Similarity-Based Sampling: Testing a Model of Price Psychophysics

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Abstract

How is the perceived attractiveness of a price influenced by the context or sample within which it appears? Current models of price judgment are often based on psychophysical models of the contextual judgment of non-economic stimuli. These existing models accommodate a number of contextual effects, but do not allow for the possibility, motivated by independent psychophysical data, that the weighting of comparison items within a sample may vary with their similarity to the target. Here we address this issue by using results from two experiments to estimate the parameters of the GEMS (Generalized Exemplar Model of Sampling) model. In both Experiment 1, when prices are simultaneously presented, and in Experiment 2, when prices are presented sequentially, some evidence for similarity-based sampling is obtained.

Keywords: Economic Psychophysics; price perception; similarity sampling; Range Frequency Theory; Generalized Exemplar Model of Sampling.

Introduction

When people decide which product to buy or which job to accept, the choice normally takes place within a context of available or retrieved options. Given a large amount of potentially available information, and limited processing time and short-term memory capacity, people tend to sample only a subset of possible alternatives and then form a judgment based on the sample (Fiedler & Juslin, in press). Here we address the question of how different prices within a sample or choice context combine to determine the judgment of a target price. More specifically, we use model-based analyses to develop and test the hypothesis that sampled prices that are similar to a target price will have a greater effect on the perceived attractiveness of a target price than will less similar prices within the sample.

The research falls within the domain of Economic Psychophysics, defined in terms of the assumption that the magnitudes of economic quantities such as prices and wages are perceived in a similar manner to simple psychophysical stimuli such as weights and loudnesses (see, e.g., Brown, Gardner, Oswald, & Qian, 2004; Qian & Brown, 2005; Stewart, Chater, Stott, & Reimers, 2003). The plan of the rest of the paper is as follows. We first describe existing models of context effects in price perception, emphasizing that such models typically derive from psychophysical accounts developed independently to account for contextual effects observed when non-economic stimuli are judged. We then show that recent models of price psychophysics do not allow for effects of similarity-based sampling, and note recent psychophysical research that suggests that similarity-sampling effects do occur when non-economic stimuli (tones for different frequencies) are judged. Finally we describe a new model of price psychophysics, GEMS (Qian & Brown, 2005), and apply the model to the results of two experiments designed to test the prediction that similarity-sampling will occur in price perception, paralleling processes involved in the judgment of non-economic quantities.

Development of Price Psychophysics

Classical models of price perception in economics assumed that a rational consumer makes purchase decisions based on the actual (absolute) prices and utilities of available options. Research from the early 1970s subsequently demonstrated that context effects are ubiquitous in price perception, and the resulting models typically claimed that price evaluations are based on the comparison of a target price to a reference price (e.g., Emery, 1970; Monroe, 1973). A reference price is an internal price to which consumers compare observed prices. This concept originally came from Helson's (1964) *Adaptation Level Theory,* where each stimulus to be rated is compared to an internal norm (adaptation level), which is partly made up of a weighted mean of the stimuli presented within a contextual set. In some instantiations, the reference price has been assumed to be simply the average price of all the contextual prices (e.g., Janiszewski & Lichtenstein, 1999).

Although the influence of Adaptation Level Theory is still prominent in the price perception literature, the model has been shown to be inadequate in the domain of non-economic psychophysics (e.g., Parducci, 1995). Departures from the predictions of single reference price models have correspondingly been found in consumer price perception research. For example, the range of prices within a contextual sample appears to have an effect on judgment that is independent of the mean of the contextual prices (Janiszewski & Lichtenstein, 1999). Furthermore, the distribution (skewness) of prices within a sample also has an independent effect on the perception of prices within that context (Niedrich, Sharma & Wedell, 2001; Qian & Brown, 2005), consistent with multiple exemplar models.

Based partly on their evidence against alternative accounts, Niedrich et al. (2001) successfully applied *Range Frequency Theory* (RFT; Parducci, 1963, 1995) to price perception. Like Adaptation Level Theory, RFT was originally developed to account for context effects on the judgment of simple psychophysical stimuli such as weights and loudnesses. RFT assumes that the judgment of a stimulus magnitude is made relative to all the contextual stimuli. Specifically, the judgment is based on two principles: The *range principle* specifies that the judgment of a stimulus is based on the ratio of the distance in value between the target stimulus, x_i, and the minimum stimulus, x_{min}, to the whole stimulus range, x_{max}-x_{min}, (R_i: Equation 1). The *frequency principle* states that the judgment of a stimulus also depends on its relative ranked position within an ordered contextual set of N stimuli (F_i: Equation 2). The overall judgment, RFT_i, is a weighted average of the results given by the above two principles (Equation 3).

$$R_i = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}} \quad (1)$$

$$F_i = \frac{i-1}{N-1} \quad (2)$$

$$RFT_i = wR_i + (1-w)F_i \quad (3)$$

where w is a weighting parameter.

RFT appears to provide a good account of price perception in the limited number of studies that have examined it to date, with participants placing approximately equal weighting on the range and frequency principles when prices are presented simultaneously, but greater weight on the range dimension when prices are presented sequentially (Niedrich et al., 2001; Qian & Brown, 2005).

Similarity Sampling

The frequency principle states that the ranked position of a price within a comparison set is an important factor underpinning its perceived attractiveness. Implicit in this formulation is the assumption that all comparator prices enter into the comparison with equal weight; i.e., that a price just a small amount higher than the target will have the same influence on the target's evaluation as a price that is substantially higher. Such an assumption is also made by models that assume only ordinal comparisons can be made (Stewart, Chater, & Brown, 2004). However intuition suggests that, when evaluating a price, prices that are similar to the target price may carry more weight in the decision process than prices that are dissimilar to the target price. For example, if a consumer is evaluating a digital music player priced $200, another music player priced $220 might seem more relevant to the evaluation of the target price than a music player priced $280 (i.e., similarity-weighted sampling will occur).

A parallel idea has been tested in a psychophysical task where the subjective frequency of each of a series of tones must be judged. Brown and Stewart (2005) reported subjective frequency judgments for tones drawn from distributions that varied in skewness and were constructed to enable test of the similarity sampling hypothesis. The central finding was that a tone that has the same range and frequency value in two different distributions may nonetheless receive a different subjective judgment, contrary to RFT's predictions. Specifically, a target tone presented in a context of N lower tones that are more similar to it than N higher tones is perceived as subjectively higher than the same tone presented in another distribution where it is more similar to N tones that are higher in pitch and less similar to N tones that are lower in pitch. This effect suggests that the judgment context for a tone consists mainly of similar tones (consistent with the operation of similarity-based memory retrieval processes in construction of a comparison set) or, equivalently, that similar tones are (contrary to RFT) given greater weight in the comparison process.

Will price attractiveness judgments mirror the similarity-sampling effects seen in judgments of non-price stimuli? Here we examine this issue by applying and testing the GEMS (Generalized Exemplar Model of Sampling) model developed by Qian and Brown (2005; see also Brown et al., 2004). Crucially for present purposes, the model incorporates a parameter that specifies the weighting given to prices as a function of the similarity of each comparator price to the target price. RFT is a special case of the GEMS model. The specification of GEMS is as follows (Equation 4):

$$J_i(x) = wR_i + (1-w)\left[0.5 + \frac{\sum_{j=1}^{i-1}(x_i - x_j)^\gamma - \sum_{j=i+1}^{N}(x_j - x_i)^\gamma}{2(\sum_{j=1}^{i-1}(x_i - x_j)^\gamma + \sum_{j=i+1}^{N}(x_j - x_i)^\gamma)}\right] \quad (4)$$

where J_i is the subjective judgment of x, x_i is the ith least expensive price, and w is the weighting on the range component. R_i is the range value for price i (see Equation 1), and γ is the similarity sampling parameter. When γ=0, equal weighting is given to all non-target items and Equation 4 is equivalent to RFT. When γ<0, the equation implements a similarity-based model, in which prices close to the target prices are weighted more heavily. When γ>0, the model gives greater weight to prices further away from the target price. The above formulation produces judgments bounded between 0 and 1; in all model-fitting described below the ratings were scaled monotonically in such a way that the highest and lowest ratings produced by the model corresponded to the highest and lowest ratings in the data to be fitted. (This accommodated cases where participants failed to utilize the full range of the scale.)

Qian and Brown (2005) applied GEMS to price perception under conditions where a small number of prices were presented for evaluation, and found partial evidence for similarity sampling. In this paper, we further test the idea of similarity sampling with a different experimental design to allow a stronger test of the hypothesis. We hypothesize that, when evaluating a price, similar prices are weighted more heavily than less similar prices (i.e., γ<0). The two experiments reported below use the same range and distributions of prices. In Experiment 1, prices are presented simultaneously, and in Experiment 2 prices are presented sequentially.

Experiment 1

Participants

Ten undergraduate students from the University of Warwick were tested. They were each paid two pounds (GBP) for participation.

Materials

Two distributions of prices were constructed as described below. The prices (in GBP) were presented as printed numbers on small colored labels. A printed attractiveness rating scale approximately 18 inches long was provided with numbers 1-7 marked on it. "1" represented "extremely unattractive" and "7" represented "extremely attractive". The small price-bearing labels could be placed at any location on this scale.

Table 1: Price stimuli used in Experiment 1

Distribution 1	Distribution 2
119.8	119.8
131.0	122.6
142.2	125.4
153.4	128.2
164.6	131.0
175.8	133.8
187.0	136.6
198.2	139.4
209.4	209.4
279.4	220.6
282.2	231.8
285.0	243.0
287.8	254.2
290.6	265.4
293.4	276.6
296.2	287.8
299.0	299.0

Design

Two distributions containing 17 prices each were used in the experiment. The distributions were constructed to maximize the differences in prediction made by similarity-based models and RFT. Table 1 lists the prices used. The prices from the two distributions have the same lowest and highest prices. The middle price ranks 9^{th} in both distributions. According to RFT this price will be given the same rating in each distribution because it has the same range value and also the same rank/frequency value across the two distributions. However, according to similarity sampling models, this price will receive lower ratings in condition 1 than in condition 2, because (in condition 1) it is more similar to lower prices than to higher prices. Figure 1 illustrates the spacing of prices in each distribution.

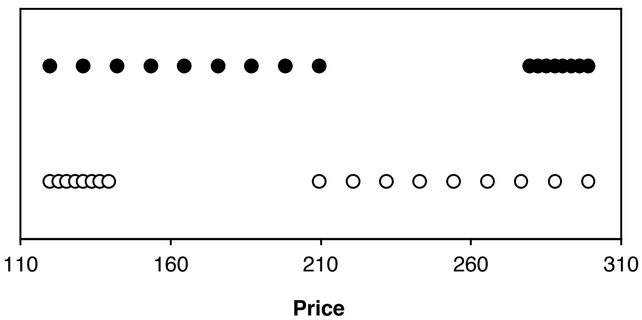

Figure 1: Price distributions used in Experiment 1 and 2. Filled circles represent price stimuli in distribution 1, and open circles represent price stimuli in distribution 2.

The experiment used a within-subject design; each participant rated every price in the two distributions. Distributions were presented one at a time, in counterbalanced order.

Procedure

Participants were asked to imagine that they were planning to buy a plane ticket and a packaged holiday to the same destination. In each condition, participants were asked to compare various products that were priced differently by placing the associated price labels on the attractiveness rating scale. The scale was continuous; participants could place the labels at any point along the scale. Labels could be moved along the scale as new labels were added. After participants evaluated one condition, the price labels and scale were removed, and participants were presented with the other set of price labels and a new rating scale.

Results

The results are shown in Figure 2.

Comparison Points The ratings of the comparison point (price £209.4) from the two distributions were compared, and a conventional t-test showed no significant difference between them although the difference between the ratings from the two distributions was in the direction similarity-based models would predict (3.76 for distribution 1; 3.86 for distribution 2). We therefore undertook more sensitive model-based analyses to take account of all data points simultaneously.

Model Based Analyses First we fit RFT (a special case of GEMS) to the mean data from each of the two distributions. R^2 was .991, with w=.31. We then examined the independent contributions of range and rank by comparing residual sums of squares of range-only (w=1) and rank-only (w=0) models' predictions with those of RFT. As both alternative models are nested within RFT, a generalized likelihood ratio test (GLRT; Lamberts, 1997) can be used. Analysis revealed an independent contribution of the range component ($\chi^2(1)$=35.9, p<.005), and of the rank/frequency component ($\chi^2(1)$=81.1, p<.005). We then estimated γ along with w, and used GLRT to compare GEMS (γ free), and RFT (γ=0), as RFT was nested within GEMS. The best fitting *w* was 0.45, and γ was –0.13 (i.e., in the direction predicted by the similarity sampling hypothesis). The improvement in fit achieved by allowing γ to vary was only marginally significant ($\chi^2(1)=3.46$, $p<.1$). The fit of the full GEMS model, and the data, are shown in Figure 2. An R^2 of .992 was obtained.

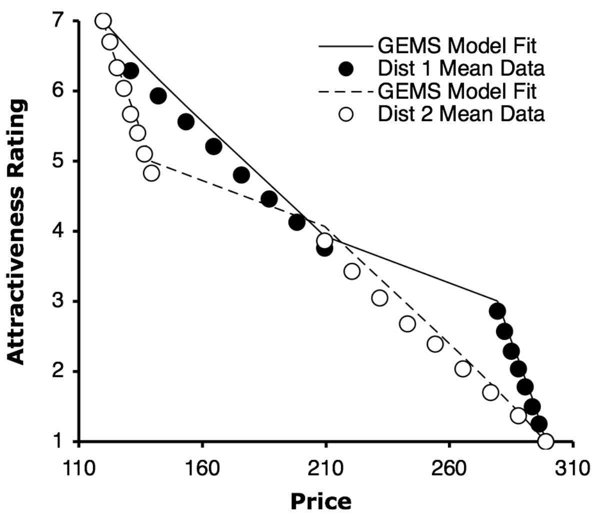

Figure 2: GEMS model fit to the average data from the two distributions.

We also fitted the GEMS model to individual participant data, thus obtaining separate estimates of *w* and γ for each individual. The average *w* estimate was .41, and the average estimate of γ was –0.36. Consistent with the assumption of similarity-based sampling, the best fitting γ obtained from individual participants was significantly lower than zero ($t(9)=2.4, p<.05$).

Discussion

The evidence for similarity sampling in Experiment 1 was mixed. There was no clear evidence for similarity sampling when we examined the averaged data from the two distributions. With a R^2 of .991, RFT provided an excellent fit to the data, in line with previous research on price perception when prices are presented simultaneously (see Qian & Brown, 2005). However, when we examined the data from each participant separately, we found some evidence of similarity-based sampling. Moreover, the γ parameter estimates that were obtained were meaningful. For example, when participants are evaluating the middle price (£209.4) the two adjacent prices in distribution 1 are £198.2 and £279.4. The middle price is more similar to the former (£11.2 more expensive) than to the latter (£70 cheaper). If a similarity weighting γ of –0.36 is used, then the more similar price is weighted almost twice as heavily ($11.2^{-0.36}=0.42$) than the more distant price ($70^{-0.36}=0.22$).

When prices are presented simultaneously as in Experiment 1, the range and relative rank of a target price in relation to the context is highly salient. This may be expected to facilitate processing that leads to conformity with RFT. In Experiment 2, we therefore examined the effect of similarity sampling when prices are presented sequentially. We hypothesized that when prices are presented in succession, and not all previous prices will be recallable, it will be more difficult to access the information about the relative rank and range of a price. Therefore prices that are similar to a target price may be more easily remembered and hence carry heavier weight than other prices in the context. Thus a larger similarity effect may be obtained.

Experiment 2

Participants

50 undergraduate students from University of Warwick were tested and were paid 2 pounds (GBP) for their participation. Five were excluded for failing to comply with the experimental instructions (making incomplete or inconsistent use of the rating scale).

Materials

102 prices were presented one at a time on a computer screen. E-prime was used to program the experiment. After each price was presented, participants were required to enter a number between 1 and 7 to represent their subjective rating of the perceived attractiveness of the price. The experiment lasted 15 minutes.

Design and Procedure

The price stimuli used in Experiment 2 were based on those used in Experiment 1. Two distributions of the same shapes were used. Gaussian noise (mean=0, SD=1.5) was added to the basic prices used in Experiment 1. As participants needed repeated exposure to become familiar with the contextual distribution and stabilize their ratings, six blocks of prices were created in this way. Each represented a noisy version of the distribution of prices in Experiment 1. Prices within each block were presented in random order, and six blocks were presented without a break.

A between-subject design was used, and each participant completed six blocks of prices evaluation of one distribution. 21 participants evaluated prices in distribution 1, and 24 evaluated prices in distribution 2. A similar cover story to the one in Experiment 1 was given at the beginning of the experiment.

Results

The results are shown in Figure 3.

Comparison Points The ratings of the comparison point (price £209.4) in the two distributions were compared across all six blocks. The mean rating was 3.15 for distribution 1 and 3.43 for distribution 2. However the effect of distribution was not statistically significant in the conventional analysis:

$F(1,22)=1.4$, NS. We therefore turned to the more sensitive model-based analyses, which effectively takes into account all data points, not just the middle one.

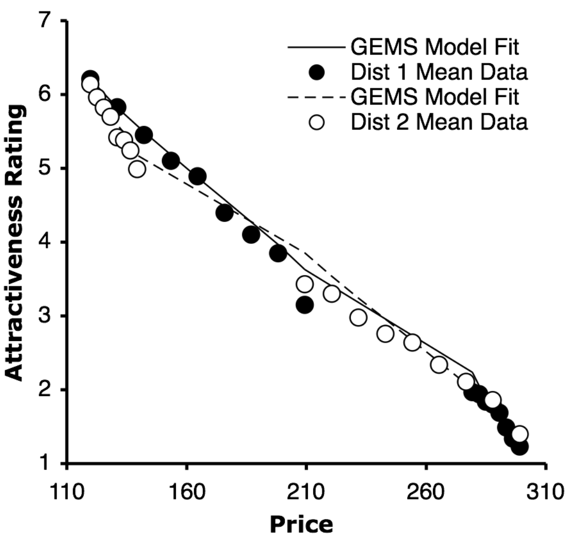

Figure 3: GEMS model fit to the average data of 6 blocks from the two distributions.

Model Based Analyses First we fitted RFT to the mean data from each of the two distributions. The value of w that best fit the data was 0.72, and a R^2 of .990 was obtained. We then examined the independent contributions of range and rank by comparing nested range-only (w=1) and rank-only (w=0) models. There was an independent contribution of the range component ($\chi^2(1)=75.3$, $p<.005$), and of the rank component ($\chi^2(1)=25.8$, $p<.005$). We then estimated γ and w simultaneously, and used a GLRT to compare GEMS and RFT (γ=0). The best fitting value of w was 0.87, and of γ was –0.66. R^2 was estimated at .991. γ made a statistically significant contribution to the improvement of fit ($\chi^2(1)= 4.2$, $p<.05$). The fit of GEMS to the average data is shown in Figure 3.

As a between-subjects design was employed, it was not appropriate to fit GEMS to individual participant data from Experiment 2.

Discussion

Model-based analysis found a small but statistically significant effect of similarity sampling in Experiment 2. This result appears consistent with the possibility that similarity-based memory retrieval processes contribute to the online construction of the sample that provides the context for judgment.

Comparison of the parameter estimates obtained from Experiment 1 and 2 suggests that, consistent with previous studies, (e.g., Niedrich et al., 2001; Qian & Brown, 2005), the weighting on the range component is larger in sequential presentation than in simultaneous presentation.

We note that closer fits between model and data can be achieved if additional parameters are included. For example, including a power-law transformation of price prior to application of Equation 4 increases R^2 significantly. However in order to maintain a clear focus on the effects of interest we avoided adding additional complexity to the model.

General Discussion

The studies reported here were motivated by the general hypothesis of Economic Psychophysics. According to this approach, the judgment of economic quantities such as prices is governed by the same processes that govern the judgment of the subjective magnitudes of unidimensional non-economic stimuli.

Consistent with this approach, several previous models of price perception have been derived from pre-existing psychophysical models such as Adaptation Level Theory and Range Frequency Theory. In the present paper we addressed the possibility that similarity-based sampling, as already observed in models of memory and perception of non-economic stimuli, would be seen in subjective judgments of price attractiveness.

In Experiment 1, where prices were presented simultaneously, analysis using the GEMS model found a small effect of similarity sampling in some analyses. It was predicted that a larger effect of similarity would be obtained when a large number of prices were presented sequentially and hence demands on memory (and hence similarity-based retrieval processes) were greater. This prediction was tested in Experiment 2, and model-based analysis found a small but statistically significant effect of similarity-based sampling. However the effect was no greater than that observed in Experiment 1.

Overall, the results suggest that models such as RFT (Niedrich et al., 2001) may need to be supplemented by similarity-based comparison processes. However, the effects we obtained were small in magnitude, and RFT may provide an excellent approximation in many circumstances. More generally, the results provide further evidence consistent with the overall claim that models developed in psychophysics may usefully be extended and applied to subjective judgments of economic quantities such as prices.

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