

System 1 Is Not Scope Insensitive: A New, Dual-Process Account of Subjective Value

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Companies can create value by differentiating their products and services along quantitative attributes. Existing research suggests that consumers' tendency to rely on relatively effortless and affect-based processes reduces their sensitivity to the scope of quantitative attributes and that this explains why increments along quantitative attributes often have diminishing marginal value. The current article sheds new light on how "system 1" processes moderate the effect of quantitative product attributes on subjective value. Seven studies provide evidence that system 1 processes can produce diminishing marginal value, but also increasing marginal value, or any combination of the two, depending on the composition of the choice set. This is because system 1 processes facilitate ordinal comparisons (e.g., 256 GB is more than 128 GB, which is more than 64 GB) while system 2 processes, which are relatively more effortful and calculation based, facilitate cardinal comparisons (e.g., the difference between 256 and 128 GB is twice as large as between 128 and 64 GB).

Keywords: product differentiation, scope sensitivity, diminishing marginal value, dual-process theory, range–frequency theory, numerical cognition

INTRODUCTION

To fit the needs of different customer segments and to sustain a competitive advantage in today's marketplace, companies offer multiple versions of their products or services. Such differentiation frequently happens along quantitative dimensions. For instance, tablet computers can differ in terms of storage capacity, screen size, or weight and annuities can differ in terms of starting monthly income, annual increases in payment, or period-certain guarantees. For marketers, it is important to anticipate how consumers will respond to quantitative product differentiation. Imagine a supplier of frontload washing machines currently sells two models: one with a capacity of 4.5 cubic feet and another with a capacity of 5.2 cubic feet. Their innovation team of engineers and marketers is contemplating whether the company should add a third model with an even greater capacity of 5.5 cubic feet to its product line. The team wonders how much more consumers might be willing to pay for this extra capacity? Would consumers' willingness to pay for extra capacity be higher or lower if the washing machines also varied along other attributes,

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such as the number of spin cycles, or whether they are equipped with VRT Plus Technology to reduce vibration? Might these additional product specifications burden consumers' cognitive resources and alter their willingness to pay for extra capacity? Would it matter whether the alternatives are presented to consumers as "small," "medium," and "large"?

Common marketing wisdom suggests that there are diminishing returns to product improvements. For instance, consumers may see greater value in a laptop with 6 hours of battery life compared to one with 4 hours (+2 hours), but the difference between a laptop with 16 hours of battery life and one with 14 hours (also +2 hours) may not be perceived as particularly valuable. In other words, the value of a unit increase in the attribute decreases with the units of the attribute offered already and sellers need to establish larger and larger increments to create equivalent increases in perceived value. Research in psychology and marketing suggests that consumers' tendency to rely on relatively effortless and affect-based information processing (i.e., "system 1" processing) reduces their sensitivity to the scope of quantitative attributes and that this explains why increments along quantitative attributes often have diminishing marginal value (Hsee and Rottenstreich 2004; Hsee, Rottenstreich, and Xiao 2005; Mukherjee 2010; Patalano et al. 2015; Schley and Peters 2014). The insight that there is a relationship between System 1 processes and diminishing marginal value has been influential in marketing (Hossain and Saini 2015; Huang and Gong 2018; Huang, Huang, and Jiang 2018; Kull and Heath 2016; Lee et al. 2019; Liu et al. 2015; Saini and Thota 2010).

While the expectation of diminishing marginal value, and the notion that it is rooted in system 1 processing, has intuitive appeal, the current article reveals that the relationship between system 1 processing and subjective value is more nuanced. First, we will show that a unit increase in an attribute can in fact have a larger impact on subjective value when it occurs at the high end of a quantitative attribute than when it occurs at the low end; that is, a pattern of increasing marginal value. It can also happen that a unit increase in an attribute has a smaller impact on subjective value when it occurs at the low end or at the high end of a quantitative attribute than when it occurs in the middle of the range; that is, a pattern of increasing-then-decreasing marginal value. Or the opposite, that a unit increase in an attribute has a larger impact on subjective value when it occurs at the low end or at the high end of a quantitative attribute than when it occurs in the middle of the range; that is, a pattern of decreasing-then-increasing marginal value. These results may appear counterintuitive, or atypical, but we will show that in fact they occur under normal conditions, for instance, when consumers assess the value of products presented side by side.

Second, we will trace these curvatures in the value function to different ways in which the mind can process quantitative information. Quantitative specifications can be compared in an ordinal way (e.g., coffee size A is larger than B, which is larger than C) or in a cardinal way (e.g., coffee size A is 8 ounces larger than B, which is 2 ounces larger than C). We argue that ordinal comparisons produce curvature in value functions, while cardinal comparisons produce linearity. Consistent with this, we show that product labels emphasizing the ordinal positions of attribute levels (e.g., "small," "medium," and "large") can amplify the extent of diminishing and increasing marginal value.

Third, we argue that system 1 processes facilitate ordinal comparisons while system 2 processes facilitate cardinal comparisons. In line with this, we show that curvature in value functions is amplified when judgments are made under time pressure, or when information about additional attributes burdens cognitive resources. On the other hand, we show that curvature in value functions is attenuated amongst consumers that score higher on the Cognitive Reflection Test (CRT), or when ordinal cues are less accurate.

The broad conclusion from our work is that system 1 processing is not uniquely associated with diminishing marginal value. Instead, system 1 has a penchant for making ordinal comparisons; this can produce diminishing marginal value, increasing marginal value, or any combination of the two, depending on the composition of the choice set. This insight has immediate implications for practitioners responsible for engineering product portfolios.

SYSTEM 1 PROCESSES AND DIMINISHING MARGINAL VALUE

Today's shopping environments are complex and cluttered, but consumers have only limited cognitive resources, so they cannot elaborate on all information to the same extent. To make satisfactory judgments, consumers recruit both system 1 and system 2 processes (Evans and Stanovich 2013; Kahneman and Frederick, 2002; Sloman 1996). System 1 processes can handle large chunks of information and produce "quick-and-dirty" assessments of alternatives, often inspired by affect. System 2 processes, instead, are calculative and rule based. They require more cognitive resources and take more time to produce a response. System 2 processes are therefore engaged only selectively, to elaborate on information that has the potential to significantly increase decision quality, and only when sufficient cognitive resources are available (Chaiken and Trope 1999; Kahneman and Frederick 2002; Sloman 1996).

System 1 processes can be related to diminishing marginal value in at least two ways. First, there is a

relationship between effort and diminishing marginal value. Studies on numerical cognition have shown that it requires more cognitive effort to discriminate between two large quantities (e.g., 110 vs. 105) than to discriminate between two small quantities (e.g., 10 vs. 5; [Parkman 1971](#)). This “size effect” occurs regardless of whether people are presented with different numbers of objects, with Arabic digits, or number words (for a review see [Dehaene 2011](#)). When people are deprived of cognitive resources, their ability to discriminate between larger quantities deteriorates ([Anobile, Cicchini, and Burr 2012](#)) and a reduced ability to discriminate between large quantities is related to diminishing marginal value ([Schley and Peters 2014](#)). Thus, consumers may perceive an increase in apartment size from 2,000 to 2,200 square feet as less valuable than an increase in apartment size from 1,000 to 1,200 square feet, because it is more difficult to discriminate between 2,000 and 2,200 than between 1,000 and 1,200.

Second, there is a relationship between affect and diminishing marginal value. In a series of articles, [Hsee and Rottenstreich \(2004\)](#), [Hsee et al. \(2005\)](#), and [Hsee and Zhang \(2010\)](#) proposed that affect-based evaluations are determined by the presence versus absence of attributes (e.g., whether a spa package includes a massage), but not by further variations in scope (e.g., whether the duration of a massage is 60 or 90 minutes). In a seminal study, [Hsee and Rottenstreich \(2004\)](#) asked participants how much they were willing to pay for five or ten Madonna CDs, either after reporting how they felt about a number of emotionally charged topics (i.e., an affect-prime aimed to induce system 1 processing) or after solving a few numerical problems (i.e., a calculation prime aimed to induce system 2 processing). The number of CDs had a smaller effect on willingness to pay in the affect-prime condition than in the calculation-prime condition. Several other studies have conceptually replicated this result using different stimuli, manipulations, and dependent measures ([Chang and Pham 2018](#); [Dickert et al. 2015](#); [Dunn and Ashton-James 2008](#); [Hasford, Farmer, and Waites 2015](#); [Peters et al. 2012](#); [Pham and Avnet 2009](#); [Pham et al. 2015](#)). The relationship between system 1 processes and diminishing marginal value is made explicit in the mathematical formalization presented by [Mukherjee \(2010\)](#).

Importantly, studies in this literature do not directly examine curvature in individual-level value functions. Participants typically evaluate one of the two alternatives: one with a lower attribute level (e.g., 5 CDs) and one with a higher attribute level (e.g., 10 CDs). Judgments are thus made in “separate evaluation mode” and the shape of the value function is inferred by averaging the perceived value of the low versus high attribute level across participants, assuming a zero point. Yet, consumers oftentimes compare three or more alternatives before buying. Research on how the mind processes numerical information hints that, in

fact, the relationship between system 1 processes and subjective value may be more nuanced under these conditions.

SENSITIVITY TO ORDINAL RANK AND SUBJECTIVE VALUE

Quantitative product specifications provide information about both ordinal rank and cardinal distance. Imagine a consumer learns that three tablet computers have storage capacities of 64, 128, and 256 GB. That tells her that the first model has less storage than the second, and the second model less than the third. These are ordinal distinctions, and they provide one potential input for decision-making. It also tells her that the difference in storage between the second and third models is two times larger than the difference in storage between the first and second models. These are cardinal distinctions, which provide another input for decision-making.

Our perception of magnitude is a function of both cardinal and ordinal comparisons. This was first recognized by range–frequency theory ([Parducci 1963, 1965](#)), and it has since shaped our understanding of how consumers interpret prices ([Cunha and Shulman 2011](#); [Niedrich, Sharma, and Wedell 2001](#); [Niedrich et al. 2009](#)), make choices ([Cooke et al. 2004](#); [Wernerfelt 1995](#)), and respond on rating scales ([Janiszewski, Silk, and Cooke 2003](#); [Lynch, Chakravarti, and Mitra 1991](#)). In range–frequency theory, the psychological intensity of a stimulus depends on the distribution of other stimuli that are available in the immediate environment. Specifically, it depends on the proportional distance of the focal stimulus to the least versus the most intense available stimuli (this is the range principle) and the proportion of stimuli that are less intense than the focal stimulus (this is the frequency principle). For instance, the way consumers perceive a tablet with 128 GB of storage capacity depends on the storage capacities of other tablets available in the immediate environment. If there are two other tablets, of 64 and 256 GB, a 128 GB tablet will appear relatively small according to the range principle (because it is only 33% of the way between the smallest and largest sizes), but average according to the frequency principle (because 50% of the other tablets are smaller). The subjective size of the 128 GB tablet is a weighted average of these two comparisons.

If subjective value is determined exclusively by cardinal distance (i.e., the range principle), increments along quantitative attributes would have constant marginal value. Sensitivity to ordinal rank (i.e., the frequency principle), however, introduces curvature in subjective value functions. To see how, assume for a moment that judgments are determined exclusively by ordinal rank. The change from 64 to 128 GB produces the same increase in ordinal rank (from third to second), and thus value, as the change from 128 to 256 GB (from second to first). Because the two

options at the low end differ only by 64 GB while the two options at the high end differ by 128 GB, changes in the attribute have diminishing marginal value. Now, suppose the tablet models had storage capacities of 64, 192, and 256 GB. Mere sensitivity to rank now produces a pattern of increasing marginal value. Increasing ordinal rank from third to second requires 128 additional GB, but only 64 additional GB are needed to further increase ordinal rank from second to first. Following the same logic, it can also happen that a unit increase in an attribute has a smaller impact on subjective value when it occurs at the low end or at the high end of a quantitative attribute than when it occurs in the middle of the range; that is, an S-shaped value function (e.g., for five models with storage capacities of 64, 144, 160, 176, and 256 GB). Or the opposite, that a unit increase in an attribute has a larger impact on subjective value when it occurs at the low end or at the high end of a quantitative attribute than when it occurs in the middle of the range; that is, an inverse S-shaped value function (e.g., for five models with storage capacities of 64, 80, 160, 240, and 256 GB).

SYSTEM 1 PROCESSES AND SENSITIVITY TO ORDINAL RANK

System 1 processes are relatively effortless and continuously running, whereas system 2 processes are more effortful and must be switched on to regulate the influence of system 1 processes. If system 2 processes do not take over, system 1 processes will determine judgments and decisions (Evans and Stanovich 2013; Kahneman and Frederick 2002). Similarly, we argue that there is a hierarchical relationship between ordinal and cardinal comparisons. System 1 continuously makes ordinal comparisons that approximate the cardinal distance between alternatives, but system 2 is required to accurately interpret cardinal distance. Thus, if system 2 is not engaged to calculate cardinal distance, subjective value is determined by system 1 and ordinal comparisons.

We base this argument on research in numerical cognition. Rhesus monkeys, cotton-top tamarins, and even rats are able to tell whether one quantity is larger than another (Brannon and Terrace 1998; Hauser et al. 2003), suggesting that ordinal comparisons are relatively easy to make and that this ability is rooted in an evolutionarily ancient neural mechanism (Dehaene et al. 2003; Pinel et al. 2004). Human infants as young as 6 months can recognize that a set of 10 dots is more numerous than a set of 5 dots, despite having no concept of the cardinal quantities “10” and “5” (Xu and Spelke 2000). This ability plays an important role in the further development of their numerical cognition (Brannon 2002; Lipton and Spelke 2003; Wynn 1990; Xu 2003). Children must first understand the rank order of a number within the number system before they can learn

the number’s cardinal quantity. For instance, to learn what the number “five” means, we must first understand that “two” is greater than “one,” “three” is greater than “two,” “four” is greater than “three,” and that “five” is greater than “four.” Thus, our ability to understand ordinal relationships is closely related to our understanding and assessment of cardinal quantity. Accurately computing the cardinal distance between two quantities adds another layer of complexity, and this ability is typically acquired at a later age through formal training (Schley and Peters 2014; Siegler and Opfer 2003). Thus, processing quantitative information at the cardinal level requires more cognitive resources than processing it at the ordinal level, suggesting an association between system 1 and ordinal comparisons.

In addition, affect has been associated with ordinal evaluations. Pham et al. (2015) asked consumers to evaluate different types of food in terms of taste and ease of preparation. Taste was pretested to be affect-rich and thus more likely to engage system 1 processing, while ease of preparation was pretested to be affect-poor and thus more likely to engage system 2 processing. Participants were asked if they wanted to rank the various food options or instead rate all options on a 7-point scale. They preferred to rank the options when evaluating taste but rate the options when evaluating ease of preparation, suggesting a congruence between affect and ordinal comparisons. Pham et al. (2015) argued that the association between affect and ordinal comparisons explains why affect-based evaluations are insensitive to scope (see above), but again, this conclusion is based solely on studies that include only two levels of a given attribute and an assumed origin point.

INTERMEDIATE SUMMARY AND OVERVIEW OF STUDIES

In sum, the current article integrates two previously unconnected literatures. From the first literature, on dual-process models of subjective value, we take that value judgments result from an interplay between system 1 and system 2 processes. While we agree that the curvature of subjective value functions changes with the relative influence of system 1 processes, we disagree that system 1 processes reduce sensitivity to scope and exclusively produce diminishing marginal value. From the second literature, on range–frequency theory, we take the idea that the perception of attribute levels is a function of both ordinal and cardinal comparisons and that ordinal comparisons can produce curvature in the mapping of objective stimuli on subjective evaluations. We add to this literature that there is a hierarchical relationship between ordinal and cardinal comparisons, such that system 1 processes facilitate ordinal comparisons while system 2 processes facilitate cardinal comparisons.

We test this new dual-process account of subjective value in 10 studies. Seven studies are presented below, and three more studies are included in a [web appendix](#). The studies measure subjective value in different ways (e.g., willingness to pay, choice, and perceived quality ratings) across a wide range of product categories (e.g., pizzas, charities, and apartments). They measure and manipulate reliance on system 1 versus system 2 processing in a variety of ways (e.g., the CRT, time pressure, and information load) and demonstrate effects in both hypothetical and consequential settings, in different populations (US-based respondents recruited through Amazon Mechanical Turk, UK-based respondents recruited through Prolific, and undergraduate students participating in a lab study).

STUDY 1

Existing dual-process models of subjective value can account for diminishing and constant marginal value, but they do not allow for any other pattern of marginal value. The primary goal of study 1 is to demonstrate that marginal value, in fact, can also be increasing.

We present consumers with three alternatives that vary along one attribute and manipulate the cardinal distance between attribute levels by varying the intermediate level, holding the extreme levels constant. We expect to find diminishing marginal value if the intermediate attribute level is closest to the inferior attribute level (which we call accelerated spacing; e.g., 10–12–18), but increasing marginal value if the intermediate attribute level is closest to the superior attribute level (which we call decelerated spacing; e.g., 10–16–18). When the intermediate attribute level is equally close to the inferior and superior attribute levels (which we call uniform spacing; e.g., 10–14–18), we do not expect to find systematic deviations from constant marginal value. In the [web appendix](#), we describe a conceptual replication of study 1 (study S1) where we manipulate the spacing of attribute levels differently, by varying the extreme levels across conditions, holding the intermediate level constant. This study reveals similar effects of attribute spacing on subjective value.

Another goal of study 1 is to provide evidence that ordinal comparisons underlie the differences in curvature described above. Marketers often use size labels (e.g., “small,” “medium,” and “large”) to influence consumer search and decision-making (Aydinoğlu and Krishna 2011). Such labels highlight the ordinal positions of alternatives in a choice set. If ordinal information processing explains why value functions are concave when attribute levels are spaced in an accelerated way and convex when spaced in a decelerated way, we should find that these patterns are more pronounced when ordinal labels are added to alternatives.

Method

Five hundred thirty-eight respondents from Amazon Mechanical Turk participated in the study for a small monetary reward (192 females, $M_{age} = 30.17$, $SD = 9.92$). The study used a 3 (attribute spacing: accelerated vs. uniform vs. decelerated) $\times 2$ (ordinal labels: no vs. yes) between-participant experimental design. We asked participants to indicate how much they were willing to pay for three different pizza sizes, spaced either in an accelerated manner (10–12–18 inches), a uniform manner (10–14–18 inches), or a decelerated manner (10–16–18 inches). About a third of participants saw the three pizza sizes without ordinal labels (e.g., 10 vs. 12 vs. 18 inches). For the other participants, we highlighted the ordinal rank of the different sizes, either with numeric labels (e.g., Option 1: 10 inches vs. Option 2: 12 inches vs. Option 3: 18 inches) or with verbal labels (e.g., small: 10 inches vs. medium: 12 inches vs. large: 18 inches). Results were similar for numeric and verbal labels, so we do not distinguish between the two types.

All participants provided one willingness-to-pay judgment for each size, so three dollar amounts in total. We want to examine how changes in attribute levels translate into subjective value at the *individual* level, but differences between participants in terms of their *average* willingness to pay for the three sizes may obscure differences within participants. To illustrate, suppose there are four participants in the condition with uniform spacing (i.e., 10–14–18 inches) providing the following dollar amounts: \$1–\$4–\$5, \$3–\$8–\$9, \$10–\$15–\$18, and \$20–\$25–\$50. Although willingness to pay is consistent with diminishing marginal value for three out of four participants, the average willingness to pay across participants for the three pizza sizes is \$8.5–\$13–\$20.5, suggesting increasing marginal value. This is because the fourth participant provided higher dollar amounts. To account for this heterogeneity in absolute willingness to pay, we transformed each participant’s judgments to a scale from 0 to 1 using the following formula: $RV = (AV - AV_{inferior}) / (AV_{superior} - AV_{inferior})$, where RV stands for relative value and AV stands for absolute value. For example, willingness to pay of \$10–\$14–\$20 would be rescaled to 0–0.40–1, reflecting that willingness to pay for the intermediate size was 40% of the way between the small and large sizes. We applied the same procedure for the attribute levels such that, for instance, 10–12–18 inches were rescaled to 0–0.25–1. In the [web appendix](#), we report absolute value judgments by attribute level for all conditions in all studies.

Before applying this rescaling procedure, we excluded data from participants who provided non-monotonic responses. We required strict monotonicity between the inferior and superior options (i.e., inferior value < superior value) and weak monotonicity for all intermediate options relative to the inferior and superior options (i.e., inferior value \leq intermediate value, intermediate value \leq superior

value). For instance, a participant with a willingness to pay of \$10 for a 10 inch pizza, \$8 for a 12 inch pizza, and \$20 for a 20 inch pizza would be excluded, but a participant with a willingness to pay \$10 for a 10 inch pizza, \$10 for a 12 inch pizza, and \$20 for a 20 inch pizza would not be excluded. We applied the same criteria in all studies. In the current study, these criteria led us to exclude data from four participants. Conclusions across studies are qualitatively similar without these exclusions.

Results

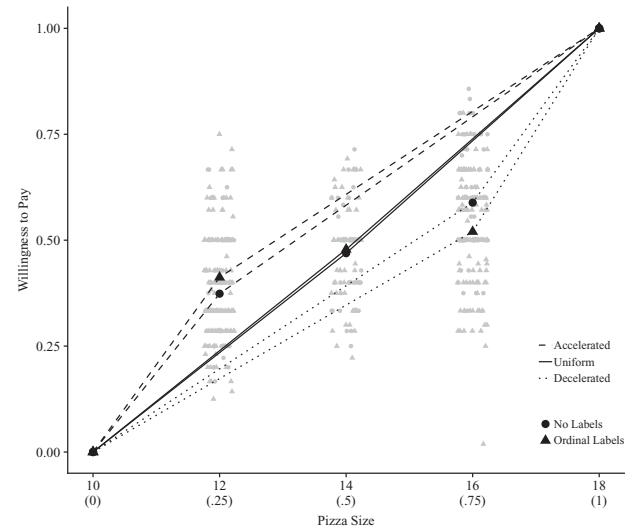
Figure 1 presents relative willingness to pay as a function of relative attribute levels. As can be seen from the graph, subjective value is a concave function of attribute levels when the spacing between attribute levels is accelerated (dashed lines), implying diminishing marginal value. It is a linear function of attribute levels when the spacing between attribute levels is uniform (solid lines), implying constant marginal value. Crucially, it is a convex function of attribute levels when the spacing between attribute levels is decelerated (dotted lines), implying increasing marginal value. Moreover, the extent of diminishing and increasing marginal value appears more pronounced when ordinal labels are present (triangles) versus not (circles).

To examine the statistical significance of these patterns, we compared relative willingness to pay with relative attribute levels. Because relative willingness to pay and attribute levels for the extreme sizes were 0 and 1 for all participants, statistical analyses are based on judgments for the intermediate size. When attribute levels were spaced in an accelerated manner, relative willingness to pay for the intermediate size amongst participants who did not see ordinal labels was 0.37 (SD = 0.11, CI₉₅ = [0.35, 0.40]). This implies that willingness to pay for the intermediate size was 37% of the way between willingness to pay for the small size and willingness to pay for the large size. This is significantly higher than the relative attribute level of the intermediate size, which was 0.25 by design ($t(68) = 9.12, p < .001, d = 2.21$). Thus, increasing the attribute by 25% of the attribute range increases subjective value by 37% of the subjective value range, implying diminishing marginal value. Moreover, relative willingness to pay amongst participants who did not see ordinal labels was lower compared to those who did see ordinal labels ($M = 0.41, SD = 0.13, CI_{95} = [0.39, 0.43], t(208) = 2.12, p = .03, d = 0.29$).

When attribute levels were spaced in a decelerated manner, relative willingness to pay for the intermediate size amongst participants who did not see ordinal labels was 0.59 (SD = 0.13, CI₉₅ = [0.56, 0.62]). This is significantly lower than the relative attribute level of the intermediate size, which was 0.75 by design ($t(69) = 10.26, p < .001, d = 2.47$), implying increasing marginal value. Moreover, relative willingness to pay amongst participants who did

FIGURE 1

RESULTS OF STUDY 1: WILLINGNESS TO PAY AS A FUNCTION OF ATTRIBUTE-LEVEL SPACING AND PRESENCE OF ORDINAL LABELS.



NOTE: For graphical purposes, the individual-level data points are jittered horizontally.

not see ordinal labels was higher compared to those who did see ordinal labels ($M = 0.52, SD = 0.12, CI_{95} = [0.50, 0.54], t(205) = 3.66, p < .001, d = 0.51$).

The pattern of results described so far is consistent with our claim that ordinal comparisons can increase curvature in subjective value functions, but ordinal comparisons need not always produce curvature. When attribute levels were spaced in a uniform way, ordinal and cardinal comparisons provide the same information—that the intermediate option lies halfway between the inferior and superior options. Thus, increasing the relative influence of ordinal versus cardinal comparisons should bear no systematic effect on judgments. In line with this, we find no difference in relative willingness to pay between participants who did not see ordinal labels ($M = 0.47, SD = 0.11, CI_{95} = [0.43, 0.50]$) and participants who did see ordinal labels ($M = 0.48, SD = 0.10, CI_{95} = [0.45, 0.50], t(115) = 0.43, p = .66, d = 0.08$). Relative willingness to pay in these uniform conditions was slightly lower than the relative attribute level of 0.50, but this difference was not significant ($p > .09$) and not systematic across studies.

A more comprehensive way of analyzing the data is to regress rescaled willingness to pay for the intermediate option on the intermediate attribute level ($0.25 = -0.25$ vs. $0.50 = 0$ vs. $0.75 = 0.25$), the presence of ordinal labels (no labels = 0 vs. ordinal labels = 1), and the interaction between these two predictors. The parameter estimate for the

intermediate attribute level indicates the marginal effect of a unit increase in the attribute on the subjective value for participants who did not see ordinal labels. If changes at the low and high ends of the attribute range have the same impact as changes in the middle of the attribute range, and thus value functions are linear regardless of attribute spacing, we should find that the parameter estimate for the intermediate attribute level is equal to 1. The regression analysis reveals that it is significantly lower than 1, but greater than 0 ($\beta = 0.43$, $CI_{95} = [0.35, 0.51]$, $t(530) = 10.41$, $p < .001$, $\eta_p^2 = .21$), reflecting that, in the absence of ordinal labels, the value function is concave in the accelerated condition and convex in the decelerated condition. The parameter estimate for the interaction term indicates whether this curvature is more or less pronounced when ordinal labels are present. The analysis reveals that it is significantly negative ($\beta = -0.21$, $CI_{95} = [-0.31, -0.11]$, $t(530) = 4.24$, $p < .001$, $\eta_p^2 = .03$), reflecting that, in the presence of ordinal labels, the value function is more concave in the accelerated condition and more convex in the decelerated condition. Finally, the parameter estimate for the presence of ordinal labels indicates how ordinal labels influence willingness to pay when attribute levels are uniformly spaced. The analysis reveals that it is not significantly different from 0 ($\beta = -0.01$, $CI_{95} = [-0.03, 0.01]$, $t(530) = 0.87$, $p = .39$, $\eta_p^2 = .00$), reflecting that ordinal labels have no influence in the uniform condition.

Alternative Explanations?

In addition to ordinal comparisons shaping the value function, it is possible that floor and/or ceiling effects introduced curvature. Consider a participant who values the 12 inch pizza at \$12 and the 18 inch pizza at \$18. For the 14 inch pizza in the accelerated condition, there could be a floor effect because there are only two dollar amounts consistent with increasing marginal value (\$12 and \$13), but four dollar amounts consistent with diminishing marginal value (\$15, \$16, \$17, and \$18). For the 16 inch pizza in the decelerated condition, there could be a ceiling effect because there are only two dollar amounts consistent with diminishing marginal value (\$17 and \$18), but four dollar amounts consistent with increasing marginal value (\$12, \$13, \$14, and \$15). In other words, because judgments for the intermediate size are constrained by the inferior and superior sizes, there are more ways to give responses consistent with diminishing marginal value when attribute levels are spaced in an accelerated way, and vice versa, more ways to give responses consistent with increasing marginal value when attribute levels are spaced in a decelerated way. We believe that this mechanism is unlikely to account for our findings for three reasons. First, the individual-level data depicted in the figures that accompany each study reveal that few participants provide judgments for intermediate options that are close to their judgments for the

extreme options, suggesting that restriction of range is unlikely producing the observed patterns. Second, studies 2 and 3 use choice as a dependent measure, for which the restriction of range is not an issue. Third, in studies 6 and 7, we predict and find curvatures in the value function that are inconsistent with this account.

Discussion

Study 1 examined the effects of attribute level spacing and ordinal labels on curvature in the value function. Depending on the spacing of attribute levels, we found diminishing, constant, or increasing marginal value. The observation of increasing marginal value is particularly interesting because existing dual-process models of subjective value cannot account for it. With regard to the effect of ordinal labels, one possible result could have been a general increase or decrease in people's willingness to pay for the intermediate option, but that is not what we found. Instead, when ordinal labels were presented, willingness to pay for the intermediate option was higher when attribute levels were spaced in an accelerated manner but lower when attribute levels were spaced in a decelerated manner.

The effects of attribute spacing on subjective value we find in study 1 are consistent with the literature on range–frequency theory, which models judgments of magnitude as a function of both cardinal and ordinal properties of stimuli (Cooke et al. 2004; Niedrich et al. 2001, 2009; Parducci 1965; Parducci and Wedell 1986). A recurring theme in this literature is whether observed differences in judgments reflect that consumers really perceive the stimuli differently (i.e., a difference in mental representation) or perceive the stimuli in the same way but interpret the rating scale differently (i.e., a response language effect). This distinction is important because if the effects are merely at the level of the response scale any observed difference may not carry over to other measures, or influence downstream consumer behavior (Lynch et al. 1991).

To examine generalizability across response scales, we conducted two additional studies, which we describe in more detail in the [web appendix](#). Participants in study S2 indicated their willingness to pay for digital cameras, and they indicated their expectations of picture quality on a 13-point rating scale (1 = “extremely low quality” and 13 = “extremely high quality”). The effects of attribute spacing on willingness to pay (an unbounded scale) and quality ratings (a bounded scale) are similar. Study S3 extends our findings from a single-attribute context to a multi-attribute context, and to three additional product categories (apartments, car insurances, and TVs). The effects of attribute-level spacing are highly consistent across attributes and product categories.

TABLE 1

RESULTS OF STUDY 2: CHOICE SHARES AS A FUNCTION OF ATTRIBUTE-LEVEL SPACING AND PRESENCE OF ORDINAL LABELS

Ordinal labels	Spacing of attribute levels	Serving size (%)				
		12 oz.	14 oz.	16 oz.	18 oz.	20 oz.
No	Accelerated	32.9	19.5			47.6
	Uniform	37.6		37.6		24.7
	Decelerated	30.1			56.6	13.3
Yes	Accelerated	27.0	28.4			44.6
	Uniform	35.3		40.0		24.7
	Decelerated	39.6			45.1	15.4

The robustness of our findings across dependent measures, attributes, and categories suggests that the effects of attribute-level spacing we observe on judgments of value are at the level of the mental representation and thus should influence meaningful consumer behavior. To further bolster this conclusion, studies 2–4 examine the effects of attribute-level spacing in a choice context and under incentive-compatible conditions.

STUDY 2

The goal of study 2 was to examine how attribute-level spacing and ordinal labels shape subjective value in a choice context. We presented consumers with three coffee sizes and their prices (which were the same for all participants), manipulating the spacing between the different sizes and the presence of ordinal labels across participants, as we did in the previous study. Because we observe only one choice per participant, we cannot assess the curvature in value functions at the individual level as we did in the previous study. We do observe the proportion of participants who prefers the intermediate option and how that proportion varies as a function of the size of the intermediate option, and the presence of ordinal labels. We expect that participants will be influenced by cardinal distinctions between alternatives and, thus, that more people will choose the intermediate option as its size increases. However, we also expect ordinal comparisons to influence choice and, thus, that the size of the intermediate option will matter less when ordinal labels are added to alternatives.

Method

Five hundred respondents from Amazon Mechanical Turk participated in the study for a small monetary reward (177 females, $M_{\text{age}} = 29.96$, $SD = 9.27$). The study used a 3 (attribute spacing: accelerated vs. uniform vs. decelerated) \times 2 (ordinal labels: no vs. yes) between-participant design. We informed participants that a local coffee shop sells coffee in three different sizes, priced at \$1.99, \$2.49, and \$2.99. The coffee sizes were spaced either in an

accelerated manner (12–14–20 ounces), a uniform manner (12–16–20 ounces), or a decelerated manner (12–18–20 ounces), and they were presented either without ordinal labels or with ordinal labels (e.g., small: 12 ounces vs. medium: 14 ounces vs. large: 20 ounces). Participants indicated which option they would choose. Because study 2 used choice as the dependent measure, there were no monotonicity-related data exclusions.

Results

The Intermediate Option. Table 1 presents the proportion of participants choosing each option as a function of attribute spacing and presence of ordinal labels. As can be seen from the table, preference for the intermediate option increases with its size, but the increase is less pronounced when participants see ordinal labels. In the condition without labels, the choice share of the intermediate option increased from 19.5% when it offered 14 ounces to 56.6% when it offered 18 ounces. In the condition with labels, the choice share of the intermediate option increased from 28.4% when it offered 14 ounces to 45.1% when it offered 18 ounces.

To examine the statistical significance of this pattern, we estimated a logistic regression model, including as predictors the size of the intermediate option (accelerated: 14 = -2 vs. uniform: 16 = 0 vs. decelerated: 18 = +2), the presence of ordinal labels (no labels = 0 vs. ordinal labels = 1), and the interaction between these two variables. This logistic model is analogous to the linear model presented in study 1 (except that a coefficient equal to one for the size of the intermediate option does not imply constant marginal value). The parameter estimate for the size of the intermediate option was positive and significant ($\beta = 0.42$, $CI_{95} = [0.25, 0.59]$, $z = 4.77$, $p < .001$, $OR = 1.52$), indicating that choice shares increased with the size of the intermediate option when no ordinal labels were presented. The parameter estimate for the interaction term was significantly negative ($\beta = -0.24$, $CI_{95} = [-0.48, -0.01]$, $z = 2.01$, $p = .04$, $OR = 0.79$), indicating that the effect of intermediate option size on choice shares was attenuated when ordinal labels were presented. The parameter

estimate for ordinal labels did not differ significantly from zero ($\beta = 0.04$, $CI_{95} = [-0.33, 0.42]$, $z = 0.22$, $p = .83$, $OR = 1.04$), indicating that ordinal labels did not influence choice shares when attribute levels were uniformly spaced.

In sum, when alternatives are presented with ordinal labels, cardinal distinctions have a smaller influence on willingness to pay (study 1) and choice (study 2). We take these findings to suggest that ordinal and cardinal comparisons jointly shape the subjective value of alternatives.

The Exterior Options. It is possible that ordinal labels do not emphasize ordinal distinctions and de-emphasize cardinal distinctions, but instead decrease attention to the task. However, we do not observe more random responses when ordinal labels are added (i.e., 33% choice shares for the small, intermediate, and large options). For instance, when attribute levels are uniformly spaced, participants did discriminate between options ($\chi^2(2) = 5.84$, $p = .05$) and ordinal labels had no influence on choice shares ($\chi^2(2) = 0.13$, $p = .94$). We also do not observe that ordinal labels systematically influence the choice shares of the extreme options. Averaged across attribute-spacing conditions, ordinal labels had no influence on the choice share of the 12 ounce option ($\chi^2(1) = 0.02$, $p = .88$), nor for the 20 ounce option ($\chi^2(1) = 0.06$, $p = .80$).

Note that relative choice shares between the 12 and 20 ounce servings do vary between attribute-spacing conditions, in line with the similarity effect (Tversky 1972). According to the similarity effect, preference for the 12 ounce option compared to the 20 ounce option should be lower when the intermediate alternative is closer to the 12 ounce option (i.e., the 14 ounce intermediate alternative) compared to when it is closer to the 20 ounce option (i.e., the 18 ounce intermediate alternative). We find that relative preference for the 12 ounce option (vs. the 20 ounce option) was 39.5% when the intermediate option was closer to the 12 ounce option, 59.6% when the intermediate option was equidistant between the 12 ounce and the 14 ounce option, and 70.9% when the intermediate option was closer to the 20 ounce option ($\beta = -0.31$, $CI_{95} = [-0.53, -0.10]$, $z = 2.87$, $p = .004$, $OR = 0.73$). The presence of ordinal labels had no effect on the magnitude of the similarity effect ($\beta = -0.05$, $CI_{95} = [-0.35, 0.25]$, $z = 0.35$, $p = .73$, $OR = 0.95$).

STUDY 3

Study 3 again examines how the spacing of attribute levels influences choice depending on whether ordinal labels are presented, but now for a consequential charity donation decision. Research has demonstrated that donors have an aversion to overhead, avoiding charities that spend a relatively high fraction of donated funds on administrative and fundraising costs (Gneezy, Keenan, and Gneezy 2014). We presented participants with three charities that differed in

terms of “program percentage” (i.e., the percentage of donated funds allocated to the advertised programs). We manipulated the program percentage of the intermediate charity such that, for one half of participants, program percentages were spaced in an accelerated way (71–78–98%) and, for the other half of participants, program percentages were spaced in a decelerated way (71–91–98%). These charities were presented with ordinal labels (letter grade: “A,” “B,” or “C”), or without labels. Unlike in study 2, where participants were forced to choose between the three alternatives, participants in study 3 were asked if they wanted to donate £10 to the intermediate charity or receive £10 as a bonus payment. We expect that more people will choose to donate when the program percentage of the intermediate option is higher, but that the increase will be smaller when ordinal labels are added to alternatives.

Method

Sample size, methods, payment, and analyses were conducted in accordance with our preregistration (AsPredicted #35978). One thousand two UK-based respondents recruited through Prolific participated in the study for a small monetary reward (669 females, $M_{age} = 37.69$, $SD = 11.81$). There were no data exclusions. The study used a 2 (attribute spacing: accelerated vs. decelerated) \times 2 (ordinal labels: no vs. yes) between-participant experimental design. Participants imagined we gave them a £10 bonus payment that they could choose to donate to a charity or keep for themselves. We told participants that 50 respondents would be randomly selected to have their decisions carried out for real. That is, if the participant chose to donate the £10 to the charity, we would send £10 to that charity, and if the participant chose to keep the £10, we would add £10 as a bonus payment to their account. We selected three charities verified by Charitywatch.org, a leading charity comparison website, to present to participants. We explained to participants that the charities varied in terms of their program percentages. For all participants, the lowest program percentage was 71% and the highest program percentage was 98%, but the intermediate program percentage was either 78% or 91%, depending on whether participants were assigned to the accelerated-spacing condition or the decelerated-spacing condition. Participants were randomly assigned to see the charities with or without ordinal labels. In the condition with ordinal labels, participants saw the charities together with the labels: “grade A” versus “grade B” versus “grade C.” In the condition without ordinal labels, the charities were presented in the same way, just without the “grades.”

Results

As in study 2, we observe only one choice per participant, so we cannot assess the curvature in value functions

at the individual level. We do observe the proportion of participants who chooses to donate to the intermediate charity and how that proportion varies as a function of the intermediate charity's program percentage, and the presence of ordinal labels. Consistent with study 2, the percentage of participants choosing to donate increased with the program percentage of the intermediate charity, but the increase was less pronounced when participants saw ordinal labels. In the condition without labels, donation likelihood increased from 24.6% in the accelerated condition to 44.2% in the decelerated condition. In the condition with ordinal labels, donation likelihood increased from 33.9% in the accelerated condition to 38.0% in the decelerated condition.

To examine the statistical significance of this pattern, we estimated a logistic regression model, including as predictors the program percentage of the intermediate option (accelerated: 78% = -0.5 vs. decelerated: 91% = 0.5), the presence of ordinal labels (no labels = -0.5 vs. ordinal labels = 0.5), and the interaction between these two variables. The parameter estimate for the program percentage of the intermediate charity was positive and significant ($\beta = 0.53$, $CI_{95} = [0.27, 0.80]$, $z = 3.96$, $p < .001$, $OR = 1.70$), indicating that choice shares increased when the program percentage was higher when no ordinal labels were presented. The parameter estimate for the interaction term was significantly negative ($\beta = -0.71$, $CI_{95} = [-1.24, -0.18]$, $z = 2.62$, $p = .009$, $OR = 0.49$), indicating that the effect of program percentage on donation likelihood was attenuated when ordinal labels were presented. The parameter estimate for ordinal labels did not differ significantly from zero ($\beta = 0.10$, $CI_{95} = [-0.17, 0.36]$, $z = 0.72$, $p = .47$, $OR = 1.10$), indicating that ordinal labels did not influence donation likelihood on average.

STUDY 4

Study 4 examines curvature in the value function in a consequential setting. We presented respondents from Amazon Mechanical Turk with three surveys that vary in length and asked them to indicate for each survey what the minimum amount is we would have to pay them to complete it. Participants listing amounts lower than our predetermined maximum willingness to pay received an invitation to participate. We manipulated the length of the intermediate survey between participants such that, for one half of participants, survey lengths were spaced in an accelerated way (8–10–18 questions) and, for the other half of participants, survey lengths were spaced in a decelerated way (8–16–18 questions). We expect that participants' prices are a concave function of survey length when options are spaced in an accelerated way but a convex function when options are spaced in a decelerated way.

Another goal of study 4 (and the studies that follow) is to provide evidence that curvature in value functions depends on the extent to which people rely on system 1 versus system 2 processes. According to our account, system 1 can approximate the cardinal distance between alternatives by making ordinal comparisons, but system 2 is necessary to accurately interpret cardinal distance. Thus, greater reliance on system 2 should increase the relative influence of cardinal distinctions on subjective value and reduce curvature in value functions. In study 4, we use the CRT to measure individual differences in reliance on system 1 versus system 2 processes (Frederick 2005; Toplak, West, and Stanovich 2011). We expect to see more curvature in the value functions of participants with lower scores on the test. In other words, participants who are less likely to engage system 2 processes should show more pronounced diminishing marginal value when survey lengths are spaced in an accelerated way and more pronounced increasing marginal value when spaced in a decelerated way.

Method

Sample size, exclusion criteria, methods, payment, and analyses were conducted in accordance with our preregistration (AsPredicted #21485). Six hundred thirty respondents from Amazon Mechanical Turk participated in the study for a small monetary reward (291 females, $M_{age} = 36.58$, $SD = 12.00$). Participants first completed the Cognitive Reflection Test (CRT; Frederick 2005). We scored their performance by counting the number of correct responses (range: 0–3; we report an analysis using the sum of intuitive-incorrect responses as a measure of reliance on system 1 processing in the [web appendix](#)). Next, participants completed an unrelated survey about which they were asked a few questions at the end, to verify attention. Sixty participants failed this attention check and were rerouted to the end of the study. The other participants received the following proposal: "We may have three more surveys for you to potentially participate in for additional payment. On the following page, you will be presented some information about the surveys. For each survey, you will indicate the minimum amount we would have to pay you for your participation. If the prices you provide are acceptable to us, you will immediately be redirected to complete these additional extra surveys. Upon completing any extra survey(s) you will be paid the amount you specified as a bonus payment to the current HIT (in addition to your payment for the current survey). Depending on the prices you set, you may be redirected to complete 0, 1, 2, or 3 additional surveys." We then asked participants if they were interested in taking advantage of this opportunity. Forty-three participants refused our offer and were rerouted to the end of the study.

Finally, we presented three surveys with different lengths to the 527 remaining participants, on a page that

looked similar to those on the Mechanical Turk assignment platform. For all participants, the shortest survey had 8 questions and the longest survey had 18 questions, but the intermediate survey had either 10 questions or 16 questions, depending on whether participants were assigned to the accelerated-spacing condition or the decelerated-spacing condition. Participants entered their price for each survey in the corresponding box. Sixty-nine participants were excluded for providing responses that violated our monotonicity criteria, leaving a final sample of 458 participants.

Our predetermined prices, unbeknownst to participants, for the 8-, 10-, 16-, and 18-question surveys were \$0.20, \$0.25, \$0.40, and \$0.45, respectively (i.e., 2.5 cents per multiple-choice question). Participants entering prices lower than ours were automatically rerouted to complete that additional survey. Completion rates for the additional surveys were 100%. We paid participants the prices they had specified to their Mechanical Turk account.

Results

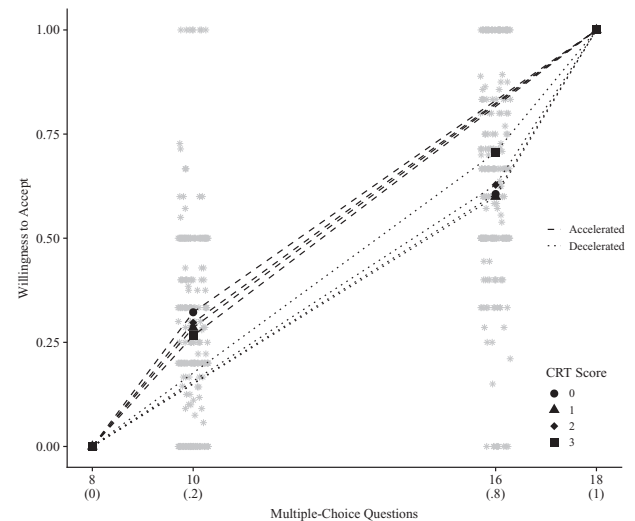
Figure 2 presents willingness to accept as a function of survey length and CRT performance. As in study 1, we observe a concave value function when the spacing between attribute levels is accelerated and a convex value function when the spacing between attribute levels is decelerated. Importantly, the extent of diminishing and increasing marginal value appears less pronounced for participants with higher CRT scores.

To examine the statistical significance of these patterns, we first compared relative willingness to accept with relative attribute levels, as in study 1. When survey length was spaced in an accelerated manner, relative willingness to accept for the intermediate survey was 0.29 (SD = 0.23, CI₉₅ = [0.26, 0.32]). This is significantly higher than the relative attribute level of the intermediate survey, which was 0.20 by design ($t(234) = 6.18, p < .001, d = 0.81$), implying diminishing marginal value. When survey length was spaced in a decelerated manner, relative willingness to accept for the intermediate survey was 0.63 (SD = 0.25, CI₉₅ = [0.60, 0.67]). This is significantly lower than the relative attribute level of the intermediate survey, which was 0.80 by design ($t(222) = 9.87, p < .001, d = 1.33$), implying increasing marginal value.

To examine the relationship between CRT performance and curvature in value functions, we regressed willingness to accept for the intermediate option on the intermediate attribute level (0.20 = -0.30 vs. 0.80 = 0.30), CRT scores (mean-centered), and the interaction between these two predictors. The parameter estimate for the intermediate attribute level in this model indicates the marginal effect of a unit increase in the attribute on the subjective value for a participant with an average performance on the CRT. If changes at the low and high ends of the attribute range had

FIGURE 2

RESULTS OF STUDY 4: WILLINGNESS TO ACCEPT AS A FUNCTION OF ATTRIBUTE-LEVEL SPACING AND PERFORMANCE ON THE COGNITIVE REFLECTION TEST.



NOTE: For graphical purposes, the individual-level data points are jittered horizontally.

the same impact as changes in the middle of the attribute range, and thus value functions were linear regardless of attribute spacing, we should find that the parameter estimate for the intermediate attribute level is equal to 1. We find a coefficient significantly lower than 1, but greater than 0 ($\beta = 0.57, CI_{95} = [0.50, 0.64], t(454) = 15.19, p < .001, \eta_p^2 = .33$), reflecting that the value function is concave in the accelerating condition and convex in the decelerating condition. The parameter estimate for the interaction term indicates whether this curvature is more or less pronounced for participants who score higher on the CRT. The analysis reveals that it is significantly positive ($\beta = 0.08, CI_{95} = [0.02, 0.14], t(454) = 2.55, p = .01, \eta_p^2 = .01$), reflecting that the value function is more linear for participants who rely more on system 2 processes. Finally, the parameter estimate for CRT in the model above indicates the relationship between CRT performance and willingness to pay, on average taken across the accelerated and decelerated conditions. We find a coefficient that is not significantly different from 0 ($\beta = 0.01, CI_{95} = [-0.01, 0.03], t(454) = 0.75, p = .46, \eta_p^2 = .00$).

In sum, study 4 demonstrates in an incentive-compatible context that attribute spacing creates curvature in subjective value functions and that this effect is stronger for participants who are less likely to engage system 2 processes. To further explore the data, we calculated the geometric means of participants' willingness to accept (to account for

the positive skew in responses). In the accelerated-spacing condition, average willingness to accept was 39 cents for the 8-question survey and 80 cents for the 18-question survey. If participants had constant marginal value, we would have expected participants to ask 47.2 cents for the 10-question survey. Instead, participants asked 51.5 cents for the 10-question survey, 9.1% more than expected assuming constant marginal value, reflecting concavity in the value function. Similarly, in the decelerated-spacing condition, average willingness to accept was 39 cents for the 8-question survey and 78 cents for the 18-question survey. If participants had constant marginal value, we would have expected participants to charge 70.2 cents for the 16-question survey. Instead, participants asked 62.9 cents for the 16-question survey, 10.4% less than expected assuming constant marginal value, reflecting convexity in the value function.

The results above suggest that participants in the accelerated-spacing condition overvalued the intermediate survey relative to the short and long surveys, while participants in the decelerated-spacing condition undervalued the intermediate survey. Because our willingness to accept per question was the same (i.e., 2.5 cents per question), regardless of survey length and attribute spacing, we should find that participants in the accelerated-spacing condition are relatively less likely to receive an invitation for the intermediate survey compared to participants in the decelerated-spacing condition. Indeed, in the accelerated-spacing condition, 30.9% of invitations we sent out were for the intermediate survey. This is lower than in the decelerated-spacing condition, where 49.0% of invitations we sent out were for the intermediate survey (Mann-Whitney-Wilcoxon $W = 659$, $p < .001$). Conclusions are similar when analyzing the likelihood of being hired for each survey with a multi-level logistic regression model.

STUDY 5

While study 4 provides correlational evidence, study 5 aims to provide causal evidence for our dual-process model of subjective value. Participants in the study indicate their willingness to pay for three printers, either under time pressure or not. Prior research suggests that time pressure inhibits system 2 processing, increasing the relative reliance on system 1 processes (Dhar and Gorlin 2013; Finucane et al. 2000; Payne, Bettman, and Johnson 1988). The printers were described to participants either in terms of print *speed*, such that they were spaced in an accelerated way (10–15–30 pages per minute) or in terms of print *time*, such that they were spaced in a uniform way (6–4–2 seconds per page). Note that manipulating attribute spacing in this way holds constant the objective performance of the printers across conditions (10 ppm = 6 spp, 15 ppm = 4 spp, and 30 ppm = 2 spp). Our account predicts that

greater reliance on system 1 processes increases curvature in value functions when options are spaced in an accelerated way, but not when options are spaced in a uniform way. We thus expect to find that time pressure changes the shape of the value function when printers are described in terms of print speed, but not when printers are described in terms of print time.

Method

Sample size, exclusion criteria, methods, and analysis were conducted in accordance with our preregistration (AsPredicted #14982). One thousand forty respondents from Amazon Mechanical Turk participated in the study for a small monetary reward (583 females, $M_{\text{age}} = 36.48$, $SD = 11.85$). We excluded data from 79 participants who failed an attention check (Oppenheimer, Meyvis, and Davidenko 2009), 10 participants with duplicate I.P. addresses, and 130 participants who violated our monotonicity criteria, leaving a sample of 821 participants. The study used a 2 (attribute spacing: uniform vs. accelerated) \times 2 (time pressure: no vs. yes) between-participant design. Participants completed the task either without time pressure or with time pressure. In both conditions, we asked participants to imagine that they print many documents at home and they were in need of a new printer. We informed participants that we would ask them how much they were willing to pay for three printers. In the time-pressure condition, we informed participants that they would see a timer that provides a recommended amount of time, but they could take as long as necessary to evaluate the printers, and that their response time would not influence their payment. When participants evaluated the printers, there was a timer at the top of the screen counting down from 8 seconds. After 8 seconds, the border of the screen began flashing red, but the page did not auto-advance after the time was up. Printers were specified in terms of pages per minute (10–15–30 ppm) or seconds per page (6–4–2 spp).

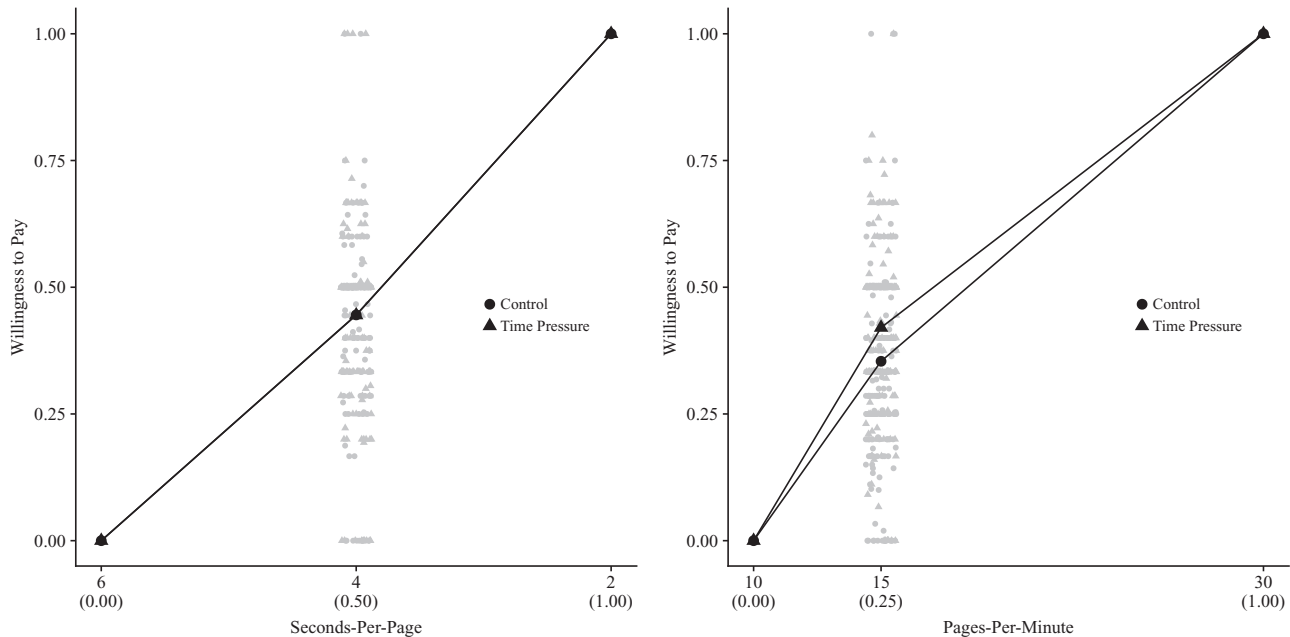
Results

Figure 3 visualizes willingness to pay when printers were described in terms of print time and thus spaced in a uniform way (left panel) and when printers were described in terms of print speed and thus spaced in an accelerated way (right panel), for participants who made judgments under time pressure (triangles) versus not (circles). As can be seen from the graph, time pressure had no effect on curvature in the value function when printers were described in terms of print time but increased curvature when printers were described in terms of print speed.

To examine the statistical significance of this pattern, we regressed willingness to pay for the intermediate option on attribute spacing (seconds per page = 0 vs. pages per minute = 1), time pressure (no = 0 vs. yes = 1), and the

FIGURE 3

RESULTS OF STUDY 5: WILLINGNESS TO PAY AS A FUNCTION OF ATTRIBUTE-LEVEL SPACING AND PRESENCE OF TIME PRESSURE.



NOTE: For graphical purposes, the individual-level data points are jittered horizontally.

interaction between these two predictors. This analysis revealed a significant interaction effect ($\beta = 0.07$, $CI_{95} = [0.02, 0.11]$, $t(817) = 2.82$, $p = .005$, $\eta_p^2 = .01$), suggesting that the effect of time pressure differed depending on whether printers were specified in terms of seconds per page or pages per minute. When printers were described in terms of seconds per page, and thus spaced in a uniform manner, time pressure had no significant effect on willingness to pay ($M_{no} = 0.45$ vs. $M_{yes} = 0.44$; $\beta = -0.00$, $CI_{95} = [-0.03, 0.03]$, $t(384) = 0.03$, $p = .98$, $\eta_p^2 = .00$). When printers were described in terms of pages per minute, and thus spaced in an accelerated way, willingness to pay was higher under time pressure ($M_{no} = 0.35$ vs. $M_{yes} = 0.42$; $\beta = 0.07$, $CI_{95} = [0.03, 0.10]$, $t(433) = 4.03$, $p < .001$, $\eta_p^2 = .04$).

Discussion

The primary goal of study 5 was to provide causal evidence that system 1 processes produce curvature in value functions when attribute levels are unevenly spaced. There is another implication of the study which we find interesting. System 1 processes are often seen as a detriment for good decision-making, but study 5 illustrates this need not be the case. Prior research suggests that the pages-per-minute metric can be misleading, because consumers fail

to realize that the relationship between print speed and print time is nonlinear. When printers are described to consumers both in terms of pages per minute and seconds per page, consumers become aware of the nonlinearity, and their willingness to pay changes accordingly (de Langhe and Puntoni 2016; de Langhe, Puntoni, and Larrick 2017). We can thus use participants' judgments in the seconds-per-page conditions as a benchmark for evaluating participants' judgments in the pages-per-minute condition. This comparison reveals that the bias introduced by the pages-per-minute metric is substantially reduced when participants made judgments under time pressure (i.e., the willingness to pay for 15 pages per minute better approximated the willingness to pay for 4 seconds per page). More generally, whether reliance on system 1 processing can help or harm decisions appears to depend in part on the relationship between the metric that is presented to consumers and the benefit that consumers ultimately care about.

STUDY 6

Study 6 builds on the idea that system 2 processes monitor the accuracy of system 1 processes and intervene when judgment quality suffers too much (Evans and Stanovich 2013; Gigerenzer and Goldstein 1996; Payne, Bettman,

and Johnson 1993). If ordinal comparisons are used as a mental shortcut to assess cardinal distance, they should influence judgments more when they provide a good approximation for cardinal distance, but less when they provide a poor approximation.

We presented participants with three different coffee sizes, either spaced in an accelerated or in a decelerated way. For about half of participants, the options were spaced such that ordinal comparisons provide a good approximation of cardinal distance (10–14–20 in the accelerated condition and 10–16–20 in the decelerated condition). For the other half of participants, the options were spaced such that ordinal comparisons provide a poor approximation of cardinal distance (10–12–20 in the accelerated condition and 10–18–20 in the decelerated condition). We predict that ordinal comparisons will have a larger influence on subjective value when they more closely approximate cardinal distance.

To assess differences in curvature in this study, we cannot directly compare rescaled willingness to pay for the intermediate option in the conditions where heuristic accuracy is high versus low. This is because the intermediate attribute levels differ across these conditions. For instance, when attributes are spaced in an accelerated way, the intermediate attribute level is 20% of the way between the inferior and superior option in the condition where heuristic accuracy is low, but 40% of the way in the condition where heuristic accuracy is high. Rescaled value judgments will thus be higher in the latter condition. We therefore use a different analysis strategy that allows us to compare the relative influence of ordinal versus cardinal comparisons on value functions. Following range–frequency theory (Parducci 1965), we can express the subjective value of any given attribute level, $V(x_i)$, as follows:

$$V(x_i) = (1 - w) \left[\frac{\text{Rank}(x_i) - 1}{N - 1} \right] + w \left[\frac{x_i - x_{\text{inf}}}{x_{\text{sup}} - x_{\text{inf}}} \right],$$

where $(\text{Rank}(x_i) - 1)/(N - 1)$ is the proportion of the N available attribute levels that are less desirable and $(x_i - x_{\text{inf}})/(x_{\text{sup}} - x_{\text{inf}})$ is the distance of the focal attribute level relative to the inferior versus the superior attribute level. The relative influence of ordinal comparisons (i.e., the first part of the equation) versus cardinal comparisons (i.e., the second part of the equation) is indicated by a weighting parameter, w , that is constrained between 0 and 1, where higher w indicates greater reliance on cardinal comparisons. Ordinal comparisons can produce curvature in value functions (depending on the cardinal distances between attribute levels). Cardinal comparisons, instead, produce constant marginal value. We expect to see a relatively greater influence of ordinal comparisons, and thus a lower w , when heuristic accuracy is high.

Method

Three hundred twenty-two respondents from Amazon Mechanical Turk participated in the study for a small monetary reward (128 females, $M_{\text{age}} = 32.00$, $SD = 11.07$). Eleven participants provided responses that violated our monotonicity criteria leaving a sample of 311 participants. The study used a 2 (attribute spacing: accelerated vs. decelerated) \times 2 (heuristic accuracy: low vs. high) between-participant design. We told participants that a local coffee shop sells three different serving sizes and asked how much they were willing to pay for each size. The smallest coffee size was always 10 ounces and the largest 20 ounces, but we manipulated the position of the intermediate size. For about half of participants, ordinal comparisons provided a better approximation of cardinal distance (i.e., high heuristic accuracy): 14 ounces in the accelerated condition and 16 ounces in the decelerated condition. For the other half of participants, ordinal comparisons poorly approximated cardinal distance (i.e., low heuristic accuracy): 12 ounces in the accelerated condition and 18 ounces in the decelerated condition.

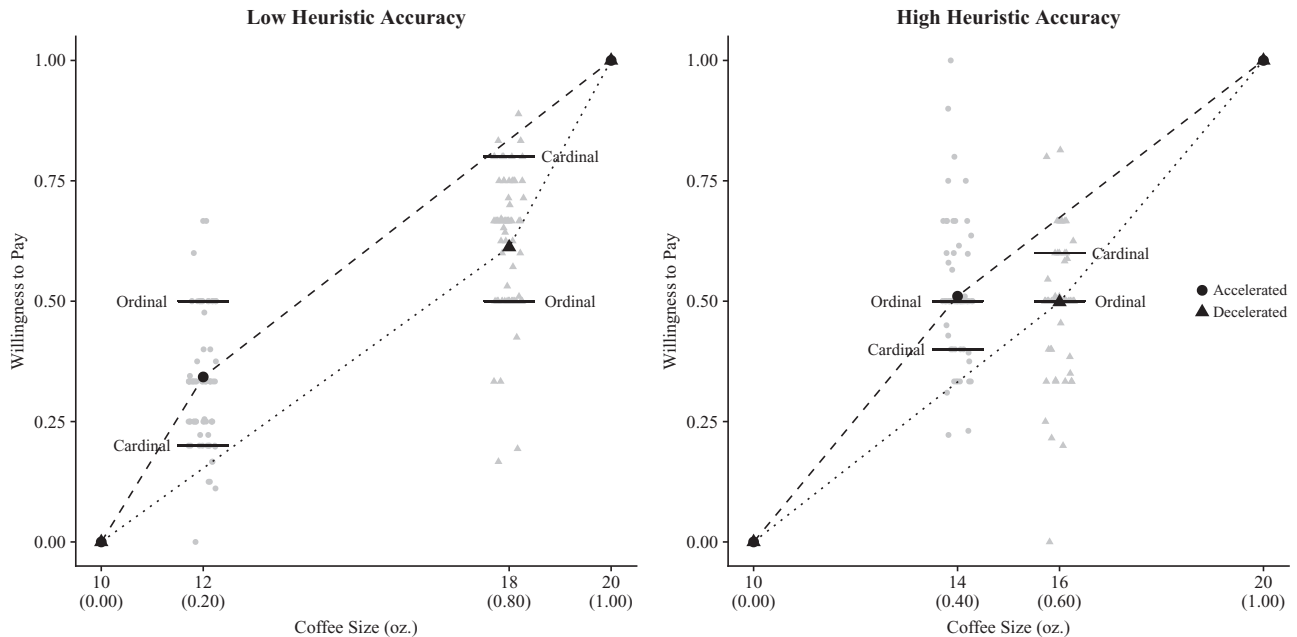
Results

Figure 4 plots willingness to pay as a function of attribute levels in the conditions with low (left panel) versus high heuristic accuracy (right panel). Short horizontal lines indicate the expected willingness to pay for the intermediate coffee size if participants' judgments were exclusively determined by ordinal comparisons or cardinal comparisons. Gray points (horizontally jittered) indicate participants' willingness to pay for the intermediate size. The location of participants' average judgments relative to these two lines gives an indication of the extent to which ordinal versus cardinal comparisons influence judgments. As can be seen from the figure, ordinal comparisons seem to have a greater influence when heuristic accuracy is high.

To examine the relative influence of ordinal versus cardinal comparisons across conditions, we estimate the weighting parameter, w , using a Bayesian estimation procedure, which we explain in more detail in the web appendix. One benefit of this procedure is that it provides parameter estimates that are more robust to outliers and non-normally distributed error terms compared to least-squares or maximum-likelihood approaches (Kruschke 2014). The latter approaches yield similar conclusions but inflate effect sizes. We model w as a function of an intercept term, attribute spacing (accelerated = 0 vs. decelerated = 1), heuristic accuracy (low = 0 vs. high = 1), and their interaction. Estimates for w were significantly lower, implying a greater influence of ordinal comparisons, when heuristic accuracy was high ($M_w = 0.24$, $CI_{95} [0.18, 0.34]$) versus low ($M_w =$

FIGURE 4

RESULTS OF STUDY 6: WILLINGNESS TO PAY AS A FUNCTION OF ATTRIBUTE-LEVEL SPACING AND HEURISTIC ACCURACY.



NOTE: For graphical purposes, the individual-level data points are jittered horizontally.

0.45, CI_{95} [0.40, 0.51]; $M_{\text{Difference}} = 0.21$, CI_{95} [0.11, 0.27]; note that Bayesian 95% credible intervals are draws from the posterior predictive distribution. As such, mean values do not need to sit symmetrically within the interval, as is necessarily the case in frequentist confidence intervals.) Estimates for w were also significantly higher, implying a greater influence of cardinal comparisons, when attribute levels were spaced in an accelerated way ($M_w = 0.43$, CI_{95} [0.39, 0.50]) versus a decelerated way ($M_w = 0.26$, CI_{95} [0.19, 0.36]; $M_{\text{Difference}} = 0.17$, CI_{95} [0.06, 0.25]), an effect we did not anticipate but could be interesting to explore in future research. There was no interaction between heuristic accuracy and attribute spacing ($M_{\text{Difference}} = 0.01$, CI_{95} [-0.16, 0.13]).

At the end of study 1, we discussed how patterns of decreasing and increasing marginal value may be produced in a mechanistic way, instead of based on ordinal comparisons. Note that floor and ceiling effects, to the extent that they occur, should be more pronounced in the conditions with low heuristic accuracy (i.e., 12 and 18 ounces) because these values are closer to the floor and ceiling imposed by the extreme options. However, consistent with our account, we found that ordinal comparisons are more influential in the conditions with high heuristic accuracy (i.e., 14 and 16 ounces).

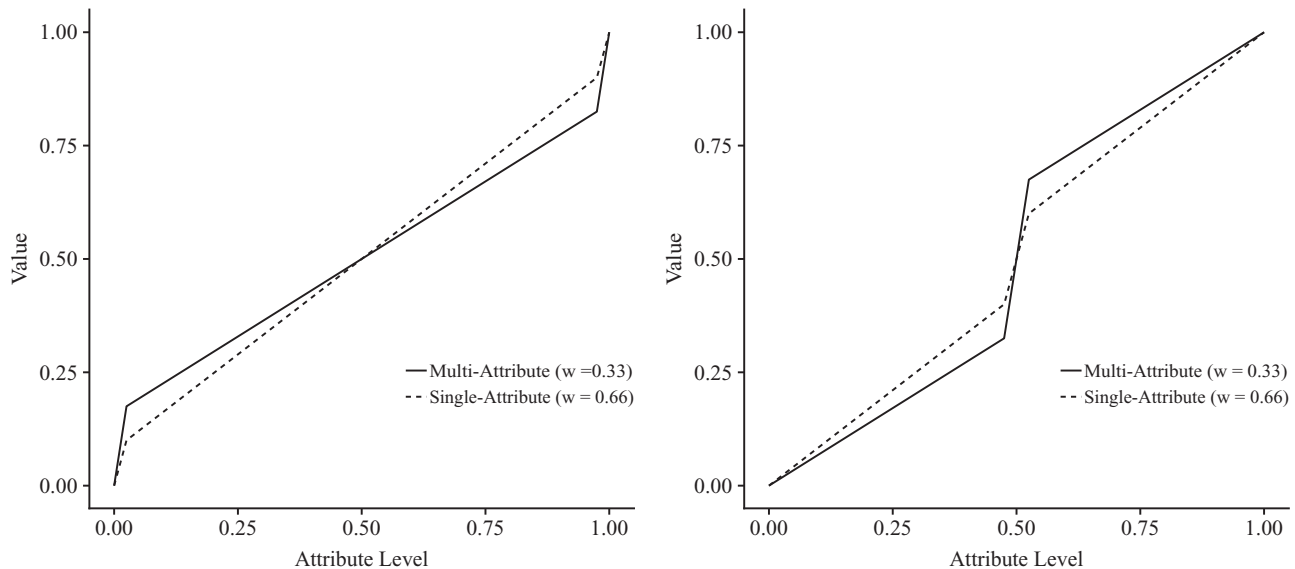
STUDY 7

The goal of study 7 is to demonstrate that reliance on system 1 processes can also produce inverse S-shaped and S-shaped value functions. To see this, consider the left panel in figure 5 with five attribute levels, two of which are at the very low end of the range, one in the middle, and two at the high end. For this spacing of attribute levels, we predict inverse S-shaped value functions that are more pronounced when people rely more on system 1 processes. The right panel in figure 5 also has five attribute levels, but now three attribute levels lie very close to the middle of the attribute range. For this spacing of attribute levels, we predict S-shaped value functions that are more pronounced when people rely more on system 1 processes.

We again manipulate reliance on system 1 versus system 2 processes in a different way. We build on the idea that system 2 processes are effortful and that people shift from more to less effortful decision strategies when decisions are more complex (Evans and Stanovich 2013; Kahneman and Frederick 2002). For instance, when there are more alternatives to choose from, or alternatives differ along more attributes, people shift from more effortful, compensatory decision rules to less effortful, non-compensatory heuristics (Payne 1976; Payne et al. 1993; Shah and Oppenheimer 2008). We manipulate whether

FIGURE 5

HYPOTHESIZED SHAPES OF THE VALUE FUNCTION WHEN ATTRIBUTE LEVELS ARE SPREAD OUT VERSUS CENTERED.



NOTE: The dotted lines reflect greater reliance on system 2 processes and thus a relatively greater influence of cardinal comparisons ($w = 0.66$). The solid lines reflect greater reliance on system 1 processes and thus a relatively greater influence of ordinal comparisons ($w = 0.33$).

the alternatives presented to participants differ along a single attribute or along multiple attributes. Thus, we expect that ordinal comparisons exert a greater influence in a multi-attribute context (lower w) than a single-attribute context (i.e., higher w), which should translate to both more pronounced inverse S-shaped and S-shaped value functions.

Method

Two hundred two respondents from Amazon Mechanical Turk participated in study 7 for a small monetary reward (78 females, $M_{\text{age}} = 33.29$, $SD = 9.93$). Twenty-eight participants provided responses that violated our monotonicity criteria leaving a sample of 174 participants. The study used a 2 (number of attributes: single vs. multiple) \times 2 (intermediate attribute levels: spread out vs. centered) between-participant design.

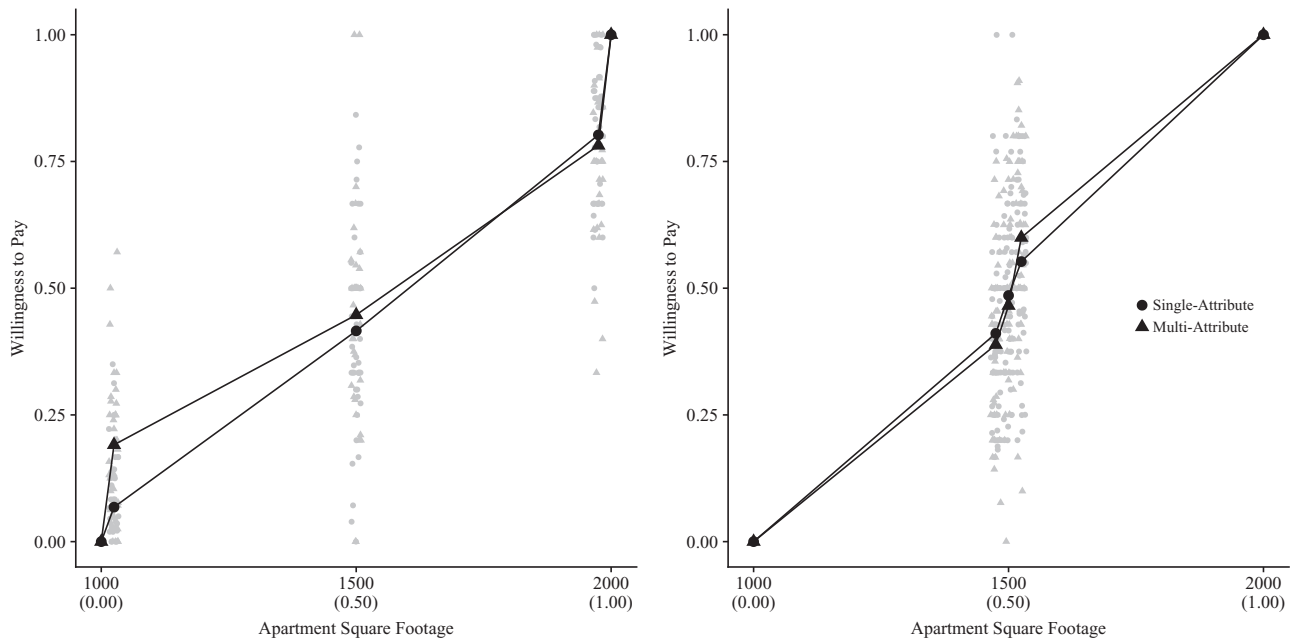
All participants saw five apartments and indicated for each apartment how much they were willing to pay per month in an average rental market. In the single-attribute condition, apartments were described to participants as identical, except for their size. This is the focal attribute in the study for which we manipulate the spacing of the attribute levels. For about half of participants, the three intermediate attribute levels were spread out across the whole range, as in the left panel of figure 5

(1,000–1,025–1,500–1,975–2,000 square feet). For the other half of participants, the three intermediate attribute levels were centered, as in the right panel of figure 5 (1,000–1,475–1,500–1,525–2,000 square feet). Note that we expect to find an inverse S-shaped value function when attribute levels are spread out but an S-shaped value function when attribute levels are centered. When attribute levels are spread out, floor and ceiling effects may push judgments up for the second attribute level and down for the fourth attribute level, in the direction of an inverse S-shaped value function. However, floor and ceiling effects are unlikely when attribute levels are centered, because the intermediate attribute levels are far from the extremes. Demonstrating inverse S-shaped value functions together with S-shaped value functions therefore increases our confidence that floor and ceiling effects have minimal explanatory power, as we discussed in study 1.

In the multiple-attribute condition, we informed participants that apartments also varied in terms of three binary attributes: flooring (carpet vs. laminate), location in the building (first vs. fourth floor), and layout (one level vs. two levels). We selected these additional attributes based on a pretest, which indicated that these non-focal attributes were considered to be important (so participants would attend to them) and that the attribute levels were equally desirable, on average. Importantly, across participants, the

FIGURE 6

RESULTS OF STUDY 7: WILLINGNESS TO PAY AS A FUNCTION OF ATTRIBUTE-LEVEL SPACING AND NUMBER OF ATTRIBUTES.



NOTE: For graphical purposes, the individual-level data points are jittered horizontally.

three additional attributes in the multi-attribute condition were uncorrelated with the square footage of the apartments.

Results

Figure 6 plots willingness to pay as a function of relative attribute levels. Gray points (horizontally jittered) are participants' willingness to pay for the intermediate apartment sizes. As can be seen from the figure, the relationship between square footage and willingness to pay is inverse S-shaped when intermediate attribute levels are spread out (left panel) and S-shaped when intermediate attribute levels are centered (right panel). Crucially, these patterns seem more pronounced when apartments varied along multiple attributes (triangles) versus a single attribute (circles), suggesting that ordinal comparisons exert a greater influence.

Similar to study 6, we model w as a function of an intercept, the number of attributes (single = 0 vs. multiple = 1), attribute spacing (spread out = 0 vs. centered = 1), and their interaction using a hierarchical Bayesian estimation procedure, described in more detail in the [web appendix](#). Estimates for w were significantly lower, implying a greater influence of ordinal comparisons, in the multi-attribute condition ($M_w = 0.55$, $CI_{95} [0.46, 0.65]$) than in

the single-attribute condition ($M_w = 0.71$, $CI_{95} [0.66, 0.75]$; $M_{\text{Difference}} = -0.16$, $CI_{95} [-0.22, -0.06]$). Estimates for w were also significantly lower, implying a greater influence of ordinal comparisons, when attribute levels were spread out ($M_w = 0.54$, $CI_{95} [0.48, 0.60]$) versus centered ($M_w = 0.72$, $CI_{95} [0.64, 0.78]$; $M_{\text{Difference}} = -0.18$, $CI_{95} [-0.22, -0.11]$). In other words, the inverse S-shape was relatively more pronounced than the S-shape, which could be because floor and ceiling effects push judgments toward an inverse S-shape when attribute levels are spread out, but away from an S-shape when attribute levels are centered, as we discussed above. There was a small interaction effect indicating that the influence of the multi-attribute manipulation was stronger when attributes were spread out ($M_{\text{Difference}} = -0.03$, $CI_{95} [-0.05, -0.01]$).

GENERAL DISCUSSION

Summary of Findings

A foundational idea in marketing is that products can be seen as bundles of attributes and that demand for products can be traced to how consumers value individual product attributes. Academics and practitioners often assume that increments along quantitative attributes have diminishing marginal value. Existing dual-process accounts of subjective value propose that such diminishing marginal value

can be traced to system 1 processes and that system 1 processes uniquely produce diminishing marginal value.

Our findings challenge these assumptions. We found diminishing marginal value when attribute levels were spaced in an accelerated manner, constant marginal value when attribute levels were spaced in a uniform manner, but increasing marginal value when attribute levels were spaced in a decelerated manner. These patterns were more pronounced when alternatives were presented with ordinal labels (studies 1–3), for people with lower scores on the CRT (study 4), when people made judgments under time pressure (study 5), when ordinal comparisons provided a better approximation of cardinal distance (study 6), and when products varied along more attributes (study 7).

Theoretical Contribution

The studies reported in this article add to our understanding of how system 1 processes influence curvature in value functions. One key difference between our studies and existing studies on dual-processes and subjective value is the number of attribute levels that each participant sees. In prior studies, each participant saw one of two attribute levels presented in isolation. Because system 1 is sensitive only to the presence versus absence of an attribute, it has been associated with diminishing marginal value (Hsee and Rottenstreich 2004; Hsee et al. 2005; Hsee and Zhang 2010). In our studies, each participant sees three or more attribute levels. We find that system 1 can produce a myriad of curvatures, depending on the spacing of attribute levels, because it has a penchant for ordinal rank.

The studies reported in this article also qualify our understanding of how evaluation mode influences curvature in value functions. Prior studies have compared the shape of the value function when participants see one of the two attribute levels presented in isolation (i.e., separate evaluation) versus both attribute levels at the same time (i.e., joint evaluation). These studies suggest that value functions are more linear when judgments are made in joint evaluation mode (Hsee and Zhang 2010). In our studies, participants always jointly evaluate three or more attribute levels. We find that value functions strongly deviate from linearity, depending on how attribute levels are spaced. The effect of attribute-level spacing on marginal value is large and robust (with Cohen's d s ranging between 0.81 and 2.47, and η_p^2 s between 0.21 and 0.33; Cohen 1988).

While the curvatures we find are consistent with range-frequency theory (Parducci 1965), we also find that the degree of curvature depends on the extent to which consumers rely on system 1 versus system 2 processes. We therefore suggest a hierarchical structure such that system 1 processes facilitate ordinal comparisons while system 2 processes are necessary to accurately assess cardinal distance. Compared to the influence of attribute-level spacing,

the influence of reliance on system 1 versus system 2 processing is smaller, but the effects are consequential and of practical significance (with Cohen's d s ranging between 0.29 and 0.51 and η_p^2 s between 0.01 and 0.04; Cohen 1988).

In sum, our contribution lies in combining elements from previously unconnected literatures. This combination provides a more nuanced understanding of how and when product differentiation can create subjective value for consumers. For instance, we predict a myriad of curvatures (depending on the spacing between alternatives) and that these curvatures tend to be more pronounced for consumers that rely more on system 1 processes, either because they are predisposed to do so (e.g., study 4), because the decision environment does not allow for more systematic information processing (e.g., studies 5 and 7), or because the benefits of systematic information processing are minimal (e.g., study 6).

Practical Implications

Consumer Welfare. Companies often describe their products to consumers using quantitative metrics, but these metrics do not always relate linearly to the benefit consumers care about (Hsee et al. 2003; Larrick and Soll 2008). For instance, the state of New York decided to sue Internet service providers, in part because the megabit-per-second metric they use is nonlinearly related to the consumer benefit in terms of download time (*The People of the State of New York v. Charter Communications* 2018). Their case is based in part on de Langhe and Puntoni (2016) who demonstrated that consumers may be spending more than they would want to spend if they properly understood the relationship between download speed and download time. Nonuniform spacing of options can exacerbate consumers' misunderstanding of nonlinear relationships between metrics and benefits. For instance, pizzas are often described in terms of their diameter (as in study 1), but consumers actually care about the total amount of pizza they are buying, or the area of a pizza. The relationship between a circle's diameter and its area is convex. This is especially problematic if alternative sizes are spaced in an accelerated way. For instance, Debonairs Pizza offers three sizes with diameters 19, 23, and 30 cm. If consumers were sensitive only to the cardinal distinctions in diameter, they would underestimate the area increase associated with a diameter increase from 23 to 30 cm relative to a diameter increase from 19 to 23 cm, and hence order too much pizza. If consumers were also sensitive to ordinal rank, the problem would be exacerbated, and presenting the pizza sizes with ordinal labels would further harm consumer welfare.

The Compromise Effect. Consumers tend to prefer compromise options (Chernev 2004; Cooke et al. 2004;

Dhar, Nowlis, and Sherman 2000; Kivetz, Netzer, and Srinivasan 2004; Simonson 1989) but managers may be unsure about where to position the intermediate attribute level. Imagine a coffee shop offers 10 ounce coffees for \$3 and 20 ounce coffees for \$5, and is looking to add a compromise option. Our studies suggest that consumers are relatively insensitive to the ounces offered by the intermediate option, because the ordinal rank remains unchanged (i.e., the intermediate option is always second out of 3). In addition, consumers will be even less sensitive when managers use labels that highlight ordinal rank (e.g., “small,” “medium,” and “large”; study 1), when decisions are made under time pressure (study 5), or when managers highlight other product attributes (study 7).

Aligning Consumers' Willingness to Pay with Firm Costs. Study 7 suggests that value functions can take virtually any monotonic shape, such as an inverse S-shape or an S-shape, depending on how the intermediate options are positioned. From a managerial point of view, this is important to take into account when marginal costs have discontinuities (e.g., requiring different production materials and equipment to scale up computer processor power from 2.4 to 4.0 GHz). Firms can use the insights in this article to adjust the composition of their product offerings so that consumer subjective value maps more closely to the firm's cost functions.

Future Research

The implications of our research go beyond product differentiation. For instance, when consumers have a goal of paying off 100% of their debt, they are most motivated when they first start paying down their debt and when they have almost paid off the entire debt and are less motivated in the middle of their goal progress (Bonezzi, Brendl, and De Angelis 2011; Huang, Jin, and Zhang 2017). At the beginning of the goal progress, consumers use 0% as their reference point and exhibit diminishing marginal sensitivity to goal progress. That is, the goal progress of the first 5% paid off feels subjectively larger than that of the second 5% paid off. When approaching the completion of their goal, consumers shift their reference points to 100% and evaluate how much is left to pay off. In this case, the goal progress of the last 5% feels subjectively larger than that of the second-to-last 5%. This research suggests that subgoals can be used to increase motivation (e.g., paying off 25%, 50%, and 75%). Extrapolating from study 7, one could predict that it is better to cluster subgoals in the middle of the range (e.g., paying off 40%, 50%, and 60%) where motivation tends to be lowest. If consumers process not only their cardinal progress (e.g., amount of debt paid off) but also their ordinal progress (e.g., completing their second then third subgoals), clustering the subgoals in the middle should increase perceived goal progress in the middle of

the range. This technique would be particularly effective in environments where consumers are more likely to rely on system 1 processes (e.g., dieting).

Conclusion

Few ideas are as deeply rooted in marketing as the principle of diminishing marginal sensitivity. It has shaped our understanding of how consumers pursue their goals (see above; Heath, Larrick, and Wu 1999; Kivetz, Urminsky, and Zheng 2006), how they form preferences for products and brands (Chandon and Ordabayeva 2009; Hardie, Johnson, and Fader 1993), how much they consume (Galak, Redden, and Kruger 2009), why they seek variety (Ratner, Kahn, and Kahneman 1999), and how satisfied they feel after consumption (Mittal, Ross, and Baldasare 1998). The current research has the potential to influence theoretical and substantive work in all these domains.

DATA COLLECTION INFORMATION

The first author programmed studies 1, 2, 6, and S2 in Qualtrics and collected the data via Amazon's Mechanical Turk. The second author programmed studies S1 and S3 in Authorware and recruited University of Colorado undergraduate students as participants. The third author programmed studies 4, 5, and 7 in Qualtrics with supplementary java-script and collected the data via Amazon's Mechanical Turk. The first and third authors programmed study 3 in Qualtrics and collected the data via Prolific's UK-based population. All data analysis (including the Bayesian modeling) was conducted by the first author in collaboration with the second author. Study 1 was collected in January 2014, study 2 in May 2014, study 3 in February 2020, study 4 in April 2019, study 5 in October 2018, study 6 in January 2015, study 7 in September 2016, study S1 in October 2013, study S2 in June 2013, and study S3 in October 2013.

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