Research Report

Six of One, Half Dozen of the Other

Expanding and Contracting Numerical Dimensions Produces Preference Reversals

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ABSTRACT—*The scales used to describe the attributes of different choice options are usually open to alternative expressions, such as inches versus feet or minutes versus hours. More generally, a ratio scale can be multiplied by an arbitrary factor (e.g., 12) while preserving all of the information it conveys about different choice alternatives. We propose that expanded scales (e.g., price per year) lead decision makers to discriminate between choice options more than do contracted scales (e.g., price per month) because they exaggerate the difference between options on the expanded attribute. Two studies show that simply increasing the size of an attribute's scale systematically changes its weight in both multiattribute preferences and willingness to pay: Expanding scales on one attribute shifts preferences to alternatives favored on that attribute.*

In the cult classic "This is Spinal Tap," Nigel points out to the director that the dials on the band's amplifiers are numbered all the way to 11: "You see, most blokes will be playing at 10. You're on 10, all the way up, all the way up . . . Where can you go from there? Nowhere. What we do, is if we need that extra push over the cliff . . . Eleven. One louder." The director asks "why don't you just make 10 louder and make 10 be the top number, and make that a little louder?" Nigel thinks for a bit and replies "these go to 11."

This arbitrary use of scales is not limited to comedy. *Consumer Reports* rates cars along six attributes. Most attributes are described on 5-point scales, but the overall test score is expressed on a 100-point scale. Will this difference in scales affect which car consumers prefer? It should not. After all, a 5-point scale can easily be converted to a 100-point scale, and vice versa (a fact that Nigel misses). More generally, a scale with ratio properties can be converted from one scale to another by multiplying the original values by some constant factor without changing the information provided by the scale. Thus, a product that is superior to another by 20 points on a 100-point scale is still superior by the same proportion if the information is expressed as a 1-point difference on a 5-point scale. Nevertheless, this trivial transformation seems psychologically consequential. The expanded scale highlights the difference between the two choice options, making it potentially easier to discriminate between them. In contrast, the contracted scale minimizes the difference.

Consider a recent demonstration of currency effects. Wertenbroch, Soman, and Chattopadhyay (2007) showed that participants were more likely to prefer costly, name-brand products to cheaper private-label brands when priced in a less numerous currency (euros) than in a more numerous currency (pesetas). The name brand's price premium seems larger when it is described on a more numerous scale. We hypothesize that this currency numerosity effect is more general. In fact, on any ratio scale, expanding the scale by an arbitrary factor greater than 1 should increase what we call *discriminability* without changing objective information about the options. We propose that an arbitrary increase in attribute scaling will lead that attribute to be increasingly favored during evaluation, inducing systematic changes in preferences.

Our argument parallels past findings on risk and ratio judgments. For example, Yamigishi (1997) has shown that people judge ratios expressed with large numerators and denominators (x/100) as riskier than larger ratios expressed with small numerators and denominators (z/1,000). Stone, Yates, and Parker (1997) were able to exaggerate such effects by putting the

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PSCI 2394 | PSCI | 2394 | B | Dispatch: 8.6.09 Journal: PSCI | CE: Blackwell
Journal Name | Manuscript No. | Author Received: No. of pages: 5 | PE: TMS Op: gsravi

information in graphs that made differences in numerators even more salient. Similarly, Pacini and Epstein (1999) have found that people prefer a gamble that has a 9 in 100 chance of winning to a gamble that has a 1 in 10 chance of winning.

Reyna and Brainerd (2008) have argued that people misunderstand simple ratio and decimal representations in many decisions due to the overweighting of numerators and neglect of denominators. Specifically, people focus mainly on the numerators' numerosity in risk assessment (9 is greater than 1) and neglect the denominator. Similarly, Stone and his colleagues (1997, 2003) have proposed that there is a bias toward using foreground information (numerators) because it is more salient than background information (denominators). For example, in a cancer-rate description, the most salient detail is the number of people who get cancer, not the total population (Yamagishi, 1997). The assessment of cancer risk also requires a comparison of the number of people getting cancer to both those getting and those not getting cancer. Researchers have argued that this comparison is difficult because it involves integrating information across multiple classes, so judges simplify the judgment by focusing on the salient class (Reyna, 1991). Consistent with these arguments, denominator neglect is lessened when processing background information is simplified. Stone et al. (2003) displayed risk information in a pie chart, which makes salient the entire "background" (those who will and will not suffer from some risk) and highlights the contrast between the foreground and background information.

We believe that previous research on denominator neglect (Reyna & Brainerd, 2008) and background neglect (Stone et al., 2003) in single-attribute risk and ratio judgments can be generalized to a wide range of multiattribute judgments in which a foreground number (any attribute value) must be interpreted in relation to a background value (the attribute's range). Because background values are typically less salient and more complex to process than foreground values, arbitrary expansion of an attribute will lead to larger perceived differences in foreground values that will be insufficiently adjusted by the background value range. Specifically, expanding an attribute on a ratio scale by a factor greater than 1 (e.g., expressing prices in cents rather than dollars) will accentuate the differences between alternatives on that attribute. This enhanced discriminability will shift preference in multiattribute choice to the alternative that is superior on the expanded attribute. Thus, purely superficial changes in scale representation can directly influence the role of a particular attribute in multiattribute decisions. We test this hypothesis in the studies that follow by arbitrarily manipulating attribute scales and observing the effects of these manipulations on choice and judgment.

STUDY 1: PREFERENCES AND CHOICE

In Study 1, we used a choice paradigm to test participants' preference for options that entail trade-offs across attributes. We predicted that participants would more strongly prefer the option that dominates on an attribute that is expanded. We created two choice sets. The first scenario presented cell-phone plans that varied in cost and number of disconnections. This scenario contained a strong manipulation such that, when one attribute was expanded, the other was contracted. The second scenario presented a movie-rental plan, in which we manipulated the expansion of one attribute (new movies per period of time) while leaving the other attribute (cost) untouched. We predicted that, in both scenarios, preference would increase for the option that was superior on an expanded attribute, and that preference reversals would arise between conditions.

Method

One hundred six University of Michigan undergraduates completed this study as part of a course requirement. The first scenario (cell-phone plans) asked participants to evaluate cellular phone plan options described in terms of number of dropped calls and cost. Number of dropped calls was either on an expanded scale (dropped calls per 1,000 calls) or a contracted scale (dropped calls per 100 calls). Price was also described either on an expanded scale (price per year) or a contracted scale (price per month). When one attribute was presented as expanded, the other was presented as contracted, thus creating two conditions (see Table 1).

The second scenario (movie rentals) tested discriminability by varying the expansion of only one attribute. Participants evaluated two movie-rental plans that were described in terms of new movie availability and price (see Table 2). Price was provided for each option but not manipulated. The number of new movies was presented as expanded (new movies per year) or contracted (new movies per month), thus creating two conditions (see Table 2).

For both scenarios, participants indicated their preference for Plan A versus Plan B on a 7-point scale (1 = *strongly prefer plan A*, 4 = *indifferent*, 7 = *strongly prefer plan B*).

TABLE 1
Plans in the Two Conditions of the First Scenario in Study 1

	Condition 1		Condition 2	
Option	Number of dropped calls per 100 calls	Price per year	Number of dropped calls per 1,000 calls	Price per month
Plan A	4.2	$384	42	$32
Plan B	6.5	$324	65	$27

Note. Participants evaluated cellular phone plan options described in terms of number of dropped calls and cost. Number of dropped calls was either on an expanded scale (dropped-calls per 1,000 calls) or a contracted scale (dropped calls per 100 calls). Price was also described either on an expanded scale (price per year) or a contracted scale (price per month). In Condition 1, the number of dropped calls was presented on a contracted scale, and price was given on an expanded scale). In Condition 2, the number of dropped calls was presented on an expanded scale, and price was given on a contracted scale.

TABLE 2

Plans in the Two Conditions of the Second Scenario in Study 1

	Condition 1		Condition 2	
Option	Number of new movies per week	Price per month	Number of new movies per year	Price per month
Plan A	7	$10	364	$10
Plan B	9	$12	468	$12

Note. Participants evaluated two movie-rental plans that were described in terms of new movie availability and price. In Condition 1, the number of new movies was presented as expanded (new movies per year). In Condition 2, the number of new movies was presented as contracted (new movies per month). Price was provided for each option but not manipulated between conditions.

Results and Discussion

An independent samples t test showed a significant shift in plan preference based on attribute expansion for both scenarios. For the first scenario, preferences favored Plan B (the plan that was superior on price) when price was expanded and the number of dropped calls was contracted ($M = 4.45$). However, preferences favored Plan A (the plan that was superior on the number of dropped calls) when the number of dropped calls was expanded and price was contracted ($M = 3.08$), $t(104) = -3.60$, $p < .001$, $d = 0.706$. We converted these data to choice proportions to test for preference reversals. Plan B was preferred when it was described as having a lower price per year but more dropped calls per 100 than Plan A (53% vs. 31%, respectively).[1] However, Plan A was preferred when it was described as having fewer dropped calls per 1,000 but a higher price per month than Plan B (69% vs. 23%, respectively); $\chi^2(2, N = 106) = 13.93$, $p < .001$, $\varphi_c = .363$ for the linear contrast of the ordinal choice categories between conditions.

For the second scenario, participants favored the superior plan on price (Plan A) when the number of new movies was contracted. However, participants favored the superior plan for new selections (Plan B) when new selections were expanded ($M = 4.33$) rather than contracted ($M = 3.38$), $t(104) = 2.16$, $p = .033$, $d = 0.424$. A test of choice proportions showed that 57% of participants preferred Plan A when number of new movies was contracted to a weekly scale, compared to 33% who preferred Plan B. Expanding number of new movies to a yearly scale resulted in 38% preferring Plan A and 56% preferring Plan B, a significant reversal for the linear contrast of the ordinal choice categories, $\chi^2(2, N = 106) = 5.24$, $p = .02$, $\varphi_c = .222$.

The results of Study 1 show that attribute expansion increases preference for the alternative favored on an expanded attribute, despite the fact that the relative differences between alternatives remained the same.

[1]We omitted reporting the neutral response percentage to minimize redundancy, but included the neutral level in the linear-by-linear chi-square test of changes in preference. It is simply 1 minus the sum of percentages favoring Plan A or Plan B.

STUDY 2: PRICING

In this experiment, we modified the second scenario of Study 1 to create a matching paradigm in order to determine participants' valuation of options that entail a trade-off across attributes (e.g., Willemsen & Keren, 2002, 2003). Specifically, participants were given a target product (movie-rental plans) that was described on one attribute: Frequency with which new movies are added to the rental plan. Participants were then given additional information on average movie-rental plans that included both frequency of adding new movies and price. Participants had to provide a price for the target movie-rental plan that made them indifferent between the target and average plan (i.e., a price that made the target plan "match" the value of the average plan).

We manipulated both attribute expansion and product valence. Valence was manipulated by presenting the product as either better or worse than the average plan. We predicted that valence would interact with attribute expansion: The difference in willingness to pay for the above-average plan versus the below-average plan would be greater when framed as movies per year (expanded) rather than movies per week (contracted).

Method

Sixty-three University of Michigan students completed this 2 (attribute expansion: expanded vs. contracted) × 2 (product valence: above vs. below average) design study in combination with other materials and were paid $8 for their participation. Participants were asked to evaluate two movie-rental plans, as in the second scenario in Study 1. One plan was labeled the average plan and the other was the target plan. Price was provided only for the average plan. Half of the participants evaluated the two movie rental plans described in terms of new movies per week (i.e., the contracted attribute). The other participants evaluated the two plans described in terms of new movies per year (i.e., the expanded attribute). These plans are presented in Table 3. The attribute-expansion manipulation was crossed with a product-valence manipulation in a full-factorial design: Half the participants saw a target plan that was better than the average plan, and half the participants saw a target plan that was worse than the average plan. Participants indicated their willingness to pay for the target plan.

Results

An analysis of variance showed a significant shift in willingness to pay for the target plan based on attribute expansion. Not surprisingly, participants were willing to pay more for the target plan when it was better than the average plan ($M = $12.68) than when it was worse ($M = $9.02), $F(1, 59) = 56.24$, $p < .001$, $\eta_p^2 = .488$. More importantly, there was a significant interaction between attribute expansion and product valence, $F(1, 59) = 7.37$, $p = .009$, $\eta_p^2 = .111$ (see Fig. 1). As expected, when number of movies was described on the contracted scale (movies

TABLE 3
The Four Conditions of Study 2

	Condition 1		Condition 2		Condition 3		Condition 4	
Option	Number of new movies per week	Price per month	Number of new movies per week	Price per month	Number of new movies per year	Price per month	Number of new movies per year	Price per month
Target plan	7	—	9	—	364	—	468	—
Average plan	9	$12	7	$10	468	$12	364	$10

Note. In each condition, subjects were given information about a so-called average plan and a target plan. The target plans in Conditions 1 and 3 were below average in the number of new movies, and the target plans in Conditions 2 and 4 were above average in the number of new movies. In Conditions 1 and 2, a contracted scale was used to indicate the number of new movies available per week in the target plan, and in Conditions 3 and 4, an expanded scale was used to indicate the number of new movies available per year in the target plan.

per week), people were willing to pay significantly more when the target was above average (M = $11.55) than when it was below average (M = $9.20), $F(1, 59) = 11.55$, $p = .001$, $\eta_p^2 = .164$. However, the size of this effect more than doubled when the same problem was presented using the expanded scale (movies per year; mean amount participants were willing to pay for the above-average plan = $13.82, mean amount participants were willing to pay for the below-average plan = $8.83), $F(1, 59) = 51.72$, $p < .001$, $\eta_p^2 = .467$.

Discussion

The results show that attribute expansion leads to more extreme valuation of the target plan compared to attribute contraction. Specifically, when the target was superior to the alternative, attribute expansion led to higher willingness to pay than attribute contraction. Again, this finding suggests that attribute expansion increases the perceived difference in attractiveness between a target option and its referent on that attribute without changing any information about the actual difference.

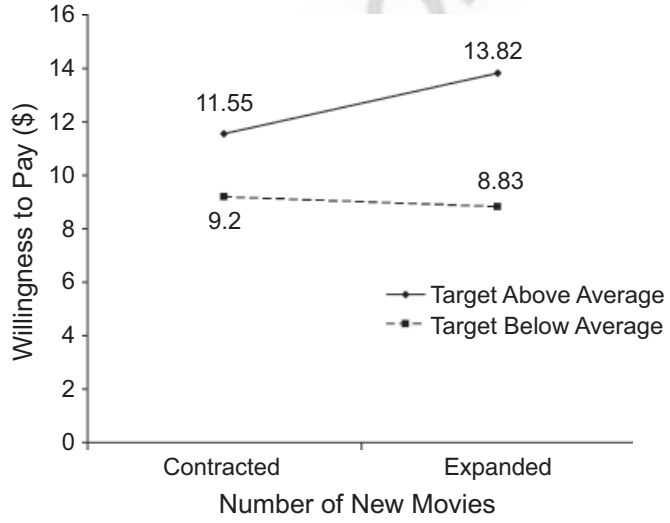

Fig. 1. Mean willingness to pay for a target plan as a function of scale and relative quality of that plan in Study 2. The expanded scale gave the number of new movies per year, and the contracted scale gave the number of new movies per week.

GENERAL DISCUSSION

We found that simply increasing the size of an attribute's scale can change preference and valuation. Although expanding and contracting the attribute's scale did not change the objective relative standing of an alternative in a choice set, these arbitrary scale changes induced preference reversals. Attribute expansion inflated the perceived difference between alternatives on that attribute, and thereby increased its weight relative to other attributes.

We speculate that factors such as graphical representation, cognitive load, and innumeracy may moderate discriminability. The effects described by Stone and his colleagues (1997, 2003) suggest that the influence of arbitrary expansion and contraction might be reduced if researchers highlight the "background" information by graphically displaying both scale values and the entire scale range. Furthermore, it is likely that the expansion and contraction of scales has a larger impact on those who are innumerate (Peters et al., 2006) or under cognitive load (Pelham, Sumarta, & Myaskovsky, 1994).

We believe that several lines of past research have manipulated attribute discriminability, including different ways of aggregating costs over time (Gourville, 1998; Price, 1994) and different ways of denominating currency (Wertenbroch et al., 2007). We propose that, because of background neglect (Stone et al., 2003; see also Reyna & Brainerd, 2008), expanded attributes will receive increased weight across a wide variety of attribute types, including frequencies (e.g., ratio and risk expressions), units of measure (e.g., distance, time, temperature, and currency), and even arbitrary scales (e.g., 10-point versus 100-point scales). Any judgmental process that requires the interpretation of a numerical dimension is potentially susceptible to discriminability effects.

Acknowledgments—We are grateful to Christopher K. Hsee and Dilip Soman for their reactions to early versions of this research.

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(Received 8/12/08; Accepted 2/14/09)

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