z_*) < g(z^*) - g(z_*)$, which in turn implies that more combinations of τ and α admit the uncertainty effect than the reverse uncertainty effect.

Fifth, TAA reveals the possibility of the co-existence of the uncertainty effect and the reverse uncertainty effect (the red region). This possibility is not admitted by theorizing that draws on mechanisms such as "direct risk aversion" (Simonsohn, 2009), the "utility of gambling" (Conlisk, 1993; Diecidue, Schmidt, & Wakker, 2004; Royden, Suppes, & Walsh,

[17] Gonzalez & Wu (2022) document substantial heterogeneity in individual-level probability weighting functions, with most participants subcertain, $\pi(.5) < .5$, but some subjects supercertain, $\pi(.5) > .5$. Our analysis suggests that the uncertainty effect is more prevalent with subcertain individuals, while the reverse effect may occur with supercertan people.

1959), innate optimism (Goldsmith & Amir, 2010), or excitement (Shen, Fishbach, & Hsee, 2015). All these mechanisms permit one or the other type of uncertainty effect but not both.

Summing Up

In the preceding sections, we have shown how the translate-and-accommodate model makes sense of three patterns that standard perspectives deem bizarre. These are instances in which (i) dominated sure things are preferred to dominating gambles (the original uncertainty effect); (ii) dominated gambles are preferred to dominating sure things (the reverse uncertainty effect); (iii) gambles become more attractive as a sure thing against which they are pit improves. The TAA model shows that all three patterns can emerge when low resolution translation is paired with relatively standard risk accommodation.

General Discussion

Risk aversion given positive, moderate-likelihood outcomes is perhaps the best-known stylized fact from decision research. Though this behavior is typically presumed to obtain across diverse real-world domains, the voluminous work documenting it has largely focused on a single, special type of decision, concerning money. Accordingly, we have contrasted the nature of risk aversion in two broad classes of decisions. In unimodal choices, outcomes are "apples-to-apples." Monetary choices are a canonical example. In crossmodal choices, outcomes are "apples-to-oranges." Sure receipt of one product and uncertain receipt of a very different product is an example.

Our data reveal two patterns by which risk matters less crossmodally. First, relative to unimodal decisions involving actuarially fair risk, corresponding crossmodal decisions exhibit less risk aversion. Second, as risk becomes increasingly unfavorable, crossmodal preferences do not exhibit as much additional distaste for it, and as risk becomes increasingly favorable, they do not exhibit as much appetite for it. Together, these patterns of insensitivity engender an interaction. Given fair or unfavorable risk, crossmodal settings show less risk aversion. Yet, given favorable risk, they show more risk aversion.

To account for risk mattering less crossmodally, we have presented a translate-and-accommodate (TAA) model. TAA builds on several streams of research, including work concerning affect-driven probability distortion or neglect. It assumes a between-options decision strategy. It characterizes unimodal preferences in terms of upside versus downside risk balancing but characterizes crossmodal preferences differently, in terms of separate processes of deterministic translation (between apples and oranges) and risk accommodation.

There are two channels by which translation-and-accommodation can cause risk to matter less crossmodally. First, translation may often be rough and blur distinctions. The less keenly people distinguish between outcomes, the less it will matter what outcomes they may receive. Second, the extent to which people accommodate risk may be diluted. The very need to translate may divert attention away from risk parameters or render their processing particularly effortful and error-prone, thereby reducing confidence and diminishing impact. Additionally, risk accommodation may proceed as an adjustment from the anchor of deterministic translations. Much research suggests that adjustments from an initial anchor are often incomplete.

The essence of the TAA model is that when people decide between sure apples and uncertain oranges (and are able to pursue a between-options decision strategy), they roughly evaluate how they feel about apples versus oranges and in addition make some allowance for the attendant risk of oranges. On the other hand, when they decide between sure and uncertain apples, they are apt to focus on the attendant risk.

In addition to translation-and-accommodation, other psychological processes likely contribute to risk mattering less crossmodally. We have discussed preference intensity, noisy decision making, and reference points. Mislavsky and Simonsohn's (2018) weirdness account is also relevant. These authors worried that behavior attributed to risk preferences may often reflect strange or unexplained experimental methods. The decisions between sure and risky household products in Studies 1a – 1f are surely weird. That said, they are arguably no weirder crossmodally than unimodally. Furthermore, one might expect that reactions to weirdness would yield a main effect, not the interaction we document.

Unlike standard accounts, the translation-and-accommodation model can make sense of the uncertainty and reverse uncertainty effects and of inverted preferences by which a gamble becomes more attractive as a sure thing against which it is pit improves. It suggests that these patterns need not reflect implausible risk attitudes per se nor error and confusion.

Choice Construction and Representation

Several important choice phenomena, including narrow bracketing, mental accounting (Thaler, 1999; Evers, Imas, & Kang, 2022), and opportunity cost neglect (Frederick et al., 2009), influence people to formulate choice sets that contain similar or related options. These phenomena thus promote unimodal rather than crossmodal choices. For example, after meeting a friend who invests in an equities fund, a parent might mull whether to invest in the same fund or a bond fund. The parent is less likely to consider whether to invest in equities or spend money on a family vacation. We do not mean to imply that crossmodal choices are rare in an absolute sense. For one thing, there are likely many circumstances by which people happen to be presented with crossmodal choices. The parent could meet two friends, one who invests in equities and another who is going on vacation. But it does appear that people may encounter an abundance of unimodal choices.

Relatedly, while some choices are apt to be perceived as unimodal and others as crossmodal, it seems clear that many choices may be perceived as either. A foundational premise of psychology is that representation matters, and that there is typically room for disparate representations. We have proposed that if a parent debates between investing in a college fund and using the money for a family vacation, they may perceive their choice as apples-and-oranges. Specifically, the investment option might be coded as "doing the responsible thing" and the vacation option as "seizing an opportunity for family bonding." Such codings seem conceivable, even realistic. But so do some alternative codings. For instance, the parent may perceive each option in terms of the attributes "taking care of my family, financially or emotionally" and "fun." Investing may hold more of the former, vacationing more of the latter. Under this alternative representation, the decision is arguably apples-to-apples. It is beyond our scope to consider what factors may prompt perceptions consistent with one modality versus the other, but the question is fundamental.

Complexity

As we have mentioned, preference construction may be more complex crossmodally than unimodally, and though complexity cannot fully account for risk mattering less crossmodally, it likely plays a role. These observations call to mind a recent stream of risky choice research which explores complexity induced by a factor other than crossmodality, the need to engage in arithmetic. This research has yielded disparate results.

Enke and Graeber (2023) presented gambles' outcome probabilities as mathematical expressions rather than simple numbers. Participants thus had to perform calculations to understand their choices. This calculational complexity *decreased* sensitivity to risk parameters, much as crossmodality decreased it in our data. Zilker, Hertwig, and Pachur (2020) observed approximately the opposite result. They presented available sure things' outcome quantities as mathematical expressions. This *increased* sensitivity to risk parameters. It would be valuable to understand how these two findings might be reconciled with each other and with our data. We note that both concern unimodal, monetary choices (see also Charles, Frydman, & Kilic, 2024; Frydman & Jin, 2022; Woodford, 2020).

An additional aspect of Enke and Graeber's (2023) research program is relevant to why risk matters less crossmodally. These authors documented that people are often unsure about what available option will maximize their utility, and that as such "cognitive uncertainty" grows, people are more likely to "produce behaviors that are severely attenuated functions of objective problem parameters and are regressive" (p. 2022; however, see Bernheim et al. 2025). In other words, cognitive uncertainty *decreases* sensitivity to risk parameters. A straightforward yet highly interesting question is whether cognitive uncertainty tends to be greater for crossmodal choices, or if perhaps the reverse is true.

Process-Oriented Evidence

It would be valuable to collect process-oriented evidence to investigate the reasons why risk matters less crossmodally and thereby corroborate or cast doubt on the translate-and-accommodate model. There are many potential directions.

Consistent with the proposition that preference construction is more complex crossmodally, we have suggested that translation is an "extra" mental operation that arises crossmodally but not unimodally. In turn, we suggested that the cognitive toll of translation may render risk accommodation particularly error-prone. If crossmodal choices are indeed more challenging, they may engender worse performance on a concurrent task, such as holding a number in memory. If they induce more errors, then repeated presentation of risky choices may yield less consistent responses crossmodally.

We have also suggested that crossmodal risk accommodation sometimes proceeds as an adjustment from a riskless anchor. If so, then verbal protocols collected during choice should mesh with anchoring-and-adjustment more often crossmodally than unimodally (Epley & Gilovich, 2001). Furthermore, if crossmodal risk accommodation is an *effortful* adjustment, it might be stymied when people are cognitively busy (Wang, Feng, & Keller, 2013). Cognitive load might therefore *increase sensitivity* to risk crossmodally but not unimodally. Consistent with this conjecture, there is evidence that cognitive load does not impact risk attitudes in unimodal choices (Olschewski, Rieskamp, & Scheibehenne, 2018).

Finally, questions about the role of effort, error, attention, and other aspects of process have been studied in a highly sophisticated manner in research on affect-driven insensitivity to probability information (Pachur, Hertwig, & Wolkewitz, 2014; Suter, Pachur, & Hertwig, 2016). The methods used in that research should be applicable the study of crossmodal insensitivity. They include eye-tracking, process-tracing, measurement of response times, and associated computational modeling (Pachur, Schulte-Mecklenbeck, Murphy, & Hertwig, 2018; Zilker & Pachur, 2022a, 2022b).

What Factors Impact the Tendency for Risk to Matter Less Crossmodally?

Under what circumstances will the tendency toward risk mattering less crossmodally be more or less pronounced? We address this matter first by considering what might influence the tendency to engage in translation-and-accommodation rather than the kind of processes envisioned by standard models. Then, we consider influences on the roughness of translation (τ) and the dilution of risk accommodation (α).

A plethora of research identifies settings that promote between-options comparisons over alternative-by-alternative evaluations (Beach & Mitchell, 1978; Payne, 1976; Payne, Bettman, & Johnson, 1988; Svenson, 1979). For instance, between-options strategies are more common when options are presented simultaneously rather than sequentially. They are also more common when people anticipate being held accountable, as they produce reasoning that can be articulated and justified (Payne, Bettman, & Johnson, 1992). Because translation-and-accommodation is a between-options decision strategy, the tendency for risk to matter less crossmodally may be more pronounced in such settings.

Preferences elicited via matching may often reflect relatively sharp translation and little dilution of risk accommodation, that is both high τ and high α. The tendency for risk to matter less crossmodally may thus arise less often in matching than choice. A large literature contrasts these elicitation methods (Lichtenstein & Slovic, 1971; Tversky, Sattath, and Slovic, 1988; Fischer & Hawkins, 1993). To juxtapose them, consider a choice between two sure bottles of Tide detergent and a gamble offering either zero or four Oxo food containers. A parallel matching task would ask the following: given that two sure bottles of Tide are available alongside a gamble with a downside of zero Oxo containers, what upside number of Oxo containers makes you indifferent between the available options? Matching appears to all but mandate between-option comparisons. It should thus engender translation-and-accommodation crossmodally. But because it puts a focus on comparisons, we speculate that matching also facilitates sensitivity to risk parameters (that is, it pushes τ and α close to 1).

Finally, we speculate that choice options with which one has little familiarity may yield especially rough translation (i.e., low τ), whereas options with which one has dealt a lot may yield sharper translation (high τ). If so, then unfamiliar options will more readily lead to risk mattering less crossmodally. This speculation is in line with Tversky & Kahneman's (1986) observation that violations of many choice axioms are more likely when individuals do not have well-established preferences and must thus construct choices on the spot. It is also consistent with findings of uncertainty and reverse uncertainty effects for unfamiliar outcomes (limited-time bookstore gift certificates and rewards for consuming water).

Future Directions and Conclusion

We have focused on gambles providing specified probabilities of positive outcomes, in the hope that these simple stimuli can reveal basic aspects of risk-taking behavior. Future work should examine additional types of stimuli.

First, it will be useful to examine gambles with negative outcomes. In their seminal research, Kahneman and Tversky highlighted a "reflection effect": negative outcomes of middling likelihood typically engender risk seeking not risk aversion. Contrasts of unimodal and crossmodal preferences may also show a form of reflection (Martin et al., 2016). In particular, our analysis suggests that in the negative domain, crossmodal preferences will be less accepting of fair and unfavorable gambles but more accepting of favorable gambles. Findings from work on affect-driven probability distortion and neglect are in line with this form of reflection (see, for example, Pachur, Hertwig, &Wolkowitz, 2014)

Second, while we examined the unimodal/crossmodal distinction under risk, and Cubitt, McDonald, and Read (2018) examined it in intertemporal settings, it would be useful to examine it in risky intertemporal decisions. A unimodal example of such a decision would be a sure bottle of Tide today versus a 50% chance of 2 bottles in one month. A crossmodal example would pit the same Tide option against a 50% chance of 2 Oxo containers in one month. There is evidence that risk and delay can each matter less when they co-occur (e.g., Keren & Roelofsma, 1995; Weber & Chapman, 2005; Vanderveldt et al., 2015; Konstantinidis et al., 2020; Fitch & Kvam, 2025). They may each matter *much* less when they co-occur crossmodally (Read, McDonald, & Cubitt, 2023).

A third, and we believe critical, avenue for further research concerns decisions whose outcomes are tied to uncertain events rather than explicit probabilities. To illustrate, begin by considering the following binary choice, which is meant to recall the scenario of a parent pondering how to invest built-up savings:

(i) $1000 if equities outperform bonds next year

(ii) $1500 if equities outperform bonds by more than 10% next year

Also consider the following choice, meant to recall a parent selecting between vacations:

(iii) 2 free nights on a future booking if a hurricane cancels your original booking

(iv) 1 free night on a future booking if an earthquake or hurricane cancels your original booking

Both choices above are unimodal with respect to outcomes. Both are also unimodal with respect to events: each taps only a single source of uncertainty, financial markets in one case and environmental conditions in the other. By contrast, consider selecting between options (i) and (iii). This choice is crossmodal with respect to outcomes. But it is also crossmodal with respect to events: it taps two qualitatively distinct sources of uncertainty.

The hypothesis that risk matters more unimodally and less crossmodally suggests greater sensitivity to variation in events given a single source of uncertainty and lesser sensitivity given multiple sources. For example, whether an outcome is contingent on equities merely outperforming bonds or outperforming them by 10% may have more impact on preferences if all available options tap financial uncertainty than if some tap financial uncertainty while others tap environmental uncertainty. Likewise, the distinction between a hurricane occurring and either an earthquake or hurricane occurring may have more impact if all options tap environmental uncertainty than if only some do.

Many real-world decisions, like those of a parent mulling whether to invest in a college fund or take the family on vacation, are crossmodal with respect to both outcomes and events. If preferences show crossmodal insensitivity to variation in uncertain events alongside the crossmodal insensitivity to variation in outcomes that we have documented, prevailing generalizations about reactions to risk will need to be further nuanced. Risk may matter *much* less when both outcomes and the events on which they are contingent differ qualitatively.

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